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Canister Storage Building (CSB) Safety Analysis Report Phase 3: Safety Analysis Documentation Supporting CSB Construction

L. J. Garvin

Fluor Daniel Hanford, Richland, WA 99352

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Abstract: The purpose of this report is to provide an evaluation of the CSB design criteria, the design's compliance with the applicable criteria, and the basis for authorization to proceed with construction of the CSB.

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**CANISTER STORAGE BUILDING SAFETY ANALYSIS REPORT - PHASE 3:
SAFETY ANALYSIS DOCUMENTATION SUPPORTING CANISTER STORAGE
BUILDING CONSTRUCTION**

~~HNF-SD-SNF-RPT-004~~
~~WHC-SD-SNF-RPT-004~~
Revision 65A

~~March 1997~~
~~December 1996~~

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EXECUTIVE SUMMARY

The U.S. Department of Energy established the K Basins Spent Nuclear Fuel Project to address safety and environmental concerns associated with deteriorating spent nuclear fuel presently stored under water in the Hanford Site's K Basins, which are located near the Columbia River. Recommendations for a series of aggressive projects to construct and operate systems and facilities to manage the safe removal of K Basins fuel were made in WHC-EP-0830, *Hanford Spent Nuclear Fuel Recommended Path Forward*,¹ and its subsequent update, WHC-SD-SNF-SP-005, *Hanford Spent Nuclear Fuel Project Integrated Process Strategy for K Basins Fuel*.² The integrated process strategy recommendations include the following ~~process~~ steps:

- Fuel preparation activities at the K Basins, including removing the fuel elements from their K Basin canisters, separating fuel particulate from fuel elements and fuel fragments greater than 0.6 cm (0.25 in.) in any dimension, removing excess sludge from the fuel and fuel fragments by means of flushing, as necessary, and packaging the fuel into multiccanister overpacks (MCOs)
- Removal of free water by draining and vacuum drying at a cold vacuum drying ~~facility~~ system
- Dry shipment of fuel from the Cold Vacuum Drying ~~Facility~~ System to the Canister Storage Building (CSB), a new facility in the 200 East Area of the Hanford Site

¹Fulton, J. C., 1994, *Hanford Spent Nuclear Fuel Recommended Path Forward*, WHC-EP-0830, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

²WHC, 1995, *Hanford Spent Nuclear Fuel Project Integrated Process Strategy for K Basins Fuel*, WHC-SD-SNF-SP-005, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

- Temporary staging in the CSB of ~~MCOs-multicanister overpacks~~ containing partially dried fuel
- Removal of the remaining absorbed water from the ~~MCOs-multicanister overpacks~~ at a conditioning facility
- Interim dry storage of the ~~MCOs-multicanister overpacks~~ in the CSB until a suitable long-term repository is established.

The purpose of this report is to provide an evaluation of the CSB design criteria, the design's compliance with the applicable criteria, and the basis for authorization to proceed with construction of the CSB. ~~The scope of this report includes the operating and support structures and equipment for receipt, staging, and interim storage of the MCOs with the exception of the MCO handling machine. The MCO handling machine will be addressed in a subsequent revision to this report.~~

Figures ES-1 and ES-2 show the CSB vault, operating deck, superstructure, and support building. This report is based on the format of DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*.³ The report includes those sections of DOE-STD-3009-94 that are applicable to the CSB based on agreement between the U.S. Department of Energy, Richland Operations Office, and Westinghouse Hanford Company, the former maintenance and operations contractor. The information provided is based on the CSB design information currently available. The information includes the identification of project requirements and criteria as applicable to the subject chapter, a summary of reference information available that documents compliance or the intent to

³DOE-STD-3009-94, 1994, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, U.S. Department of Energy, Washington, D.C.

Figure ES-1. Cutaway View of the Canister Storage Building.

Figure ES-2. Cross Section of the Canister
Storage Building through Vault 1.

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LIST OF TERMS

ALARA	as low as reasonably achievable
ARF	airborne respirable release fraction
CAM	continuous air monitor
CAEM	continuous airborne effluent monitor
CEDE	committed effective dose equivalent
CLEW	Cle Elum-Wallula deformed zone
CRBG	Columbia River Basalt Group
CSB	Canister Storage Building
CSER	criticality safety evaluation report
CSR	criticality safety representative
CVDFS	Cold Vacuum Drying Facility System
DBA	design basis accident
DBE	design basis earthquake
DCS	distributed control system
DESH	DE&S Hanford, Incorporated
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
EDE	effective dose equivalent
FDH	Fluor Daniel Hanford, Incorporated
FFTF	Fast Flux Test Facility
HCS	Hot Conditioning System
HEPA	high-efficiency particulate air (filter)
HMS	Hanford Meteorological Station
HR-NR	Hog Ranch-Naneum Ridge
HVAC	heating, ventilating, and air conditioning
HWVP	Hanford Waste Vitrification Plant
IFM	irradiated fissile material
ISFSI	independent spent fuel storage installation
Ma	million years ago
MCC	motor control center
MCO	multicanister overpack
MHM	multicanister overpack handling machine
MKIA	Mark IA fuel
MKIV	Mark IV fuel
MLRS	Multiple Launch Rocket System
NPH	natural phenomena hazard
NRC	U.S. Nuclear Regulatory Commission
OWL	Olympic-Wallowa lineament
PFP	Plutonium Finishing Plant
PHA	preliminary hazard analysis
PMP	probable maximum precipitation
PUREX	Plutonium-Uranium Extraction
QAPP	quality assurance program plan
RF	respirable fraction
SAR	safety analysis report
SNF	spent nuclear fuel
SPR	single pass reactor
SSC	structure, system, and component
SSI	soil-structure interaction
Supply System	Washington Public Power Supply System
TSR	technical safety requirement

UCAT	United Engineers and Constructors-Catalytic
WESF	Waste Encapsulation and Storage Facility
WHC	Westinghouse Hanford Company
WNP	Washington Nuclear Plant
YFB	Yakima Fold Belt

1.0 SITE CHARACTERISTICS

1.1 INTRODUCTION

The Canister Storage Building (CSB) will be constructed in the 200 East Area of the U.S. Department of Energy (DOE) Hanford Site. The CSB will be used to stage and store spent nuclear fuel (SNF) removed from the Hanford Site K Basins. The objective of this chapter is to describe the characteristics of the site on which the CSB will be located. This description will support the hazard analysis and accident analyses in Chapter 3.0.

1.2 REQUIREMENTS

This section lists the design codes, standards, regulations, and DOE orders that are required for establishing the safety basis for the CSB. Only the requirements that are specific to Chapter 1.0 and that pertain to the safety basis for the facility are provided.

1.2.1 U.S. Department of Energy Orders and Standards

The following DOE orders and standards are applicable to the safety basis for the facility.

- DOE Order 6430.1A, *General Design Criteria*, 1989. This order provides requirements for meteorology, hydrology, and seismology as they relate to facility siting. DOE Order 5480.28, *Natural Phenomena Hazards Mitigation*, provides more explicit requirements for those aspects of facility siting.
- DOE Order 5480.28, 1993, *Natural Phenomena Hazards Mitigation*. This Order establishes DOE facility safety requirements for dealing with natural phenomena hazards (NPHs). The Order establishes NPH mitigation requirements, performance categories, and target probabilistic performance goals for each category. DOE Order 5480.28 will be replaced by DOE Order 420.1, which is expected to have the same NPH requirements as the implementing standards listed below.
- DOE-STD-1020-94, 1994, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*. This standard gives design and evaluation criteria for NPH effects including guidance for defining NPH loads.
- DOE-STD-1021-93, 1993, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components*. This standard provides guidance for assigning structures, systems, and components (SSCs) to one of five performance categories and recommends systematic procedures for implementing this guidance.

- DOE-STD-1022-94, 1994, *Natural Phenomena Hazards Site Characterization Criteria*. This standard provides criteria for selecting the site-specific information needed to implement DOE Order 5480.28.
- DOE-STD-1023-95, 1995, *Natural Phenomena Hazards Assessment Criteria*. This standard provides criteria for assessing NPHs to ensure that adequate design basis load levels are established for design or evaluation of DOE facilities.

The orders and standards listed above were not in existence at the time the below-grade portion of the CSB was designed. The impact of these orders and standards is reflected in WHC-SD-SNF-DB-009, *Canister Storage Building Natural Phenomena Hazards* (Tallman 1996).

1.2.2 U.S. Nuclear Regulatory Commission Rules and Guidance

In Memorandum EM-36-3.1.6.7, *Concurrence with K-Basins Spent Nuclear Fuel Project Policy on Nuclear Safety Requirements* (Grumbly 1995), DOE established the requirement for new SNF Project facilities to achieve "nuclear safety equivalency" to comparable U.S. Nuclear Regulatory Commission (NRC)-licensed facilities. The SNF Project identified the NRC requirements that were needed in addition to existing and applicable DOE requirements to establish nuclear safety equivalency. These NRC requirements and the process used to identify them are documented in WHC-SD-SNF-DB-003, *Spent Nuclear Fuel Project Path Forward, Additional NRC Requirements* (Garvin 1996), and in WHC-SD-SNF-DB-009 (Tallman 1996). These documents establish the design requirements for the CSB.

1.2.3 Industry Consensus Standards and Other Documentation

The following industry standards are applicable to the safety basis.

- ANSI/ANS-2.8-1992, 1992, *Determining Design Basis Flooding at Power Reactor Sites*. This standard provides criteria to establish design basis flooding for nuclear safety-related features at power reactor sites.
- ASCE 7-93, 1993, *Minimum Design Loads for Building and Other Structures*. This standard sets the minimum acceptable fastest mile wind speed.
- NFPA 780, 1995, *Lightning Protection Systems*. This code provides requirements for the safeguarding of persons and property from hazards arising from exposure to lightning.
- ASCE Standard 4, 1986, *Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety-Related Nuclear Structures*. This code provides guidance on seismic analysis of safety-related nuclear structures.

1.3 SITE DESCRIPTION

The following sections address the geography, demography, and regional land and water use of the area encompassed by, and surrounding, the Hanford Site. Much of the information contained in this section was obtained from DOE/EIS-0245F, *Management of Spent Nuclear Fuel from K Basins at the Hanford Site, Richland, Washington* (DOE 1996).

1.3.1 Geography

The Hanford Site is a 1,450 km² (560 mi²) area located in the state of Washington, as shown in Figure 1-1. Principal cities and towns and prominent natural features are shown in Figure 1-1. Use of the Site is institutionally controlled by DOE for national security and health and safety reasons.

The Columbia River enters the Hanford Site at the northwest corner and flows through the northern portion of the Site before turning southward to form part of the eastern boundary. The Yakima River flows from west to east, forming part of the southern boundary of the Site and empties into the Columbia River at the Tri-Cities (Richland, Kennewick, and Pasco) (Figure 1-2). The Hanford Site is bordered on the north by the Saddle Mountains and on the west by the Umtanum and Yakima Ridges and Rattlesnake Mountain (Figure 1-3). Dominant natural features include the Columbia River, anticlinal ridges of basalt in and along the Hanford Site boundary, and sand dunes located near the Columbia River. The surrounding basaltic ridges rise to elevations as high as 1,100 m (3,600 ft).

The location of the Hanford Site with respect to local counties and regional highways is shown in Figure 1-2. The Hanford onsite road network consists primarily of rural arterial routes. Only 104 of the 461 km (65 of the 288 mi) of paved roads are accessible to the public. Most onsite employee travel occurs along Route 4, with controlled access at the Yakima and Wye Barricades, as shown in Figure 1-4. Route 4 passes within 350 m (1,155 ft) of the CSB. State Route 240 is the main public route through the Site. State Routes 24 and 243 also traverse the Site. State Route 240 passes through the Hanford Site and within 8 km (5 mi) of the CSB. An additional access point to the 200 Areas from State Highway 240 (Rattlesnake Barricade), with limited hours of operation, is located near the southeastern corner of the 200 West Area (see Figure 1-4). Public access through the Hanford Site on Highways 24, 240, and 243 is not strictly controlled by DOE under normal circumstances. Large shipments, in particular components from dismantled nuclear submarines, are offloaded at the Port of Benton dock facilities discussed below. Overland wheeled trailers are then used to transport the shipments to the Site.

Onsite rail transport is provided by a short-line railroad owned and operated by DOE. This line connects just south of the Yakima River with the Union Pacific line, which in turn interchanges with the Washington Central and Burlington Northern-Santa Fe railroads at Kennewick. The mainline of the Hanford Railroad passes 3,000 m (9,000 ft) to the north of the CSB.

There is no barge traffic on the Columbia River upstream (north) of the Port of Benton barge slip, which is just north of Richland. The barge slip is

located near the upper end of the McNary Dam impoundment and above this location the river is too swift and shallow to allow for safe operation of barges. In addition, there are no lock facilities at Priest Rapids Dam, the next upstream dam, and there are no industrial facilities between the Port of Benton barge slip and the dam that would benefit from barge service.

There are three commercial airports within 50 km (31 mi) of the CSB. These are the Tri-Cities and Richland airports and Vista Field. They are discussed in detail in Section 1.6.1.

Traffic on the Columbia River, in the airspace over the Hanford Site, and on access routes into the areas used by U.S. Ecology, Incorporated, and the Washington Public Power Supply System (Supply System) are not subject to strict controls under normal circumstances. Under emergency plan conditions, DOE will control all road and railroad access to the Hanford Site and may close these Site routes to normal traffic. Access by the Columbia River cannot be immediately controlled, as discussed in Section 1.3.1.3.

1.3.1.1 Hanford Site Vegetation. The most broadly distributed vegetation on the Hanford Site is sagebrush, wheatgrass, blue bunch wheatgrass, cheatgrass, and other shrub plant species common to central Washington. The flora is prone to destruction by fire and can burn rapidly. The most recent severe grass fire at the Hanford Site occurred in August 1984 as a result of a range fire that started northeast of Sunnyside, Washington (see Figure 1-1). Extremely dry vegetation, inaccessible mountain terrain, and winds up to 64 km/h (40 mi/h) limited attempts to extinguish the fire. The fire front entered the Hanford Site adjacent to Rattlesnake Mountain, crossed Highway 240, and traveled northeast along Army Loop Road south of the 200 East Area (Figure 1-4). The fire was not controlled until it reached the Columbia River, by which time it had burned approximately 809 km² (312 mi²) of range land. Hanford Site facilities near the fire were protected by fire breaks cut by bulldozers and blades, and by fire-fighting tanker trucks. Vehicle access is available for the areas around all major Hanford Site facilities. For this fire, air drops of fire retardant material by U.S. Forest Service planes from the Wenatchee National Forest were used to help protect major facilities. Losses related to this severe grass fire were limited to burned railroad ties, wooden power poles, and several trailers. Several fire-fighting vehicles also were damaged.

To protect the CSB, a clear space of at least 18.3 m (60 ft) will be provided on all sides of the CSB. Unpaved areas will be overlaid with a crushed rock surface. With this protection, the only potential risk to CSB operation is related to the need to maintain natural circulation in the vault. This is discussed in Section 3.4.2.6.

1.3.1.2 Hanford Site Facilities. In 1943 the U.S. Army Corps of Engineers selected the Hanford Site for construction of nuclear reactors and chemical processing facilities in support of the war effort. The current mission is environmental management of radioactive and hazardous wastes, restoration of Site land, and conversion of useable facilities for other uses. DOE nuclear facilities currently occupy approximately 6% of the total available Hanford Site land area. Site operating areas are identified by area numbers and are briefly described below. Figure 1-4 shows these numbered areas. The CSB is

in the 200 East Area and will store spent fuel currently located in the 100 K Area.

Six 100 Areas border directly on the Columbia River in the northernmost portion of the Site. These areas were the locations for nine graphite-moderated plutonium production reactors. Eight of these reactors, which started operation before 1960, were shut down in the early 1970s. The ninth reactor, N Reactor, became operational in 1963 and continued operating until 1986. Spent fuel from the N Reactor will be stored in the CSB. The 100 Areas occupy about 11 km^2 (4 mi^2).

The CSB is located in the 200 East Area, near the center of the Hanford Site on a relatively flat terrace known as the 200 Area Plateau (Figure 1-5). In the past, the 200 East and 200 West Areas have received waste from the 100, 300, and 400 Areas in addition to the waste produced by 200 Area separation processes.

The 300 Area, located just north of Richland, is the site of nuclear research and development. This area covers 1.5 km^2 (0.6 mi^2).

The 400 Area is the site of the Fast Flux Test Facility (FFTF), a liquid-metal-cooled fast reactor used for testing breeder reactor fuels, materials, and components. The FFTF is currently shut down and is being defueled as part of eventual decontamination and decommissioning activities. However, the FFTF is being considered for other missions. This area covers 0.6 km^2 (0.25 mi^2).

The 600 Area includes all of the Hanford Site not occupied by the 100, 200, 300, or 400 Areas. Land uses within the 600 Area, other than those described previously, include the following (Figure 1-4).

- An area measuring 310 km^2 (120 mi^2), known as the Fitzner-Eberhardt Arid Lands Ecology Reserve, is located along the southwest boundary of the Hanford Site (Figure 1-3). This area is a limited-access area managed by Pacific Northwest National Laboratory and has been set aside for ecological studies.
- An area measuring 4 km^2 (1.5 mi^2), located between the 200 West and 200 East Areas, is leased by Washington State. A part of this area is managed by U.S. Ecology, Incorporated, for the disposal of solid, low-level radioactive waste from commercial — not Hanford Site — sources.
- An area measuring 4.4 km^2 (1.6 mi^2) is used by the Supply System for commercial nuclear power plants. This area is located approximately 17 km (10.5 mi) southeast of the 200 East Area and approximately 5 km (3 mi) west of the Columbia River. Three commercial nuclear power plants were originally planned for this site. Washington Nuclear Plant (WNP)-2, a boiling-water reactor, is currently in operation at this location. Construction has been terminated at the other two reactors, WNP-1 and WNP-4. Both were to be pressurized water reactors. Also located on the Supply System leased property are the Supply System's Plant Engineering Center and Plant Support

Facility and the Bonneville Power Administration's H. J. Ashe substation.

- An area measuring 2.6 km² (1 mi²) has been transferred to Washington State as a potential site for the disposal of nonradioactive hazardous wastes. See Figure 1-4.
- About 130 km² (50 mi²) of land north of the Columbia River, the Saddle Mountains National Wildlife Refuge, is managed under a revocable use permit by the U.S. Fish and Wildlife Service. The U.S. Fish and Wildlife Service also manages seven islands in the Hanford Reach section of the Columbia River as part of the McNary National Wildlife Refuge.
- Another 225 km² (87 mi²) of land north of the Columbia River, the Wahluke Wildlife Recreation Area, is under a revocable use permit managed by the Washington State Department Wildlife for recreational game management. Public outdoor recreational use is permitted in this area.
- Support facilities for the controlled access areas and an electrical transmission substation at Midway near the northwest corner of the Hanford Site are maintained by the Bonneville Power Administration.

1.3.1.3 Boundaries for Evaluation of Accident and Effluent Release Limits.

Activities in the 200 East Area are within the DOE-controlled zone, which is surrounded by a security fence limiting general access. No special security clearance other than a Site badge is required to pass through the gates that control access to the 200 Areas. However, the DOE has the authority to determine all activities in this area including exclusion or removal of personnel and property; an exception exists relative to the Columbia River as discussed below. There are no permanent residences in this area.

Consequences of accident releases to collocated workers are calculated in Section 3.4.2 at 100 m (328 ft) from the point of release in accordance with approved procedures ~~WHC CM 4-46, Safety Analysis Manual~~. Routine and accidental releases to the public (offsite receptor) are calculated at the Site boundary shown in Figure 1-2. This is also the location of the controlled area boundary as the term is defined in Title 10, *Code of Federal Regulations*, Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," Section 106, "Controlled Area of an ISFSI or MRS" (10 CFR 72.106). However, for both cases, the Columbia River is taken as the location of the offsite receptor to the east as DOE does not control activities on the river. This is in accordance with DOE direction that states, "Therefore, the river must be viewed as a location of the public for safety analysis purposes" (Scott 1995). For Highway 240 to the west, DOE and its contractors can control access during emergency and accident conditions. This access control meets the requirements of 10 CFR 72.106(b). For undetected accidents or accidents with a puff release, this control may not be effective. For the location of the offsite receptor for CSB events, this is not of concern as the Columbia River represents the more limiting case even though it is farther from the CSB site than Highway 240.

Radiological consequences calculated in Section 3.4.2 were developed considering only the current Hanford Site boundary (Figure 1-2) with the exception of the location of an offsite receptor on the Columbia River as discussed above. Before changes to the Site boundaries are placed into effect by the proper authorities, the calculations in this safety analysis report (SAR) will be reviewed (and reanalyzed if required) in accordance with the unreviewed safety question procedure outlined in WHC-CM-1-5, *Standard Operating Practices*, Section 7.3, "Identifying and Resolving Unreviewed Safety Questions."

1.3.1.4 Regional Land and Water Use. This section characterizes regional land and water use both inside and outside the Hanford Site boundaries based on information contained in DOE/EIS-0113, *Final Environmental Impact Statement: Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes, Hanford Site, Richland, Washington* (DOE 1987), *Hanford Site National Environmental Policy Act (NEPA) Characterization* (Cushing 1995), and DOE/EIS-0245F (DOE 1996).

1.3.1.4.1 Land Use Within the Hanford Site Boundaries. The majority of the land within the Hanford Site boundary is a limited-access area under control of the DOE for use in environmental restoration and remediation efforts. A number of areas at the Hanford Site are managed under a multipurpose concept and serve as buffer zones around areas of nuclear activity. These multipurpose areas are shown in Figure 1-4.

1.3.1.4.2 Agricultural Land Use Outside Hanford Site Boundaries. Land use in the six-county region surrounding the Hanford Site (i.e., Franklin, Walla Walla, Benton, Yakima, Adams, and Grant Counties [Figure 1-2]) is predominantly agricultural. Over 75% of the land area in this region is in agriculture-related use compared with less than 40% statewide. The percentage of agricultural land that is irrigated in this region varies from a low of 33% in Yakima County to a high of 73% in Grant County. However, areas of Yakima County near the Hanford Site have intensive irrigation.

Regional land used for agricultural purposes lies primarily north and east of the Columbia River and south of the Yakima River. The U.S. Bureau of Reclamation's Columbia Basin Irrigation Project is northeast of Othello. Part of the farmland northeast of Priest Rapids Dam is irrigated by the Columbia Basin Project; the rest is used for dryland farming. The area from Othello south to the Columbia River is irrigated farmland. The principal agricultural crops associated with the irrigated and dryland farming include hay, wheat, potatoes, corn, apples, soft fruit, and vegetables. Land in the area just outside the Hanford Site to the south and west is available for farming but is used mainly for grazing cattle and sheep. The agricultural land along the Yakima River is used for fruit orchards, grapes, hops, alfalfa, and annual row crops. Higher land away from the Yakima Valley floor is used principally for livestock grazing, dairies, and fruit orchards, with some grain crops. South and west of Kennewick, the land is used principally for dryland wheat farming, with some orchards.

1.3.1.4.3 Nonagricultural Land Use Outside Hanford Site Boundaries. The main industries in the Tri-Cities are, or are related to, agriculture and energy production. The DOE nuclear and nonnuclear industrial activities within an 8-km (5-mi) radius of the CSB are described in detail in

Section 1.7. All industrial activities on Hanford Site leased land must be compatible with DOE activities and must be approved by the DOE. These land uses are discussed in Section 1.3.2.1. The DOE retains the right to remove from lease any land not currently used or not under development by the state. The Big Bend Alberta Company owns mineral rights to several parcels of land in the Arid Lands Ecology Reserve (Figure 1-4) and holds the right to perform exploratory drilling.

The U.S. Army's Yakima Training Center covers 326,000 acres just northwest of the western Hanford Site boundary (Figure 1-2). The Center is used for firing all types of ordnance, both in a direct mode and by indirect artillery and mortars. Weapons to 8-in. are fired. Firing occurs frequently. Live ordnance usage at the Center includes bombs, up to 500 lb, delivered by high-performance aircraft; helicopter weapons, which include automatic weapons and 2.75-in. folding fin rockets; and antiaircraft missiles. The majority of the ordnance impacts a 20,000-acre area that is located in the central portion of the Center. All activities are confined to the geographical limits of the Center and/or its restricted air space unless special arrangements are made with affected agencies. Mechanized units (i.e., tanks and armored personnel carriers) from Fort Lewis and Reserve components conduct extensive maneuvers on all accessible areas of the Yakima Training Center and use specially designed ranges to practice firing their weapons. Infantry and engineering units that support the mechanized units also train at the Center. Training activity is greatest from March to November. War games sometimes involve troop and equipment deployment at the Richland airport and along Highway 243 west of the Vernita Bridge. Helicopters may fly near the Hanford Site, or military vehicles may travel over Highway 240.

1.3.1.4.4 Water Use. The major water uses, in decreasing order, are agricultural, industrial, and municipal. CSB operation will involve no water withdrawals from or direct discharges to the Columbia River. Also no liquid effluent waste streams from the CSB will be generated.

1.3.2 Demography

The 1990 U.S. Bureau of the Census population distribution statistics for cities within an 80-km (50-mi) radius of the Hanford Meteorological Station (HMS) are shown in Figure 1-6. The HMS often serves as the center for population distribution around the 200 Areas, and its close proximity to the CSB (about 4.8 km [3 mi] east of the HMS) warrants use of the HMS as the population distribution centerpoint for this description.

The population distribution in the area surrounding the Hanford Site is not uniform. Most of the adjacent area to the east, north, and west is farm or range land with scattered farming communities. Table 1-1 shows the actual 1990 residential population and the projected residential population within an 80-km (50-mi) radius of the HMS for decennial census years through 2040 (Beck et al. 1991). The Tri-Cities are located to the south and southeast of the CSB and comprise the major population center of the area. The three cities (Kennewick, Pasco, and Richland) are estimated to have a combined population of approximately 104,000 based on 1994 estimates. The estimated unincorporated population of Benton County is 33,000 and of Franklin County is 18,000 (DOE 1996). More recent data on the Tri-Cities population are not

available although Hanford Site and total nonfarm employment is on a downward trend. The projected increase in the total population of Franklin County from 1995 to 2005 is from 41,336 to 48,213 (8.03%) and for Benton County from 121,328 to 136,892 (6.32%) (DOE 1995).

Table 1-1. Projected Residential Population in an 80-km (50-mi) Radius of the Hanford Meteorological Station for the Period 1990 through 2040.

Year	Decade	Average annual rate of growth during decade (%)	Population
1990	--	--	375,860
2000	1990 to 2000	0.633	400,346
2010	2000 to 2010	0.413	417,200
2020	2010 to 2020	0.351	432,062
2030	2020 to 2030	0.157	438,909
2040	2030 to 2040	0.068	441,911

Other population centers of note within an 80-km (50-mi) radius include the cities of Sunnyside, Moses Lake, and Yakima. The Yakima River Valley, stretching in an arc from the city of Yakima to the Tri-Cities, is a relatively densely populated agricultural area with a number of small towns. The nearest residence to the 200 East Area is approximately 19 km (11 mi) east across the Columbia River. The Richland city limits are approximately 27 km (16 mi) to the southeast.

Figure 1-7 shows the estimated populations of migrant agricultural workers and recreationists. Both are defined as transient. These estimates were developed by the Supply System in 1988 and are documented in *WNP-1, 2 Ten Mile EPZ Evacuation Time Assessment Study* (Mogle 1987). The center of the Supply System's 16-km (10-mi) emergency planning zone, which is located midway between WNP-1, WNP-2, and WNP-4, is the geographic point from which estimates are made. The CSB is located approximately 19 km (12 mi) west-northwest from the center point (see Figure 1-7). This distance from the center point is not significant to the accident analyses in Section 3.4 as the location of the offsite receptor is determined by consideration of the Site boundary and the ability to control activities within the boundary as discussed in Section 1.3.1.3.

In late 1995, approximately 15,000 persons were employed on the Hanford Site. Figure 1-8 shows estimated 200 East Area employee distributions by facility. Some Hanford Site work assignments include shift and weekend coverage. The total number of persons on the Site at any one time varies with the time of day, staffing requirements for current projects, and daily fluctuations in employee work attendance.

There are currently no hospitals, nursing homes, or penal institutions in the Supply System's 16-km (10-mi) emergency planning zone. The closest school to the CSB site is the Edwin Markham Elementary School with a 1995-1996 enrollment of 283 students. Evacuation of the Edwin Markham School and of the nearby Country Haven and Country Christen School is provided for in the Benton and Franklin Counties Fixed Nuclear Facility Emergency Response Plan.

1.4 ENVIRONMENTAL DESCRIPTION

The following sections address the meteorology, hydrology, and geology of the Hanford Site.

1.4.1 Meteorology

This section describes the regional climatology and the meteorological conditions of the Hanford Site. Climatological data are available for the HMS, which is located between the 200 East and 200 West Areas (Figure 1-9). Data have been collected at this location since 1945. Data from the HMS are representative of the general climatic conditions for the region and describe the specific climate of the 200 Area Plateau. Information contained in this section is taken primarily from PNL-10553, *Climatological Data Summary 1994 with Historical Data* (Hoitink and Burk 1995), and PNL-4622, *Climatological Summary for the Hanford Area* (Stone et al. 1983).

A wide range of meteorological variables is measured at the HMS and at the 125-m (410-ft) tower, which is located 492 m (1,614 ft) east of the HMS. Temperature, relative humidity, precipitation, atmospheric pressure, solar radiation, cloud cover, visibility, and subsurface temperature are parameters measured or observed at the HMS. Wind data are measured at various levels on the 125-m (410-ft) tower. Three 60-m (200-ft) towers, with wind and temperature measuring instruments at various levels, are located at the 300, 400, and 100 N Areas. Wind and temperature measurements also are taken on 23 9.1-m (30-ft) towers distributed on and around the Hanford Site (see Figure 1-9). Data from all towers are telemetered to the HMS. The Hanford Meteorological Monitoring Network is described in detail in PNL-6684, *The Data Collection Component of the Hanford Meteorological Monitoring Program* (Glantz and Islam 1988).

1.4.1.1 Regional Climatology. The climate of the Pasco Basin, in which the CSB is located, can be classified as midlatitude semiarid or midlatitude desert, depending on the climatological classification scheme used. Summers are warm and dry with abundant sunshine. Large diurnal temperature variation results from intense solar heating during the day and radiational cooling at night. Daytime high temperatures in June, July, and August periodically exceed 38 °C (100 °F). Winters are cool with occasional precipitation. Outbreaks of cold air associated with modified arctic air masses can reach the area and cause temperatures to drop below -18 °C (0 °F). Overcast skies and fog occur periodically during the winter season (Stone et al. 1983).

Topographic features have a significant impact on the climate of the Hanford Site. All air masses that reach the Pasco Basin undergo some modification as a result of their passage over the complex terrain of the

Pacific Northwest. The climate of the Pasco Basin is strongly influenced by the Pacific Ocean and the Cascade Range to the west. The relatively low annual average rainfall of 16.8 cm (6.6 in.) at the HMS is caused largely by the rain shadow created by the Cascade Range. This mountain range limits much of the maritime influence of the Pacific Ocean, resulting in a more continental-type climate than would exist if the range were not present. Maritime influences are experienced in the region during the passage of frontal systems and as a result of movement through the gaps in the Cascade Range (e.g., Columbia River Gorge).

The Rocky Mountains to the east and north of the Pasco Basin also influence the climate of the region. These mountains play a key role in protecting the region from the more severe winter storms and the extremely low temperatures associated with modified arctic air masses that move southward through Canada. The Yakima Ridge, Rattlesnake Hills, and Horse Heaven Hills to the west and south of the Hanford Site, the Saddle Mountains to the north, and the Columbia River also influence the local climate (see Figure 1-10).

The position of the jet stream directs storm systems into Washington State during the cooler months. These systems cause the majority of the precipitation at the Hanford Site. The cold, or occluded, fronts associated with these storm systems originate in maritime polar, continental polar, or arctic air masses. Warm fronts occur as warmer maritime air flows over colder continental air. An average of 10 identifiable warm fronts and 52 cold fronts pass through the Pasco Basin each year (Stone et al. 1983). A majority of these passages occur during the colder months leading to increased frequency and intensity of precipitation. Periodic persistent high-pressure ridges in the upper troposphere in the cool season, which can trap cold air near the surface, lead to extended periods of wintertime stagnation.

The jet stream directs most storms north of the state of Washington during the warmer months; therefore, frontal passages are fewer and weaker than in the cooler months. High pressure with stable, subsiding air is the dominant meteorological condition during this period. Warm weather precipitation tends to be associated with convective activity and the advection of moist, maritime air into the region (Stone et al. 1983).

1.4.1.1.1 Temperature. Monthly and annual daily average and extreme temperatures for the Hanford Site from 1961 through 1990 are given in Table 1-2. At the Hanford Site, the annual average temperature is 12 °C (53 °F) (Hoitink and Burk 1995). July is typically the warmest month with an average maximum temperature of 33 °C (91 °F), an average minimum temperature of 16 °C (61 °F), and an average temperature of 25 °C (76 °F). January tends to be the coolest month with an average maximum temperature of 4 °C (38 °F), an average minimum temperature of -4 °C (24 °F), and an average temperature of 0 °C (32 °F). Observed temperature extremes for the Hanford Site range from 45 °C (113 °F) to -31 °C (-23 °F). The highest temperature ever recorded on the Hanford Site was 46 °C (115 °F) on July 27, 1939. The lowest temperature ever recorded on the Hanford Site was -33 °C (-27 °F) on December 12, 1919. These temperatures were recorded before the HMS was operational and are not included in Table 1-2.

Table 1-2. Monthly and Annual Daily Average and Extreme Temperatures at the Hanford Meteorological Station.

Month	Average daily temperature, 1961-1990 (°F)			Extreme temperature, 1945-1994 (°F)	
	Maximum	Minimum	Monthly	Maximum	Minimum
January	38	24	31	72	-22
February	47	29	38	72	-23
March	57	34	46	83	6
April	66	40	53	94	21
May	75	47	61	104	28
June	84	55	70	111	37
July	91	61	76	111	39
August	90	60	75	113	41
September	80	51	66	106	30
October	66	40	53	89	12
November	49	32	40	75	-13
December	38	25	31	69	-14
Year			53	113	-23

Note: Information in this table is from D. J. Hoitink and K. W. Burk, 1995, Climatological Data Summary 1994, with Historical Data, PNL-10553, Pacific Northwest Laboratory, Richland, Washington.

Table 1-3 shows the number of days per month averaged over the period 1945 through 1994 that the Hanford Site maximum and minimum temperatures were above or below specified values (Hoitink and Burk 1995). Maximum temperatures greater than or equal to 38 °C (100 °F) occur an average of 11 days a year and vary from 1 to 28 days. Maximum temperatures greater than or equal to 32 °C (90 °F) occur an average of 51 days per year and vary from a low of 29 to a high of 79 days. Maximum temperatures less than or equal to 0 °C (32 °F) occur an average of 25 days a year and vary from 2 to 58 days. Minimum temperatures less than or equal to 0 °C (32 °F) occur an average of 107 days per year and vary from a low of 70 to a high of 143 days. Minimum temperatures less than or equal to -18 °C (0 °F) occur an average of 3 days per year and vary from 0 to 18 days. An average of 183 days a year are free of freezing temperatures, with the recorded range being 142 to 216 days.

Table 1-3. Average Number of Days at the Hanford Meteorological Station that Maximum and Minimum Temperatures were above or below Specified Limits for the Period 1945 through 1994.

Month	Maximum temperature			Minimum temperature	
	≥ 100 °F	≥ 90 °F	≤ 32 °F	≤ 32 °F	≤ 0 °F
January	0	0	11	26	2
February	0	0	3	20	*
March	0	0	*	14	0
April	0	*	0	4	0
May	*	3	0	*	0
June	1	8	0	0	0
July	6	19	0	0	0
August	4	16	0	0	0
September	*	5	0	*	0
October	0	*	*	4	0
November	0	0	2	15	*
December	0	0	9	24	1
Year	11	51	25	107	3

Note: Information in this table is from D. J. Hoitink and K. W. Burk, 1995, Climatological Data Summary 1994, with Historical Data, PNL-10553, Pacific Northwest National Laboratory, Richland, Washington.

*Denotes less than half a day.

The Hanford Site and vicinity are known for severe and abrupt temperature changes. During winter the Site frequently experiences rapid rises in temperature accompanied by moderate west winds. This phenomenon, known as a chinook wind, has produced temperature variations of up to 6 °C (22 °F) in 0.5 hours and is responsible for rapid melting of snow (DOE 1987).

1.4.1.1.2 Precipitation. The annual average precipitation value at the HMS is 16.8 cm (6.6 in.) with the annual precipitation value for the wettest documented year (1950) being 29.1 cm (11.45 in.) and for the driest year (1976) being 7.6 cm (2.99 in.) (Hoitink and Burk 1995). An unpublished record precipitation of 31.3 cm (12.3 in.) occurred in 1995 at the HMS. Monthly averaged and extreme precipitation amounts for the Hanford Site from 1945 through 1994 are given in Table 1-4. On average, 54% of normal annual precipitation falls during November through February. December is the wettest month, receiving 2.6 cm (1.03 in.), and July is the driest month, receiving only 0.46 cm (0.18 in.). The wettest month on record is June 1950 with 7.4 cm (2.92 in.); September 1991, August 1988, and August 1955 recorded no precipitation. An average of 125 days per year have a trace (less than 0.013 cm [0.005 in.]) or more of precipitation. The average number of days per month with a trace or more ranges from 16 days in January to 5 days in July. Only 24 days a year receive totals of 0.25 cm (0.1 in.) or more. During the 49-year period of record (1945 through 1994), only 3 days have had 2.5 cm (1 in.) or more of precipitation.

Table 1-4. Monthly and Annual Average and Extreme Precipitation in Inches at the Hanford Meteorological Station for the Period 1945 through 1994.

Month	Average	Maximum	Year	Minimum	Year
January	0.88	2.47	1970	0.08	1977
February	0.62	2.10	1961	T*	1988
March	0.49	1.86	1957	0.02	1968
April	0.44	1.22	1969	T*	1986
May	0.52	2.03	1972	T	1992
June	0.54	2.92	1950	T*	1986
July	0.22	1.76	1993	T*	1980
August	0.25	1.36	1977	0*	1988
September	0.31	1.34	1947	0	1991
October	0.52	2.72	1957	T*	1987
November	0.86	2.64	1973	T	1976
December	0.95	2.34	1964	0.11	1976
Year	6.61	11.45	1950	2.99	1976

Notes: Information in this table is from D. J. Hoitink and K. W. Burk, 1995, Climatological Data Summary 1994, with Historical Data, PNL-10553, Pacific Northwest Laboratory, Richland, Washington.

*Most recent of multiple occurrences.

T = trace (0.005 in. or less).

A recent cooperative study by the National Oceanic and Atmospheric Administration, the Bureau of Reclamation, and the U.S. Army Corps of Engineers has updated the probable maximum precipitation (PMP) estimates for the Pacific Northwest (Hansen et al. 1994). This document supersedes earlier work done by these organizations and is the source used for the PMP shown in Table 1-5. The PMP values are estimates of the maximum precipitation physically possible for both general storms (large air mass interactions) and local storms (unstable air, thunderstorms). At the Hanford Site the 6-hour local storm produces more precipitation than the 24-hour general storm. The 6-hour local storm PMP is related to the area of the storm, the smaller area yielding the most intense storm and highest precipitation. Data are presented for the 1-mi² and the 10-mi² storm. The CSB will be designed to accommodate the full range of PMP identified in Table 1-5. The effects of local PMP will be determined according to ANSI/ANS-2.8-1992 (ANSI/ANS 1992). Local protection for run-off will be provided by earthwork and grading design and by the storm drain system consisting of culverts, ditches, channels, and catch basins as required. These features will not impact the below-grade portion of the CSB. No annual probability of exceedance is given in Hydrometeorological Report No. 57, *Probable Maximum Precipitation — Pacific Northwest States* (Hansen et al. 1994), for the PMP for either general or local storms. The PMP is conservatively assumed to have an annual probability of exceedance of less than 1×10^{-6} (ASCE 1988).

Table 1-5. Extreme Precipitation Estimates for the Hanford Site.

Time	PMP 24-hour general storm (10 mi ² a)	PMP local storm (1 mi ² a)	PMP local storm (10 mi ² a)	25-year average return period ^b	100 Year average return period ^b	1,000-year average return period ^b
15 minutes	--	4.0	3.2	--	--	--
20 minutes	--	--	--	0.47	0.60	0.80
30 minutes	--	6.0	4.8	--	--	--
45 minutes	--	7.2	5.8	--	--	--
1 hour	1.6	8.0	6.4	0.62	0.81	1.11
6 hours	4.7	9.2	7.4	1.21	1.59	2.20
24 hours	8.0	--	--	1.56	1.99	2.68
48 hours	9.6	--	--	--	--	--
72 hours	10.4	--	--	--	--	--

Note: Precipitation depths are in inches. To convert to centimeters, multiply by 2.54.

^a Hansen, E. M., D. D. Fern, P. Corrigan, J. L. Vogel, L. C. Schreiner, and R. U. Stodt, 1994, Probable Maximum Precipitation - Pacific Northwest States, Hydrometeorological Report No. 57, National Weather Service, Silver Spring, Maryland.
^b Stone, W. A., S. K. Mullen, P. Gifford, and D. J. Holtink, 1983, Climatological Summary for the Hanford Site, PNL-4422, Pacific Northwest Laboratory, Richland, Washington.

PMP = probable maximum precipitation.

The 6-hour PMP for more frequent storms shown in Table 1-5 is from PNL-4622 (Stone et al. 1983) and is based on the analysis of extreme values from 22 years of meteorological data from the Hanford Site. The precipitation estimates for the 100- and 1,000-year return period are based on data from the HMS. Although these values cannot be compared directly with either the 1-mi² storm or the 10-mi² storm, they provide a data-based estimate for extreme precipitation on the 200 Area Plateau. A 6-hour precipitation hazard curve is estimated using the 100-year and 1,000-year average return period values (10^{-2} and 10^{-3} annual probability of exceedance respectively) of PNL-4622 (Stone et al. 1983) and the 6-hour PMP at an assumed frequency of 10^{-6} (Figure 1-11).

Total annual snowfall, which includes all frozen precipitation, varied for the period 1945 through 1994 from a low of 0.76 cm (0.3 in.) to a high of 142 cm (56.1 in.) (Hoitink and Burk 1995). The average snowfall is 38 cm (15 in.) a year. Table 1-6 presents the monthly and annual average and extreme snowfalls. The record snow depth at the HMS is 39.6 cm (15.6 in.) in December 1995, but the record snow depth on the Hanford Site is 61 cm (24 in.) in February 1916. The record number of days with snow depth greater than or equal to 15.2 cm (6 in.) is 43 days in the winter of 1992-1993. The probability the depth of snow on the ground will not exceed 15 cm (6 in.) is 30% during the winter season (Figure 1-12).

The design ground snow load for the CSB is 98 kg/m² (20 lb/ft²), which is the ground snow load for the NRC-licensed WNP-2. This value is 24 kg/m² (5 lb/ft²) greater than the ASCE requirement (ASCE 1993).

Glaze ice is a coating of ice formed when rain or drizzle freezes on contact with any surface having a temperature that is below freezing. The average number of days with freezing rain or freezing drizzle is six and they generally occur between November and March. The highest number of days with glaze in any winter season was 18. The least number of days with glaze in any winter season was one. The greatest number of days with glaze in any given month was nine, in January 1970. Rime ice (i.e., supercooled droplets that freeze on contact with solid objects) is generally associated with supercooled fog in the nearby hills or along the banks of the Columbia River.

1.4.1.1.3 Thunderstorms. A thunderstorm day is one in which thunder is heard at the observing station one or more times during a calendar day. Table 1-7 shows the number of thunderstorm days per month and per year for the period 1945 through 1994. The average number of thunderstorm days per year is 10. The total varies from a low of 3 to a high of 23 days (Hoitink and Burk 1995). The largest number of thunderstorm days in a single month was eight. Thunderstorms can theoretically occur during any month of the year, but none have been observed in November or January. Thunderstorm season is essentially from April through September.

Thunderstorms are classified by the National Weather Service as severe when wind gusts exceed 93 km/h (58 mi/h) and/or hail size equals or exceeds 2 cm (1 in.) in diameter. Only 1.9% of all thunderstorm events observed at the HMS have been severe storms (Cushing 1995). All severe storms met the wind gust criteria, but hail was seldom observed at the HMS. The maximum recorded number of days with hail in a year is two.

Table 1-6. Monthly and Seasonal Snowfall at the Hanford Meteorological Station in Inches, Average and Maximum for the Period 1945 through 1994.

Month	Average	Maximum	Year	Maximum 24-hour	Year
January	5.0	23.4	1950	7.1	1954
February	2.5	17.0	1989	10.2	1993
March	0.5	4.2	1951	2.7	1989
April	T	1.0	1982	*	--
May	0	0	--	0	--
June	0	0	--	0	--
July	0	0	--	0	--
August	0	0	--	0	--
September	0	0	--	0	--
October	0.1	1.5	1973	1.5	1973
November	1.5	18.3	1985	8.8	1985
December	5.3	21.0	1992	6.6	1985
Year	15	56.1	1992-93	10.2	February 1993

Notes: Information in this table is from D. J. Hoitink and K. W. Burk, 1995, Climatological Data Summary 1994, with Historical Data, PNL-10553, Pacific Northwest National Laboratory, Richland, Washington.

*No value given for maximum 24-hour snowfall.

Table 1-7. Average Number of Thunderstorm Days at the Hanford Meteorological Station for the Period 1945 through 1994.

Month	Thunderstorm Days
January	0
February	≤0.1
March	0.2
April	0.8
May	1.6
June	2.4
July	2.0
August	2.1
September	0.8
October	0.2
November	0
December	≤0.1
Year	10.1

Note: Information in this table is from D. J. Hoitink and K. W. Burk, 1995, Climatological Data Summary 1994, with Historical Data, PNL-10553, Pacific Northwest National Laboratory, Richland, Washington.

1.4.1.1.4 Extreme Winds and Tornadoes. Table 1-8 shows the maximum recorded peak gusts at the HMS for the period 1945 through 1994. The highest peak gust measured at the 15-m (50-ft) height was 129 m/sec (80 mi/h) in January 1972 (Hoitink and Burk 1995). Estimates of extreme winds, based on peak gusts observed from 1945 through 1980, are given in PNL-4622 (Stone et al. 1983). The extreme peak gust at 15 m (50 ft) for a return period of 100 years is estimated to be 137 km/h (86 mi/h). The return period on gusts of 114 km/h (70 mi/h) at 15 m (50 ft) is 10 years.

Two probabilistic wind hazard assessments have been completed for the Hanford Site. The first assessment was completed by Lawrence Livermore National Laboratory and reported in UCRL-53526, *Natural Phenomena Hazards Modeling Project: Extreme Wind/Tornado Hazard Models for Department of Energy Sites* (Coats and Murray 1985). This assessment was based on more than 30 years of pre-1979 Hanford Site wind data. The results are shown in Figure 1-13. The wind speeds are fastest mile and therefore, for an equivalent probability, considerably lower than the peak gusts illustrated in Table 1-8. Further, the hazard curves are based on winds at 9 m (30 ft) above ground surface and the peak gusts in Table 1-8 were measured at 15 m (50 ft) above ground surface. Wind speed increases with distance above ground surface. A second study, NUREG/CR-4492, *Methodology for Estimating Extreme Winds for Probabilistic Risk Assessments* (Ramsdell et al. 1986), describes a procedure for estimating extreme wind probabilities. The application of this methodology to Hanford Site data, including post-1979 data, resulted in hazard curves also shown in Figure 1-13.

Table 1-8. Maximum Peak Gusts 15 Meters (50 Feet) Off the Ground at the Hanford Meteorological Station for the Period 1945 through 1994.

Month	Peak gust speed	Direction of peak	Year
January	80	SW	1972
February	65	SW	1971
March	70	SW	1956
April	73	SSW	1972
May	71	SSW	1948
June	72	SW	1957
July	69	WSW	1979
August	66	SW	1961
September	65	SSW	1953
October	63	SSW	1950
November	67	WSW	1993
December	71	SW	1955
Year	80	SW	January 1972

Note: Information in this table is from D. J. Hoitink and K. W. Burk, 1995, Climatological Data Summary 1994, with Historical Data, PNL-10553, Pacific Northwest National Laboratory, Richland, Washington.

The wind hazard annual probability of exceedance for performance categories 1 and 2 is 2×10^{-2} (DOE-STD-1020-94). On Figure 1-13, this is about 25 m/s (55 mi/h) on the Coats-and-Murray curve and about 26 m/s (58 mi/h) on the Ramsdell-et-al. curve. However, a minimum design wind speed of 31.3 m/s (70 mi/h) is required by the American Society of Civil Engineers in ASCE-7-93 (ASCE 1993) and recommended by DOE-STD-1020-94. Therefore, the Hanford Site design basis wind speed for performance categories 1 and 2 is 31.3 m/s (70 mi/h). All wind speeds are fastest mile speeds at 9 m (30 ft) off the ground.

The straight wind hazard exceedance probability for performance category 3 is 1×10^{-3} . On Figure 1-13, this is approximately 30 m/s (67 mi/h) on the Coats-and-Murray curve and 32 m/s (72 mi/h) on the Ramsdell-et-al. curve. In DOE-STD-1020-94, the minimum straight wind speed for a performance category 3 design is 35.8 m/s (80 mi/h), which is higher than either of the wind hazard studies and is, therefore, the design basis for the Hanford Site.

The intersection of the straight-wind and tornado hazard curves determines whether tornadoes should be included in the design and evaluation criteria for DOE facilities, including the CSB (Coats and Murray 1985).

If the exceedance probability at the intersection is less than 2×10^{-5} , straight winds control the design criteria. In Figure 1-13, the intersection is at 3×10^{-6} on the Coats-and-Murray curve and 8×10^{-6} on the Ramsdell-et-al. curve. Therefore, following DOE guidance, the Hanford Site does not have a DOE design basis tornado.

The NRC tornado criteria will be followed at the CSB. This will be achieved by following the same requirement as the Supply System. The NRC staff have proposed dividing the United States into two regions and making the total rotational and translational wind speeds for sites west of the Rocky Mountains 322 km/h (200 mi/h) (NRC 1993). The basis for this consideration is a tornado hazards study, NUREG/CR-4461, *Tornado Climatology of the Contiguous United States* (Ramsdell and Andrews 1986). The Supply System requested a revision of the tornado criteria for WNP-2 (Parrish 1995) based upon the NRC staff's proposal for tornado wind speeds west of the Rocky Mountains and on the staff's acceptance of the design basis tornado characteristics in NUREG-1503, *Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design* (NRC 1994). The NRC accepted the proposed revision (Clifford 1996). These same criteria will be applied to the CSB:

- Wind speed
 - 322 km/h (200 mi/h) total
 - 257 km/h (160 mi/h) rotational
 - 64 km/h (40 mi/h) translational
- Pressure drop
 - 6,205 Pa (0.90 lb/in²) at 2,068 Pa/s (0.30 lb/in²/s)

For the CSB the need for protection of specific targets is addressed on a risk assessment basis. By this process, an estimate is made of the probability that a tornado-generated missile will strike a particular target and fail the target in such a way that unacceptable consequences result. If the probability obtained of a missile striking and failing a target, or simply striking the target, satisfies established acceptance criteria, then no physical barriers against missiles need be provided.

The use of probabilistic risk assessment techniques to establish the need to provide tornado-generated missile protection for specific targets has been accepted by the NRC for several years and is well documented in their review and design guidance. For example, the NRC Standard Review Plan (NRC 1981), Section 3.5.1.5, "Site Proximity Missiles (Except Aircraft)," includes the following statement relative to low risk of exposure to the public.

This requirement is met if the probability of site proximity missiles impacting the plant and causing radiological consequences greater than 10 CFR Part 100 exposure guidelines is less than about 10^{-7} per year (see SRP Section 2.2.3).

The NRC Standard Review Plan (NRC 1981), Section 2.2.3, "Evaluation of Potential Accidents," accepts 10^{-6} events/yr for offsite hazards exceeding the

guidelines in Title 10, *Code of Federal Regulations*, Part 100, "Reactor Site Criteria" (10 CFR 100), if, when accompanied by reasonable qualitative arguments, the realistic value can be shown to be lower. These provisions have remained in the 1996 draft revision to Standard Review Plan 2.2.3. For the CSB, an acceptance criterion to not exceed the 5 rem (50 mSv) limit of 10 CFR 72.106 at the controlled area boundary should be used.

The probability of a tornado occurring near the site and generating a missile that results in acceptable consequences can be expressed as follows:

$$P_{TM} = P_s \times P_{ms} \times P_f \times P_D$$

where

P_{TM} = The annual probability of a tornado missile striking such that an unacceptable radiological or chemical release occurs

P_s = The tornado annual point strike frequency (events/yr)

P_{ms} = The probability of a tornado-generated missile impacting a specific target (this includes the probabilities of the missile existing on the site, being lifted, and striking the target of a given area)

P_f = The probability of target failure as a result of being struck by a missile (this considers that not all missiles that strike the target will be of sufficient energy to fail the target)

P_D = The probability, given the failure of the target by a missile, that unacceptable radiological or chemical release occurs (this considers that not all target failures will be of sufficient severity to result in unacceptable consequences).

The above expression is simplified in that the analyses are usually performed for a range of tornado intensities and potential missiles. The tornado intensities considered are based upon available local severe weather data. The missiles considered vary in terms of their density on the site, ability to be lifted by a tornado of a given intensity, and ability to damage the target. The missiles appropriate for consideration are often established by a site survey with a radius of about 600 m (2,000 ft).

It should be noted in the above equation that the missile selection is based upon identification of potential missiles based upon a site survey. The results of the tornado missile risk assessment for the CSB are provided in Letter FRF-2855, *Tornado Loading Design Criteria - Revised* (Jacobs 1996). This assessment has been accepted by DOE (Sellers 1996b). The estimated frequency for a missile strike on the CSB is 4×10^{-9} events/yr, which is well below the NRC criterion of 1×10^{-6} events/yr.

The ability of the CSB to withstand the tornado loadings is addressed in Section 4.3.

1.4.1.1.5 Dust and Blowing Dust. Dust and blowing dust are weather phenomena that occur with some frequency at the Hanford Site. Dust and

blowing dust are recorded at the HMS when horizontal visibility is reduced to 9.65 km (6 mi) or less. Dust is carried into the area from distant sources and may or may not occur during strong winds. Dust has been observed with wind speeds ranging from 1.8 m/s (4 mi/h) to 13.4 m/s (30 mi/h). Blowing dust occurs when dust is being picked up locally and occurs with strong winds. Blowing dust has been observed with wind speeds ranging from 8.5 m/s (19 mi/h) to 35.8 m/s (80 mi/h). While both dust and blowing dust occur at the HMS, blowing dust is the most commonly observed.

Table 1-9 shows the average number of days of recorded dust or blowing dust for the period 1945 through 1994. The average number of days per year with dust or blowing dust is five. The greatest number of such days in any year is 20, while the fewest is 0. The greatest number of days with dust or blowing dust in any month was nine in May 1980. Dust and blowing dust occur most frequently between March and May and again in September and occur least frequently during November and December.

Table 1-9. Average Number of Days of Dust or Blowing Dust at the Hanford Meteorological Station for the Period 1945 through 1994.

Month	Days of dust or blowing dust
January	0.4
February	0.4
March	0.5
April	0.6
May	0.7
June	0.4
July	0.4
August	0.3
September	0.5
October	0.3
November	0.2
December	0.2
Year	4.8

Note: Information in this table is from D. J. Hoytink and K. W. Burk, 1995, *Climatological Data Summary 1994, with Historical Data*, PNL-10553, Pacific Northwest National Laboratory, Richland, Washington.

1.4.1.1.6 Fog and Sky Cover. Table 1-10 shows the average monthly and annual number of days with fog and dense fog for the period 1945 through 1994. Fog is reported any time horizontal visibility is reduced to 9.7 km (6 mi) or

less because of suspension of water droplets in the surface layer of the atmosphere. Dense fog is reported when horizontal visibility is reduced to 0.40 km (0.25 mi) or less. Most of the fog at the HMS is radiation fog, a common type of fog that forms on nights characterized by light wind, clear sky, and moist air in the lower levels of the atmosphere. Nearly 90% of both fog and dense fog occur during the late autumn and winter months. The longest duration for fog on the Hanford Site was 114 hours in December 1985, and the longest duration for dense fog was 47 hours in December 1957.

Table 1-10. Monthly and Annual Number of Days with Fog and Dense Fog at the Hanford Meteorological Station for the Period 1945 through 1994.

Month	Days with fog ^a			Days with dense fog ^b		
	Average	Maximum	Minimum	Average	Maximum	Minimum
January	11.2	25	0	6	15	0
February	6.7	20	0	3.2	11	0
March	2.1	10	0	0.9	5	0
April	0.4	3	0	0.1	1	0
May	0.2	3	0	<0.1	1	0
June	0.1	2	0	<0.1	1	0
July	<0.1	1	0	0	0	0
August	0.1	1	0	<0.1	1	0
September	0.3	2	0	0.1	1	0
October	2.0	9	0	1.0	7	0
November	9.5	19	0	5.3	13	0
December	14.1	25	2	7.6	17	2
Year	46.7	84	22	24.3	42	9

Note: Information in this table is from D. J. Hoitink and K. W. Burk, 1995, Climatological Data Summary 1994, with Historical Data, PNL-10553, Pacific Northwest National Laboratory, Richland, Washington.

^aHorizontal visibility is reduced to 9.7 km (6 mi) or less.

^bHorizontal visibility is reduced to 0.40 km (0.25 mi) or less.

The term sky cover is used to express the portion of the celestial dome that is (1) covered, but not necessarily hidden by clouds or obscuring phenomena aloft; (2) hidden by an obscuring phenomenon on the ground (e.g., fog, smoke); or (3) a combination of (1) and (2). Sky cover is then determined hourly by scanning the sky and estimating the number of tenths that are covered (zero denotes clear sky and ten denotes overcast). Each day can be assigned a designation depending upon the average sky cover from sunrise to sunset. The designations are clear (zero to three tenths), partly cloudy (four to seven tenths), and cloudy (eight to ten tenths). Table 1-11 shows

the average monthly sunrise to sunset sky values from 1946 through 1994 and the number of days of clear, partly cloudy, and cloudy days for the years 1956 to 1994. During the period of record (1954 through 1994), an average of 199 sunny days (sum of clear and partly cloudy days) were recorded per year at the HMS.

Table 1-11. Average Sky Cover (Sunrise to Sunset) for the Period 1946 through 1994 and Number of Clear, Partly Cloudy, and Cloudy Days for the Period 1954 through 1994 at the Hanford Meteorological Station.

Month	Average sky cover (in tenths)			Number of clear days	Number of partly cloudy days	Number of cloudy days
	Average	Maximum	Minimum	Average	Average	Average
January	8.0	9.2	4.3	3	5	22
February	7.6	9.3	6.1	4	5	19
March	6.8	8.5	4.9	6	8	17
April	6.4	8.1	3.7	6	9	15
May	5.9	8.1	3.6	8	11	12
June	5.2	7.0	2.8	10	11	10
July	3.1	5.0	0.9	19	7	5
August	3.3	5.9	0.6	18	8	5
September	3.9	6.7	1.4	15	8	7
October	5.7	8.0	3.3	10	8	13
November	7.5	9.1	5.2	5	6	20
December	8	9.3	6.4	4	4	23
Year	5.9	6.6	5.1	110	89	166

Note: Information in this table is from D. J. Hoytink and K. W. Burk, 1995, Climatological Data Summary 1994, with Historical Data, PNL-10553, Pacific Northwest National Laboratory, Richland, Washington.

1.4.1.1.7 Relative Humidity. The annual mean relative humidity recorded at the HMS is 54%, with the highest average monthly relative humidity (80%) occurring in December and the lowest average monthly relative humidity (33%) occurring in July. Daily relative humidity can change 20% to 30% between early morning and late afternoon, except for the winter months when changes are less pronounced (Stone et al. 1983). Higher relative humidity can be expected at locations near the Columbia River and at some locations on the Site periphery where there is increased airborne water vapor from the Columbia River, Yakima River, and irrigated land.

1.4.1.1.8 Dispersion Climatology. Atmospheric dispersion is a function of wind speed, duration and direction of wind, atmospheric stability, and mixing depth. Dispersion conditions are generally favorable if winds are moderate to strong, if the atmosphere is of neutral or unstable stratification, and if there is a deep mixing layer. These conditions exist more than half the time at the Hanford Site in the summer. A less favorable dispersion condition may occur when the wind speed is light and the mixing layer is shallow. This condition is most common in the winter when moderately to extremely stable stratification exists about two-thirds of the time (Cushing 1995). Less favorable dispersion conditions also occur periodically for surface and low-level releases in all seasons from about sunset to about an hour after sunrise as a result of ground-based temperature inversions and shallow mixing layers.

Mixing layers at the HMS are estimated remotely using a Doppler acoustic sounder. Variations in the mixing layer are summarized in Table 1-12. The shallowest mixing layers are usually found in the nighttime during the winter months. Mixing layers are usually larger in the daytime during the summer months.

Table 1-12. Percent Frequency of Occurrence of Mixing Layer Thickness by Season and Time of Day at the Hanford Site.

Mixing layer (m)	Winter		Summer	
	Night	Day	Night	Day
<250	65.7	35.0	48.5	1.2
250-500	24.7	39.8	37.1	9.0
>500	9.6	25.2	14.4	89.9

Note: Information in this table is from C. E. Cushing, 1995, Hanford Site National Environmental Policy Act (NEPA) Characterization, PNL-6415, Rev. 7, Pacific Northwest Laboratory, Richland, Washington.

Low-level inversions can also be associated with stagnant air in stationary high-pressure systems that occur primarily in the winter months. The probability of extended periods of low-level inversions is estimated in BNWL-1605, *Climatology of the Hanford Area* (Stone et al. 1972). The probability of an inversion period extending more than 12 hours varies from a low of about 10% in May and June to a high of about 64% in September and October. These probabilities decrease rapidly for durations of greater than 12 hours. Table 1-13 summarizes the probabilities associated with extended surface-based inversions.

Table 1-13. Percent Probabilities for Extended Periods of Surface-Based Inversions at the Hanford Site.

Months	Inversion duration		
	12 hours	24 hours	48 hours
January-February	54.0	2.5	0.28
March-April	50.0	<0.1	<0.1
May-June	10.0	<0.1	<0.1
July-August	18.0	<0.1	<0.1
September-October	64.0	0.11	<0.1
November-December	50.0	1.2	0.13

Note: Information in this table is from D. J. Moitink and K. W. Burk, 1995, Climatological Data Summary 1994, with Historical Data, PNL-10553, Pacific Northwest National Laboratory, Richland, Washington.

The joint frequency distribution of hourly averaged wind data from the 200 East Area meteorological tower for the 9-year period January 1982 to December 1991 are provided in *Recommended Environmental Dose Calculation Methods and Hanford-Specific Parameters* (Schreckhise et al. 1993) and are shown in Table 1-14. Stability class was determined using the method based on Pasquill (1961), which is a parameterization scheme based on time of year, time of day, wind speed, cloud cover, and visibility. Cloud cover and visibility were measured at the HMS, but should be representative of the 200 East Area. The percent frequency of occurrence of each of the stability classes for the 9-year period is given in Table 1-15. Stability Class D, relatively neutral dispersion conditions, occurred 28% of the time. Conditions favorable for turbulent dispersion, represented by the unstable classes A, B, and C, occurred about 31% of the time. The stable classes, E, F, and G, indicative of conditions unfavorable for turbulent dispersion, occurred about 41% of the time.

A graphical representation of the joint frequency distribution data in the form of a wind rose and wind speed histogram is shown in Figure 1-14. The wind rose data indicate that winds from the west-northwest sector occur most frequently (nearly 20% of the time). That is, the emissions are transported toward the east-southeast sector. Winds out of the northwest and west also occur with a relatively high frequency (12% and 11%, respectively). For hours of unstable classes A, B, and C, wind directions from the west-northwest and northwest sectors occur more frequently than the other directions. Winds are more frequently from the west-northwest sector during stable conditions (classes E, F, and G).

Table 1-14. Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed at the 200 East Area. (3 sheets)

Stability class	Direction from which the wind is blowing	Wind speed class (mi/h)					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
A	North	0.00008	0.00058	0.00008	0.00001	0.00000	0.00000
A	North-northeast	0.00010	0.00070	0.00025	0.00003	0.00000	0.00000
A	Northeast	0.00014	0.00073	0.00007	0.00003	0.00000	0.00000
A	East-northeast	0.00012	0.00080	0.00007	0.00000	0.00000	0.00000
A	East	0.00008	0.00066	0.00003	0.00000	0.00000	0.00000
A	East-southeast	0.00014	0.00104	0.00006	0.00002	0.00000	0.00000
A	Southeast	0.00004	0.00107	0.00029	0.00000	0.00000	0.00000
A	South-southeast	0.00008	0.00082	0.00026	0.00008	0.00000	0.00000
A	South	0.00009	0.00041	0.00010	0.00005	0.00000	0.00000
A	South-southwest	0.00004	0.00035	0.00009	0.00000	0.00000	0.00000
A	Southwest	0.00005	0.00025	0.00017	0.00005	0.00002	0.00000
A	West-southwest	0.00006	0.00026	0.00019	0.00020	0.00005	0.00001
A	West	0.00006	0.00024	0.00011	0.00007	0.00001	0.00002
A	West-northwest	0.00006	0.00033	0.00010	0.00012	0.00008	0.00000
A	Northwest	0.00004	0.00049	0.00016	0.00014	0.00011	0.00003
A	North-northwest	0.00006	0.00047	0.00005	0.00005	0.00000	0.00000
B	North	0.00269	0.00756	0.00209	0.00031	0.00002	0.00000
B	North-northeast	0.00260	0.00736	0.00202	0.00045	0.00015	0.00003
B	Northeast	0.00287	0.00570	0.00098	0.00025	0.00009	0.00002
B	East-northeast	0.00333	0.00624	0.00039	0.00004	0.00000	0.00000
B	East	0.00280	0.00756	0.00045	0.00002	0.00000	0.00000
B	East-southeast	0.00233	0.00820	0.00105	0.00002	0.00000	0.00000
B	Southeast	0.00169	0.00820	0.00169	0.00014	0.00000	0.00000
B	South-southeast	0.00094	0.00475	0.00194	0.00033	0.00000	0.00000
B	South	0.00071	0.00250	0.00084	0.00020	0.00000	0.00001
B	South-southwest	0.00065	0.00177	0.00062	0.00030	0.00004	0.00002
B	Southwest	0.00077	0.00185	0.00136	0.00072	0.00036	0.00011
B	West-southwest	0.00078	0.00227	0.00222	0.00154	0.00078	0.00033
B	West	0.00091	0.00264	0.00186	0.00084	0.00022	0.00012
B	West-northwest	0.00139	0.00451	0.00350	0.00128	0.00045	0.00007
B	Northwest	0.00196	0.00740	0.00431	0.00141	0.00071	0.00014
B	North-northwest	0.00250	0.00774	0.00197	0.00023	0.00005	0.00000
C	North	0.00188	0.00528	0.00240	0.00035	0.00003	0.00000
C	North-northeast	0.00182	0.00497	0.00298	0.00049	0.00014	0.00004
C	Northeast	0.00168	0.00433	0.00088	0.00032	0.00013	0.00000
C	East-northeast	0.00228	0.00387	0.00042	0.00005	0.00001	0.00000
C	East	0.00177	0.00445	0.00073	0.00002	0.00000	0.00000
C	East-southeast	0.00175	0.00522	0.00105	0.00003	0.00000	0.00000
C	Southeast	0.00121	0.00548	0.00156	0.00018	0.00000	0.00000
C	South-southeast	0.00099	0.00366	0.00149	0.00055	0.00002	0.00000
C	South	0.00078	0.00212	0.00091	0.00039	0.00004	0.00002

Table 1-14. Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed at the 200 East Area. (3 sheets)

Stability class	Direction from which the wind is blowing	Wind speed class (mi/h)					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
C	South-southwest	0.00059	0.00178	0.00082	0.00034	0.00010	0.00007
C	Southwest	0.00056	0.00195	0.00189	0.00079	0.00052	0.00013
C	West-southwest	0.00051	0.00252	0.00285	0.00178	0.00071	0.00026
C	West	0.00092	0.00304	0.00326	0.00131	0.00034	0.00009
C	West-northwest	0.00129	0.00539	0.00697	0.00211	0.00053	0.00008
C	Northwest	0.00193	0.00786	0.00578	0.00167	0.00080	0.00042
C	North-northwest	0.00175	0.00672	0.00228	0.00028	0.00001	0.00000
D	North	0.00112	0.00330	0.00204	0.00108	0.00012	0.00000
D	North-northeast	0.00067	0.00285	0.00212	0.00152	0.00079	0.00008
D	Northeast	0.00088	0.00317	0.00119	0.00098	0.00025	0.00023
D	East-northeast	0.00092	0.00311	0.00080	0.00018	0.00002	0.00003
D	East	0.00116	0.00399	0.00133	0.00005	0.00002	0.00000
D	East-southeast	0.00118	0.00482	0.00208	0.00017	0.00003	0.00000
D	Southeast	0.00092	0.00587	0.00381	0.00046	0.00001	0.00000
D	South-southeast	0.00098	0.00462	0.00473	0.00138	0.00013	0.00000
D	South	0.00084	0.00361	0.00336	0.00134	0.00023	0.00002
D	South-southwest	0.00070	0.00319	0.00243	0.00198	0.00119	0.00043
D	Southwest	0.00075	0.00370	0.00385	0.00457	0.00312	0.00156
D	West-southwest	0.00092	0.00512	0.00863	0.00743	0.00456	0.00180
D	West	0.00109	0.00735	0.01488	0.00740	0.00146	0.00037
D	West-northwest	0.00113	0.01079	0.02796	0.02068	0.00790	0.00133
D	Northwest	0.00097	0.00866	0.01272	0.00849	0.00502	0.00152
D	North-northwest	0.00105	0.00500	0.00309	0.00070	0.00011	0.00002
E	North	0.00055	0.00153	0.00102	0.00036	0.00000	0.00000
E	North-northeast	0.00071	0.00131	0.00085	0.00031	0.00001	0.00000
E	Northeast	0.00039	0.00091	0.00044	0.00006	0.00000	0.00000
E	East-northeast	0.00052	0.00106	0.00016	0.00003	0.00001	0.00003
E	East	0.00048	0.00129	0.00030	0.00000	0.00001	0.00000
E	East-southeast	0.00056	0.00242	0.00068	0.00007	0.00000	0.00000
E	Southeast	0.00068	0.00331	0.00166	0.00011	0.00000	0.00000
E	South-southeast	0.00076	0.00361	0.00279	0.00043	0.00004	0.00001
E	South	0.00099	0.00269	0.00163	0.00037	0.00010	0.00001
E	South-southwest	0.00063	0.00209	0.00096	0.00037	0.00012	0.00005
E	Southwest	0.00090	0.00282	0.00142	0.00082	0.00039	0.00011
E	West-southwest	0.00077	0.00486	0.00473	0.00187	0.00067	0.00012
E	West	0.00099	0.00826	0.01244	0.00324	0.00022	0.00003
E	West-northwest	0.00091	0.01213	0.02585	0.00831	0.00157	0.00019
E	Northwest	0.00086	0.00838	0.00752	0.00248	0.00078	0.00018
E	North-northwest	0.00082	0.00302	0.00108	0.00009	0.00001	0.00000
F	North	0.00136	0.00240	0.00051	0.00021	0.00003	0.00000
F	North-northeast	0.00133	0.00216	0.00054	0.00019	0.00006	0.00001

Table 1-14. Joint Frequency Distribution of Atmospheric Stability, Wind Direction, and Wind Speed at the 200 East Area. (3 sheets)

Stability class	Direction from which the wind is blowing	Wind speed class (mi/h)					
		1 - 3	4 - 7	8 - 12	13 - 18	19 - 24	> 25
F	Northeast	0.00113	0.00234	0.00033	0.00005	0.00003	0.00000
F	East-northeast	0.00160	0.00201	0.00013	0.00001	0.00003	0.00000
F	East	0.00187	0.00293	0.00037	0.00004	0.00002	0.00000
F	East-southeast	0.00204	0.00422	0.00069	0.00001	0.00000	0.00000
F	Southeast	0.00172	0.00593	0.00143	0.00015	0.00000	0.00000
F	South-southeast	0.00149	0.00558	0.00202	0.00026	0.00002	0.00000
F	South	0.00124	0.00335	0.00107	0.00018	0.00009	0.00000
F	South-southwest	0.00122	0.00246	0.00073	0.00031	0.00013	0.00006
F	Southwest	0.00157	0.00312	0.00107	0.00065	0.00040	0.00017
F	West-southwest	0.00151	0.00509	0.00272	0.00099	0.00041	0.00007
F	West	0.00192	0.01016	0.00863	0.00146	0.00010	0.00000
F	West-northwest	0.00238	0.01410	0.01530	0.00438	0.00080	0.00016
F	Northwest	0.00230	0.00900	0.00427	0.00111	0.00069	0.00013
F	North-northwest	0.00199	0.00407	0.00072	0.00009	0.00005	0.00000
G	North	0.00110	0.00179	0.00023	0.00011	0.00000	0.00002
G	North-northeast	0.00114	0.00154	0.00018	0.00006	0.00001	0.00002
G	Northeast	0.00114	0.00167	0.00007	0.00003	0.00006	0.00000
G	East-northeast	0.00125	0.00138	0.00005	0.00000	0.00003	0.00000
G	East	0.00146	0.00219	0.00016	0.00001	0.00001	0.00000
G	East-southeast	0.00166	0.00365	0.00033	0.00002	0.00000	0.00000
G	Southeast	0.00142	0.00382	0.00078	0.00005	0.00000	0.00000
G	South-southeast	0.00120	0.00392	0.00100	0.00009	0.00002	0.00000
G	South	0.00099	0.00211	0.00034	0.00005	0.00002	0.00000
G	South-southwest	0.00104	0.00160	0.00021	0.00005	0.00005	0.00008
G	Southwest	0.00128	0.00166	0.00048	0.00029	0.00019	0.00008
G	West-southwest	0.00133	0.00279	0.00106	0.00053	0.00030	0.00000
G	West	0.00163	0.00436	0.00327	0.00055	0.00002	0.00000
G	West-northwest	0.00204	0.00832	0.00602	0.00165	0.00027	0.00003
G	Northwest	0.00237	0.00457	0.00167	0.00069	0.00011	0.00002
G	North-northwest	0.00189	0.00229	0.00022	0.00008	0.00002	0.00000

Note: Atmospheric stability is determined using the Pasquill method. Wind measurements were made onsite at 10 m (33 ft) above ground level. Data are based on measurements made from 1982 through 1989.

Table 1-15. Percent Frequency of Occurrence of Pasquill-Gifford Atmospheric Stability Classes A through G for the 200 East Area.

Class	Percent occurrence per year
A (extremely unstable)	1.4%
B (moderately unstable)	15.4%
C (slightly unstable)	14.2%
D (neutral)	28%
E (slightly stable)	15.8%
F (moderately stable)	16.0%
G (extremely stable)	9.2%

To support the accident analyses of Section 3.4.2, downwind radiological exposures were calculated using a unit release dispersion parameter (X/Q), which may be defined as the time-integrated air concentration at the receptor location per unit release at the source. The acute X/Q s for the analyses were calculated using joint frequency distribution data so as to be exceeded only 0.5% of the time (99.5 percentile) for each sector, or to be exceeded only 5% of the time (95 percentile) for data from all sectors combined (whichever is greater). Since the downwind distance where the plume touches down from a stack release varies with stability and windspeed, a parametric study was performed to determine the distance at which the maximum onsite dose occurred. For the calculation of the CSB X/Q s, the CSB's dimensions were considered to be 97.8 m x 55.2 m x 16.9 m high (320 ft x 181 ft x 55 ft high) with a 36.6-m (120-ft) stack; the inside diameter of the stack was considered to be 1.02 m (40 in.). The normal exhaust flow from the stack is specified to be 5.66 m³/s (12,000 ft³/min) with one fan running. In an accident situation a second fan is to start giving a specified accident flow rate of 11.3 m³/s (24,000 ft³/min). In both cases the exhaust temperature is given as 38 °C through 41 °C (100 °F through 105 °F). The design and operation of this ventilation system will be described in Chapter 4.0 of the final SAR as required by DOE-STD-3009-94.

X/Q s are required at the worst-case onsite location and at the worst-case location on the Site boundary (see Section 1.3.1.3). Both the Site boundary, at 18.3 km east, and the near river shore, at 15.0 km east, were evaluated.

The required X/Q s were calculated using the GXQ code (Hey 1994) using the ISC2 momentum/buoyancy plume rise model (EPA 1992). Variation of wind speed with height, wind entrainment, initial volume rate effects, and plume downwash were accounted for. A two-dimensional parametric calculation was used to determine the worst-case onsite receptor with respect to both distance and direction. The worst-case Site boundary receptors were found by evaluating each of the 16 direction sectors around both the Site boundary and the near river shore.

Using the atmospheric stabilities and wind speeds determined in the above calculations, effective plume heights were determined for onsite and Site boundary conditions. If the effective release height (stack height plus plume rise) is greater than 2.5 times the building height, the plume can be assumed to be unaffected by the building wake (EPA 1992).

The resulting parametric arrays of 99.5 percentile onsite X/Qs for one fan and two fans in operation are shown in Tables 1-16 and 1-17. The maximum X/Qs are indicated with asterisks.

Of these two cases, the lower plume rise would be associated with the lesser exhaust flow rate (i.e., the single fan case shown in Table 1-16. The conditions that produce the worst case shown in Table 1-16 for the west sector at 230 m (755 ft) are Pasquill A with a 2.65 m/s (6 mi/h) wind speed. The effective release height for these conditions was found to be 45.1 m (148 ft). In order to eliminate building wake effects, the effective release height must be greater than 2.5 times the building height of 16.9 m (55 ft), or 42.3 m (138 ft).

The resulting X/Qs for the Site boundary and near river shore are shown in Tables 1-18 and 1-19. The values shown in parentheses for the worst-case locations on the near river shore correspond to potential agricultural sites on the far river bank.

As before, the lower plume rise would be associated with the lesser exhaust flow rate (i.e., the single fan case shown in Table 1-18. The conditions that produce the worst case shown in Table 1-18 for the east sector at 18.3 km (11.4 mi), 15.0 km (9.3 mi), or 15.7 km (9.7 mi) are Pasquill F with a 0.89 m/s (2 mi/h) wind speed. The effective release height for these conditions was found to be 58.0 m (190 ft).

The specific X/Q values used for accident consequence analyses are provided in Section 3.4.1.2. Data are provided for ground level and stack release.

1.4.2 Hydrology

The primary surface water features associated with the Hanford Site are the Columbia River and its tributary, the Yakima River (Figure 1-15). West Lake, about 4 ha (10 acres) in size and less than 1 m (3 ft) deep, is the only natural lake on the Hanford Site. Artificial surface water bodies include ponds and ditches that were used in the past for waste water disposal.

The Hanford Site is underlain by unconsolidated to semiconsolidated sediments of the Hanford and Ringold Formations. The Columbia River Basalt Group (CRBG) and associated sedimentary interbeds lie beneath the sediments. The geology of the Hanford Site is described in Section 1.4.3.

The vadose zone at the Hanford Site is comprised mainly of unconsolidated gravels and sands. Its thickness ranges from 0 m (0 ft) at the river bank and West Lake to over 100 m (328 ft) in the 200 Areas.

Table 1-16. Onsite 99.5% X/Qs for One Fan (5.66 m³/s [12,000 ft³/min]) for Various Downwind Distances.

Sector	X/Q (s/m ³)					
	220 m	230 m	240 m	250 m	260 m	270 m
S	4.01 E-05	4.06 E-05	3.15 E-05	3.35 E-05	3.53 E-05	3.69 E-05
SSW	2.88 E-05	3.02 E-05	3.10 E-05	3.04 E-05	2.97 E-05	2.88 E-05
SW	2.66 E-05	2.91 E-05	2.93 E-05	2.93 E-05	2.91 E-05	2.87 E-05
WSW	2.90 E-05	3.04 E-05	3.14 E-05	3.08 E-05	3.00 E-05	2.91 E-05
W	4.12 E-05	*4.18 E-05*	3.15 E-05	3.39 E-05	3.60 E-05	3.79 E-05
WNW	3.18 E-05	3.17 E-05	3.14 E-05	3.16 E-05	3.15 E-05	3.13 E-05
NW	2.87 E-05	3.02 E-05	3.01 E-05	2.99 E-05	2.94 E-05	2.88 E-05
NNW	2.05 E-05	2.03 E-05	1.99 E-05	1.94 E-05	1.87 E-05	1.86 E-05
N	1.99 E-05	1.97 E-05	1.94 E-05	1.90 E-05	1.85 E-05	1.80 E-05
NNE	2.67 E-06	3.15 E-06	3.63 E-06	4.10 E-06	4.42 E-06	4.29 E-06
NE	1.31 E-05	1.32 E-05	1.32 E-05	1.31 E-05	1.26 E-05	1.25 E-05
ENE	1.82 E-05	1.85 E-05	1.87 E-05	1.87 E-05	1.74 E-05	1.69 E-05
E	2.11 E-05	2.13 E-05	2.13 E-05	2.12 E-05	1.87 E-05	1.87 E-05
ESE	2.19 E-05	2.28 E-05	2.34 E-05	2.38 E-05	1.99 E-05	2.02 E-05
SE	2.53 E-05	2.85 E-05	2.81 E-05	2.85 E-05	2.87 E-05	2.87 E-05
SSE	2.92 E-05	3.05 E-05	3.09 E-05	3.04 E-05	2.97 E-05	2.88 E-05
All (95%)	3.34 E-05	3.33 E-05	3.15 E-05	3.22 E-05	3.28 E-05	3.31 E-05

Table 1-17. Onsite 99.5% X/Qs for Two Fans ($11.3 \text{ m}^3/\text{s}$ [$24,000 \text{ ft}^3/\text{min}$]) for Various Downwind Distances.

Sector	X/Q (s/m^3)					
	220 m	230 m	240 m	250 m	260 m	270 m
S	2.81 E-05	2.90 E-05	2.95 E-05	2.97 E-05	2.97 E-05	2.94 E-05
SSW	2.24 E-05	2.26 E-05	2.25 E-05	2.20 E-05	2.22 E-05	2.23 E-05
SW	1.93 E-05	1.93 E-05	1.92 E-05	1.89 E-05	1.97 E-05	2.04 E-05
WSW	2.13 E-05	2.15 E-05	2.14 E-05	2.20 E-05	2.22 E-05	2.23 E-05
W	2.86 E-05	2.95 E-05	3.01 E-05	*3.04 E-05*	*3.04 E-05*	3.01 E-05
WNW	2.48 E-05	2.51 E-05	2.52 E-05	2.50 E-05	2.47 E-05	2.42 E-05
NW	2.18 E-05	2.20 E-05	2.20 E-05	2.20 E-05	2.22 E-05	2.23 E-05
NNW	1.47 E-05	1.59 E-05	1.70 E-05	1.64 E-05	1.62 E-05	1.60 E-05
N	1.37 E-05	1.44 E-05	1.54 E-05	1.53 E-05	1.55 E-05	1.59 E-05
NNE	6.90 E-07	8.47 E-07	1.02 E-06	1.22 E-06	1.46 E-06	1.74 E-06
NE	1.14 E-05	1.13 E-05	1.21 E-05	1.17 E-05	1.17 E-05	1.13 E-05
ENE	1.45 E-05	1.58 E-05	1.69 E-05	1.54 E-05	1.56 E-05	1.57 E-05
E	1.67 E-05	1.70 E-05	1.72 E-05	1.70 E-05	1.67 E-05	1.61 E-05
ESE	1.75 E-05	1.75 E-05	1.73 E-05	1.73 E-05	1.74 E-05	1.63 E-05
SE	2.06 E-05	2.07 E-05	2.06 E-05	1.92 E-05	2.00 E-05	2.06 E-05
SSE	2.26 E-05	2.29 E-05	2.28 E-05	2.25 E-05	2.27 E-05	2.26 E-05
All (95%)	2.56 E-05	2.60 E-05	2.62 E-05	2.60 E-05	2.57 E-05	2.52 E-05

Table 1-18. Site Boundary 99.5% X/Qs for One Fan (5.66 m³/s [12,000 ft³/min]) for the Site Boundary and Near River Shore.

Sector	Site boundary		Near river shore	
	Distance (km)	X/Q (s/m ³)	Distance (km)	X/Q (s/m ³)
S	20.0	2.98 E-06	8.7	5.69 E-06
SSW	17.0	2.22 E-06	8.9	4.95 E-06
SW	18.3	1.82 E-06	8.9	4.98 E-06
WSW	20.0	1.64 E-06	9.3	4.66 E-06
W	19.4	3.73 E-06	11.1	6.32 E-06
WNW	20.0	3.58 E-06	14.6	4.82 E-06
NW	21.1	3.73 E-06	12.4	6.94 E-06
NNW	20.9	4.83 E-06	12.0	8.27 E-06
N	23.9	4.45 E-06	13.3	8.24 E-06
NNE	27.4	2.20 E-06	15.2	3.96 E-06
NE	21.6	2.89 E-06	13.7	4.29 E-06
ENE	18.4	3.93 E-06	13.3	4.96 E-06
E	18.3	*7.14 E-06*	15.0 (15.7)	*8.31 E-06* (8.01 E-06)
ESE	22.8	4.21 E-06	22.8	4.21 E-06
SE	27.2	2.92 E-06	27.2	2.92 E-06
SSE	22.0	2.84 E-06	11.7	4.67 E-06

Table 1-19, Site Boundary 99.5% X/Qs for Two Fans (11.3 m³/s [24,000 ft³/min]) for the Site Boundary and Near River Shore.

Sector	Site boundary		Near river shore	
	Distance (km)	X/Q (s/m ³)	Distance (km)	X/Q (s/m ³)
S	20.0	2.87 E-06	8.7	4.89 E-06
SSW	17.0	2.00 E-06	8.9	4.33 E-06
SW	18.3	1.68 E-06	8.9	4.35 E-06
WSW	20.0	1.52 E-06	9.3	4.17 E-06
W	19.4	3.36 E-06	11.1	5.63 E-06
WNW	20.0	3.26 E-06	14.6	4.20 E-06
NW	21.1	3.16 E-06	12.4	5.85 E-06
NNW	20.9	4.12 E-06	12.0	6.59 E-06
N	23.9	3.83 E-06	13.3	6.52 E-06
NNE	27.4	2.02 E-06	15.2	3.37 E-06
NE	21.6	2.64 E-06	13.7	3.59 E-06
ENE	18.4	3.44 E-06	13.3	4.18 E-06
E	18.3	*6.05 E-06*	15.0 (15.7)	*7.13 E-06* (7.07 E-06)
ESE	22.8	3.60 E-06	22.8	3.60 E-06
SE	27.2	2.58 E-06	27.2	2.58 E-06
SSE	22.0	2.59 E-06	11.7	4.15 E-06

The saturated sediments of the Hanford and Ringold Formations make up a series of aquifers and aquitards. In general, sand- and gravel-dominated stratigraphic units form aquifers and fine-grained deposits form aquitards. The shallowest suprabasalt aquifer is unconfined beneath most of the Hanford Site. Confined aquifers are present in the sedimentary interbeds and/or interflow zones between dense basalt flows of the CRBG. The main water-bearing portions of the interflow zones are networks of interconnecting vesicles and fractures of the flow tops and flow bottoms.

The remainder of this section describes the surface water features, vadose zone, and aquifers as they relate to the 200 Areas of the Hanford Site.

1.4.2.1 Surface Water. This section describes the surface water bodies and the river flooding potential at the CSB site from the Columbia River, Yakima River, and Cold Creek. An overview of artificial surface water bodies in and near the 200 Areas is also presented.

1.4.2.1.1 West Lake. The only natural lake, West Lake, is described in Section 1.4.2 above.

1.4.2.1.2 Columbia River. The Columbia River flows through the Hanford Site and forms part of its eastern boundary (Figure 1-15). The section of the river flowing through the Site, known as the Hanford Reach, is free-flowing and extends from Priest Rapids Dam, upstream of the Site, to the 300 Area. Flow through the Hanford Reach fluctuates significantly and is controlled by Priest Rapids Dam. Discharge ranges from lows of about 36,000 ft³/s to highs around 300,000 ft³/s.

The Columbia River originates in the mountains of eastern British Columbia, Canada, and drains an area of approximately 70,800 km² (27,300 mi²) en route to the Pacific Ocean (Figure 1-16). Flow on the Columbia River is regulated by seven upstream dams within the United States and several in Canada. The three dams with the largest reservoirs upstream from the Hanford Site are the Mica Dam and Hugh Keenleyside Dam in Canada and the Grand Coulee Dam in the United States. The dam-controlled flow of the Columbia River results in a lower flood hazard for high-probability floods (e.g., 100-year flood); however, dam-failure scenarios are significant contributors for very-low-probability floods. A flood scenario involving a 50% breach of Grand Coulee Dam (ERDA 1976) results in a flood level of about 143 m (470 ft) above mean sea level at Columbia River kilometer 587 (mile 365) (Figure 1-5), the closest flood route to the 200 Plateau. This flood level is about 70 m (230 ft) below the ground surface at the CSB. The CSB is a flood-dry site with respect to the Columbia River (ANSI/ANS 1992).

A probabilistic flood hazard assessment of the Columbia River was performed as part of a safety evaluation of the Hanford Site N Reactor (McCann and Boissonnade 1988). The most extreme potential flood scenarios on the Columbia River result from dam failure. Specifically, failure of Grand Coulee Dam and Mica Dam pose the greatest threat. The results of the flood hazard assessment show that the greatest contribution to the likelihood of flooding is dam failure initiated by seismic events. Conservative estimates of the seismic capacity of upstream dams were made primarily on engineering judgment. Further, the likelihood of random dam failure was based primarily on engineering judgment and the historic frequency of dam failures. See

UCRL-21069, *Probabilistic Flood Hazard Assessment of the Department of Energy N-Reactor, Hanford, Washington* (McCann and Boissonnade 1988), for a detailed discussion of the hazard assessment.

The performance category 3 flood level (10^{-4} annual probability of exceedance [McCann and Boissonnade 1988]) at river kilometer 587 (mile 365), the closest flood route to the 200 Area Plateau and the CSB (Figure 1-5), is approximately 134 m (435 ft) above mean sea level, which is lower than the 50% breach scenario (Tallman 1996). The 200 Areas are dry sites with respect to Columbia River flooding and such flooding need not be considered in design or accident scenarios.

Extreme flooding on the Columbia River can also occur during extreme meteorologic and hydrologic events. Historically, the largest floods have occurred when rapid snow melt was accompanied by spring rain. Such floods are controlled by the dam system and are predicted to be less severe than comparable predam record floods.

1.4.2.1.3 Yakima River. The Yakima River forms part of the southern boundary of the Hanford Site (Figure 1-15). The Yakima River is approximately 20 km (12 mi) south and more than 60 m (200 ft) below the 200 Areas. The Yakima River is not a flood hazard for the CSB site.

Cold Creek, a tributary of the Yakima River, and its tributary, Dry Creek, are ephemeral streams within the Yakima River drainage basin (Figure 1-17). The Cold Creek watershed, located in the southwestern portion of the Hanford Site, extends about 16 km (10 mi) up the Cold Creek and Dry Creek valleys. A flood risk analysis of Cold Creek was conducted in 1980 (Skaggs and Walters 1981) to determine the probable maximum flood for the Cold Creek system (Figure 1-15). The recurrence interval is not estimated for this flood; however each occurrence would be a flash flood of short duration. The probable maximum flood reaches an elevation of about 195 m (640 ft) on the southwestern portion of 200 West Area and is not a hazard for the CSB.

1.4.2.1.4 Artificial Surface Water Bodies. In the past, numerous artificial surface water bodies were present in the 200 Areas. Effluent disposal sites (e.g., cribs, ponds, ditches) allowed waste water to infiltrate the ground and, in many cases, affect groundwater flow and chemistry. Today only B Pond and the Treated Effluent Disposal Facility, both located east of 200 East Area, receive significant volumes of effluent.

1.4.2.2 Vadose Zone. The term "vadose zone" is used here to refer to unsaturated sediments between the water table and the ground surface. Flow of water through the vadose zone is a function of the moisture content, matric potential, and unsaturated hydraulic conductivity for each hydrostratigraphic unit. In general, water flows and spreads laterally at a much greater rate in fine-grained units than in coarse-grained units. Fine-grained units in the vadose zone significantly influence the lateral distribution of water and the flux of water to the uppermost aquifer. Coarse-grained units may impede the flux of water through the vadose zone because of the formation of a capillary pressure barrier between the coarse-grained units and overlying fine-grained units.

The vadose zone in the 200 East Area is comprised of interlayered gravel, sand, silt, and "mud" (i.e., silt and clay). In some locations the basalt has been uplifted and composes part of the vadose zone. Thickness of the vadose zone in the 200 East Area ranges from 37 m (121 ft) near B Pond to 104 m (341 ft) near the southern border of the area (Ford and Trent 1994). Fine-grained units in the Hanford formation and the Ringold Lower Mud unit significantly influence the lateral distribution and flux of water in the 200 East Area.

The fine-grained sedimentary units in the 200 East Area may produce perched water conditions near active waste disposal facilities. Perched water results when a discontinuous impermeable layer in the vadose zone traps discontinuous water above the saturated zone. Perched water has been observed to the east of the 241-BY tank farm and above the Lower Mud near B Pond and the Treated Effluent Disposal Facility.

Routson and Johnson (1990) estimated the magnitude of recharge from natural precipitation on the 200 Areas plateau. Two sources of data were used in their evaluation: (1) moisture accumulated for 13 years in an 18-m- (59-ft-) deep 200 East Area lysimeter, and (2) distribution of ^{137}Cs in a 200 West Area solid-waste burial ground in which contaminated soil had been buried for 10 years. There had been no detectible moisture accumulation in the bottom of the lysimeter from 1972 to 1985. Thus, the recharge rate was approximately zero over the 13-year period. Cesium-137 contaminated soil was placed in a burial ground in 1970. After 10 years the distribution of ^{137}Cs was determined from core-drilled samples. No ^{137}Cs above background was detected beneath the bottom of the trench, indicating there was no measurable downward movement; however, ^{137}Cs was detected above the trench, most likely from evapotranspiration.

Routson and Johnson (1990) conclude that there appears to be very little potential for downward movement of contaminants in the upper vadose zone beneath much of the 200 Areas plateau under natural or minimally disturbed conditions. Highly disturbed sites with little vegetation (e.g., the CSB site) may allow more movement of water through the vadose zone.

PNL-10285, *Estimated Recharge Rates at the Hanford Site* (Fayer and Walters 1995), compiled estimates of natural recharge on the Hanford Site. Recharge through the vadose zone was 87 mm/yr (3.4 in/yr) in a gravel-covered, unvegetated lysimeter constructed to mimic the surface conditions at the tank farms.

Site-specific variables must be considered to estimate time for water to travel through the vadose zone. Variables include the amount of moisture infiltrating, the grain size and stratigraphy of the sediments, the amount of moisture already in each sedimentary layer, and the hydraulic conductivity. WHC-SD-EN-TI-014, *Hydrogeologic Model for 200 West Groundwater Aggregate Area* (WHC 1992), contains calculated travel times in four examples for the 200 West Area with steady recharge rates of 0.5 and 5 cm/yr (0.2 and 2.0 in/yr). Calculated travel times range from 150 years to over 2,000 years. The methods applied in WHC-SD-EN-TI-014 (WHC 1992) are not valid for transient conditions (e.g., spills, pipe leaks).

1.4.2.3 Aquifers. Two major aquifer systems lie beneath the 200 Areas: the suprabasalt aquifer system and the basalt and interbed aquifer system (see Figure 1-18). Stratigraphy of the 200 Areas is discussed in greater detail in Section 1.4.3.

1.4.2.3.1 Suprabasalt Aquifer System. The suprabasalt aquifer system under the 200 Areas occurs primarily within the sediments of the Hanford and Ringold Formations. These sediments contain interlayered coarse- and fine-grained units forming a series of aquifers and aquitards. The depth to the water table under the 200 East Area ranges from less than 40 m (131 ft) near B Pond to approximately 104 m (341 ft) west of the 200 East Area. The CSB site is at about 216 m (708 ft) above mean sea level, and the elevation of the bottom of the basement is 201 m (659 ft) above mean sea level. The water table, at 126 m (413 ft) above mean sea level, is 75 m (246 ft) below the CSB basement.

The suprabasalt aquifer system in the 200 East Area includes the Ringold Formation and parts of the Hanford formation. Sandy gravels dominate the saturated Hanford formation and gravels dominate the Ringold Formation. Significant silt- and clay-dominated intervals are absent except in the southwestern part of the 200 East Area and east of B Pond where the Lower Mud sequence is found. The suprabasalt aquifer system ranges in thickness from zero where basalt is present above the water table to 60 m (197 ft) in the south and west portions of the 200 East Area. At the CSB site the suprabasalt aquifer is about 90 m (300 ft) below surface and about 30 m (100 ft) thick.

Horizontal hydraulic conductivity of units within the suprabasalt aquifer system varies considerably (Table 1-20). WHC-SD-EN-TI-019, *Hydrogeologic Model for the 200 East Groundwater Aggregate Area* (Connelly et al. 1992), documents the compiled and mapped hydraulic conductivity data for the upper portion of the uppermost aquifer in the 200 West and 200 East Areas. The highest conductivity occurs in a channel stretching from northwest to southeast across the 200 East Area.

Groundwater flow beneath the 200 East Area is complex because of the convergence of flow from the west (natural groundwater flow system) and from the east (artificial recharge from B Pond and the Treated Effluent Disposal Facility) (Figure 1-19). The high transmissivity beneath most of the 200 East Area causes hydraulic gradients to be very small. It is often difficult to define groundwater flow directions from water table maps of the 200 East Area, but contaminant plume maps of the 200 Areas indicate long-term trends in groundwater flow directions (Dresel et al. 1995). These plume maps indicate a north to northwest direction of flow in the extreme north central portion of the 200 East Area and a south to southeast direction of flow in the southeast portion of the 200 East Area.

Groundwater in the suprabasalt aquifer system is contaminated with various hazardous and radioactive constituents from waste previously discharged to the ground in the 200 Areas. The most significant contaminants include nitrate, carbon tetrachloride, tritium, and ⁹⁹Tc. Contaminant plume maps for 1994 are presented in PNL-10698, *Hanford Site Ground-Water Monitoring for 1994* (Dresel et al. 1995).

Table 1-20. Aquifer Properties in the 200 Areas.

Location	Interval	Hydraulic conductivity (m/d)	Transmissivity (m ² /d)	Data source
200 Areas (undifferentiated)	Elephant Mountain Member interflow zone	--	0.7 to 569	Graham ^{a,b}
	Rattlesnake Ridge interbed	--	0.74 to 108	
200 West	Ringold unconfined aquifer	0.2 to 61	--	Last ^c
		0.093 to 475	--	Connelly ^d
	Ringold lower mud	1.6 x 10 E-05	--	Last ^c
200 East	Top of unconfined aquifer (Hanford and Ringold)	8 to 7,600	--	Connelly ^d

^aGraham, M. J., M. D. Hall, S. R. Strait, and W. R. Brown, 1981, *Hydrology of the Separations Area*, RHO-ST-42, Rockwell Hanford Operations, Richland, Washington.

^bGraham, M. J., G. V. Last, and K. R. Fecht, 1984, *An Assessment of Aquifer Intercommunication with B Pond Mountain Pond Area of the Hanford Site*, RHO-RE-ST-12P, Rockwell Hanford Operations, Richland, Washington.

^cLast, G. V., B. N. Bjornstad, M. P. Bergeron, D. W. Wallace, D. R. Newcomer, J. A. Schrenke, M. a. Chamness, C. S. Cline, S. P. Airhart, and J. S. Wilbur, 1989, *Hydrogeology of the 200 Areas Low Level Burial Grounds - An Interim Report*, PNL-6820, Pacific Northwest Laboratory, Richland, Washington.

^dConnelly, M. P., B. H. Ford, J. W. Lindberg, S. J. Trent, C. D. Delaney, and J. V. Borghese, 1992, *Hydrogeologic Model for the 200 East Groundwater Aggregate Area*, WHC-SD-EN-TI-019, Westinghouse Hanford Company, Richland, Washington.

1.4.2.3.2 Basalt and Interbed Aquifer System. The CRBG and associated sedimentary interbeds form a series of aquifers and aquitards. Generally the dense basalt flows form aquitards and interflow zones (fractured basalt) and the sedimentary interbeds form aquifers. The uppermost regionally extensive confined aquifer beneath the 200 Areas comprises the Rattlesnake Ridge interbed and adjacent interflow zones. The interbed is 15 to 25 m (49 to 82 ft) thick beneath the 200 Areas and generally thickens toward the west (Graham et al. 1981 and 1984). Recharge to the Rattlesnake Ridge interbed aquifer occurs in the higher elevations to the west, north, and northeast. The flow of groundwater is generally toward the northeast beneath the 200 West Area and west to west-northwest beneath the 200 East Area (Delaney et al. 1991).

Beneath the 200 Areas the Rattlesnake Ridge interbed aquifer is generally separated from the unconfined aquifer system by the Elephant Mountain Member of the CRBG. The Elephant Mountain Member is up to 35 m (115 ft) thick. North of the 200 East Area the Elephant Mountain Member has been locally removed by erosion, allowing hydraulic communication between the Rattlesnake Ridge interbed aquifer and the suprabasalt aquifer system. RHO-RE-ST-12P, *An Assessment of Aquifer Intercommunication with B Pond-Gable Mountain Pond Area of the Hanford Site* (Graham et al. 1984), determined that contamination found in the Rattlesnake Ridge interbed aquifer resulted from intercommunication through erosional windows between it and the overlying unconfined aquifer. Transmissivity of the Rattlesnake Ridge interbed and the Elephant Mountain interflow zone are included in Table 1-20.

1.4.3 Geology

The Hanford Site lies within the Pasco Basin, and the Pasco Basin lies within the Columbia Plateau, a broad plain constructed from the Miocene CRBG and situated between the Cascade Range to the west and the Rocky Mountains to the east (Figure 1-20). The Columbia Plateau is often called the Columbia Basin because it forms a broad lowland and is surrounded on all sides by mountains. In the central and western parts of the Columbia Plateau where the Hanford Site is located, the basalt is underlain predominantly by Tertiary continental sedimentary rocks and overlain by late Tertiary and Quaternary fluvial and glaciofluvial deposits. All these deposits were folded and faulted during the Cenozoic to form the present landscape of the region.

1.4.3.1 Physiographic Setting of the Hanford Site. The physiography of the Columbia Basin is controlled by the late Cenozoic faulting and folding of the CRBG and the overlying sediments of the Ringold Formation. Surface topography has been modified within the past several million years by geomorphic processes related to Pleistocene cataclysmic flooding, Holocene eolian activity, landsliding, and the Columbia River. The physiography of the Hanford Site is dominated by the low-relief plains of the Central Plains physiographic region and anticlinal ridges of the Yakima Folds physiographic region (Figure 1-21).

Cataclysmic flooding of the Hanford Site occurred when ice dams in western Montana and northern Idaho were breached allowing large volumes of water to spill across eastern and central Washington. The last major flood occurred about 13,000 years ago, during the late Pleistocene Epoch. Anastomosing flood channels, giant current ripples, berm mounds, and giant flood bars are among the landforms created by the floods and are readily seen on the Hanford Site. Most of the large landslides in the region occurred when these flood waters eroded the steep slopes of the ridges. The 200 East Area and the CSB are located on one major Pleistocene flood bar, the Cold Creek bar.

Since the end of the Pleistocene, winds have locally reworked the flood sediments, depositing dune sands in the lower elevations and loess (windblown silt) around the margins of the Pasco Basin. Generally sand dunes have been stabilized by anchoring vegetation except where they have been reactivated where vegetation is disturbed.

1.4.3.2 Stratigraphy. The stratigraphy of the Pacific Northwest is a collection of accreted terrane rocks added onto the North American craton between the Precambrian and early Cenozoic that are now mostly covered by extensive Cenozoic volcanic rocks. Intercalated with the volcanic rocks in structural basins and along the evolving continental margin are sedimentary rocks derived from eroding uplands areas.

The generalized stratigraphy of the Columbia Basin and Hanford Site is shown in Figure 1-22. The principal bedrock of the Hanford Site is the CRBG and intercalated and overlying sedimentary rocks of the Ellensburg Formation. The overlying sedimentary rocks are principally of the Ringold Formation and the Pleistocene catastrophic flood deposits of the Hanford formation (informal designation). This is the general stratigraphy present at the CSB.

Rocks older than the CRBG are exposed primarily along the margins of the Columbia Basin and vary widely in age, lithology, and structure. It is this complex stratigraphy and structure that underlies the CRBG of the Columbia Basin and Hanford Site and that is the probable source for seismic hazards under the basalt. Because of the thick basalt cover, the exact nature of the stratigraphy and the types of the structure under the Hanford Site is uncertain.

Along the northern and northwestern margins of the Columbia Basin in early Tertiary time, a series of sedimentary basins formed in the accreted terranes of the North Cascades (DOE 1988; Campbell 1989). These basins are now separated by tectonic "blocks" or uplifts that have a northeast- to northwest-trending structural grain and trend toward the Hanford Site. Along the northeastern and eastern margins of the Columbia Basin, the CRBG laps onto Paleozoic rocks and Precambrian miogeosynclinal and cratonic rocks that are interspersed with granites of the Idaho Batholith and other Jurassic and Cretaceous intrusions (DOE 1988). To the south and southwest, lower- to middle-Tertiary volcanic rocks and related volcanoclastic rocks primarily of the Clarno and John Day Formations directly underlie the CRBG and overlie accreted terranes of the Blue Mountains. To the west, younger volcanic rocks that erupted from the High Cascades cover the CRBG and obscure early Cenozoic volcanic and volcanoclastic rocks of predominantly Eocene and Oligocene age.

1.4.3.2.1 Columbia River Basalt Group. The CRBG, the principal bedrock unit in the Yakima Fold Belt (YFB) and under the Hanford Site, is a sequence of tholeiitic flood basalt flows that were erupted between 17 and 6 million years ago (Ma) (Figure 1-22). The CRBG now covers approximately 164,000 km² (63,325 mi²) and consists of 174,000 km³ (41,700 mi³) of basalt (Tolan et al. 1989). The flows were erupted from north-northwest-trending fissures or linear vent systems in north-central and northeastern Oregon, eastern Washington, and western Idaho (Swanson et al. 1975).

The CRBG has been divided into five formations (Swanson et al. 1979a); only the Grande Ronde Basalt, the Wanapum Basalt, and the Saddle Mountains Basalt are exposed on the Hanford Site. The Imnaha Basalt occurs at the base of the CRBG under the Hanford Site (Tolan et al. 1989).

The basalt flows of the CRBG are recognized using a combination of lithology, chemistry, and paleomagnetic data (Swanson et al. 1979a). Chemical composition and paleomagnetic data have proven to be the most reliable criteria for flow recognition and correlation; lithology is reliable for many flows primarily within the Wanapum and Saddle Mountains Basalts, but chemical compositions are still used to confirm identifications.

Over 85% of the CRBG was erupted during the 2-million-year span of the Grande Ronde Basalt eruptions. In the field, the Grande Ronde Basalt is divided into four magnetostratigraphic units, which, from oldest to youngest are Reversed 1 (R₁), Normal 1 (N₁), Reversed 2 (R₂), and Normal 2 (N₂) (Swanson et al. 1979a). The Grande Ronde Basalt is further subdivided into seventeen groups of flows based on chemical compositions (Reidel et al. 1989a).

The younger basalt flows of the Wanapum and Saddle Mountains Basalts on the Hanford Site have been locally eroded to varying degrees. Uplift along

anticlinal ridges has resulted in erosion to different depths along the margins of the Pasco Basin. Within the synclines where the basalt surface is covered by sediment fill, the upper basalt flows have been locally eroded by fluvial activity and proglacial flooding. North of the 200 Areas between Gable Mountain and Gable Butte, the Saddle Mountains Basalt has been eroded down to the oldest member, the Umatilla Member. The Elephant Mountain Member is suspected of being eroded near the northeast corner of 200 East Area.

1.4.3.2.2 Intercalated and Post-Columbia River Basalt Group Sediments. The Hanford Site and CSB are situated on a sequence of sedimentary units that overlie the CRBG. These sediments are confined largely to the synclinal valleys and basins of the western Columbia Basin. The sedimentary record is incomplete, but it is a direct reflection of the structural development of the area (Fecht et al. 1987). The upper-Miocene to middle-Pliocene (late Neogene) record of the Columbia River system in the Columbia Basin is represented by the upper Ellensburg Formation, Ringold Formation, and Snipes Mountain conglomerate. Except for local deposits (e.g., the Pliocene-Pleistocene unit and the early Palouse soil [DOE 1988]), there is a hiatus (i.e., lack of sedimentation or erosion) in the stratigraphic record between the end of the Ringold (3.4 Ma) and the Pleistocene (1.6 Ma).

Pleistocene to Recent (Quaternary) sediments overlying the CRBG at the Hanford Site include cataclysmic flood gravels and slackwater sediments of the Hanford formation; terrace gravels of the Columbia, Snake, and Yakima Rivers; and eolian deposits, including the Palouse Formation in eastern Washington.

Late Neogene Sediments. Two main late Neogene sedimentary units occur in the Columbia Basin and at the Hanford Site, the Ellensburg Formation and the Ringold Formation (Figure 1-22).

Ellensburg Formation. The Ellensburg Formation includes epiclastic and volcanoclastic sedimentary rocks that are intercalated with and overlie the CRBG (Waters 1961; Swanson et al. 1979a). The Ellensburg stratigraphy of the Hanford Site has been discussed in RH0-BWI-ST-14, *Subsurface Geology of the Cold Creek Syncline* (Reidel and Fecht 1981), in Geological Society of America Special Paper 239, *Volcanism and Tectonism in the Columbia River Flood-Basalt Province* (Reidel et al. 1989a), and in Bulletin 77, *Selected Papers on the Geology of Washington* (Fecht et al. 1987). At the Hanford Site, the Ellensburg Formation is mixed with sediments deposited by the ancestral Clearwater River and Columbia River.

Ringold Formation. Sediments continued to be deposited in most synclinal valleys of the central Columbia Basin, including the Hanford Site, long after the eruptions of the CRBG; these sediments are the Ringold Formation. Although exposures of the Ringold Formation are limited to the White Bluffs on the east side of the Hanford Site, isolated exposures on the west side of the Hanford Site, and the Smyrna and Taunton Benches within the Othello Basin, extensive data on the Ringold Formation have been obtained from boreholes at the Hanford Site.

The Ringold Formation at the Hanford Site is up to 185 m (607 ft) thick in the deepest part of the Cold Creek syncline south of the 200 West Area and 170 m (558 ft) thick in the western Wahluke syncline near the 100 B Area. The Ringold Formation pinches out against the Gable Mountain, Yakima Ridge, Saddle

Mountains, and Rattlesnake Mountain anticlines. The formation is largely absent in the northern and northeastern parts of the 200 East Area but is present under the CSB.

The Ringold Formation consists of semi-indurated clay, silt, pedogenically altered sediment, fine- to coarse-grained sand, and granule to cobble gravel. Ringold strata typically are below the water table and the textural variations of the strata influence groundwater flow. The Ringold Formation historically has been divided into a variety of units, facies types, and cycles (Newcomb 1958; Myers et al. 1979; Tallman et al. 1979; Bjornstad 1984; and DOE 1988). However, these terminologies have proven to be of limited use because they are too generalized to account for significant local stratigraphic variation or because they were defined in detail for relatively small areas and do not account for basinwide stratigraphic variation (Lindsey and Gaylord 1989; Lindsey 1991a).

Recent studies of the Ringold Formation in the Hanford Area indicate it contains significant stratigraphic variations (Lindsey and Gaylord 1989; Lindsey 1991a) that are best described on the basis of sediment facies. Sediment facies in the Ringold Formation are defined on the basis of lithology, stratification, and pedogenic alteration.

- The fluvial gravel facies consists of clast-supported granule to cobble gravels with a sandy matrix and intercalated sands and muds. Clast composition is variable, but typically includes basalt, quartzite, porphyritic volcanics, and greenstone. Sands generally are quartzo-feldspathic with less than 25% basalt content. Bedforms have low angle to planar stratification, massive bedding, wide shallow channels, and large-scale cross-bedding. The facies was deposited in a gravelly fluvial braidplain characterized by wide, shallow, shifting channels.
- The fluvial sand facies consists of quartzo-feldspathic sands, cross-bedded and cross-laminated sands that are intercalated with lenticular silty sands, clays, and thin gravels. These sands usually contain less than 15% basalt lithic fragments, and fining upwards sequences are common. Strata of this type were deposited in wide, shallow channels.
- The overbank facies consists of laminated to massive silt, silty fine-grained sand, and paleosols containing variable amounts of pedogenic calcium carbonate. Overbank deposits occur as thin lenticular interbeds in the gravels and sands and as thick laterally continuous sequences. These sediments record deposition in proximal levee to more distal floodplain conditions.
- The lacustrine facies is characterized by plane laminated to massive clay with thin silt and silty sand interbeds displaying some soft-sediment deformation. Deposits coarsen upwards. Strata were deposited in a lake under standing water to deltaic conditions.
- The alluvial fan facies is characterized by massive to crudely stratified, weathered to unweathered basaltic detritus. These deposits generally are found around the periphery of the Pasco Basin

and record deposition by debris flows in alluvial fan settings and in sidestreams draining into the Pasco Basin.

The lower half of the Ringold Formation is the main unconfined aquifer under the Hanford Site and contains five separate stratigraphic intervals dominated by the fluvial gravels facies. These gravels, designated units A, B, C, D, and E (Figure 1-23), are separated by intervals containing deposits typical of the overbank and lacustrine facies (Lindsey 1991a). The lowermost of the fine-grained sequences, overlying unit A, is designated the Lower Mud sequence. The uppermost gravel unit, unit E, grades upwards into interbedded fluvial sand and overbank deposits that are in turn overlain by lacustrine-dominated strata. Fluvial gravel units A and E correspond to the lower basal and middle Ringold units respectively as defined in DOE/RW-0164, *Site Characterization Plan Reference Repository Location, Hanford Site, Washington* (DOE 1988). Gravel units B, C, and D do not correlate to any previously defined units (Lindsey 1991a). The Lower Mud sequence corresponds to the upper basal unit and lower unit as defined by DOE/RW-0164 (DOE 1988).

The upper part of the Ringold Formation consists of the sequence of fluvial sands, overbank deposits, and lacustrine sediments overlying unit E. These sediments correspond to the upper unit as originally defined in "Ringold Formation of the Pleistocene Age in the Type Locality, The White Bluffs, Washington" (Newcomb 1958), along the White Bluffs in the eastern Pasco Basin. The fluvial sand facies is the principal facies of the upper part under the CSB.

Quaternary Stratigraphy of the Pasco Basin. Quaternary sediments, as much as 100 m (328 ft) thick within the Pasco Basin, overlie the Ringold Formation and are the main units at the CSB. The most extensive of these is the Pleistocene-aged Hanford formation (Figure 1-23). Locally the Hanford formation and underlying Ringold Formation are separated by several laterally discontinuous and informally defined units. These units are the Plio-Pleistocene unit, the pre-Missoula gravels, and the early Palouse soil (Figure 1-23), but they are largely absent at the CSB.

Quaternary Alluvium. Fluvial deposits from major rivers (Yakima, Snake, Columbia) are represented in the Pasco Basin ranging in age from Tertiary to present (Baker et al. 1991). There are two main alluvial units that are recognized at the Hanford Site: the Plio-Pleistocene unit and the pre-Missoula gravels.

Overlying the tilted and truncated Ringold Formation in an unconformable relationship in the western Cold Creek syncline in the vicinity of 200 West Area is the laterally discontinuous Plio-Pleistocene unit (DOE 1988). The Plio-Pleistocene unit appears to be correlative to other sidestream alluvial and pedogenic deposits found near the base of the ridges bounding the Pasco Basin on the north, west, and south. These sidestream alluvial and pedogenic deposits are inferred to have a late Pliocene to early Pleistocene age on the basis of stratigraphic position and the magnetic polarity of interfingering loess units.

In the central Pasco Basin, mainstream alluvium lies stratigraphically between the Ringold Formation and the Hanford formation. A thick sheet of well-rounded and well-sorted quartzose to gneissic clast-supported pebble to

cobble gravel with a quartzo-feldspathic sand matrix gravel, informally called the "pre-Missoula gravels," overlies the Ringold Formation in much of the central Pasco Basin. Based on magnetic polarity and stratigraphic position, this unit is interpreted to be early Pleistocene. Mainstream alluvium of probable early Pleistocene age is exposed along Cold Creek and the Yakima Bluffs. It is unclear whether the pre-Missoula gravels overlie or interfinger with the early Palouse soil and Plio-Pleistocene unit. The pre-Missoula gravels are interpreted as mainstream deposits in the Columbia River.

Eolian Deposits. Loess deposits at Hanford contain a detailed Quaternary record; five units are represented within the Pasco Basin (Reidel et al. 1992). These units are informally referred to as L1 through L5 and differentiated on the basis of position relative to other stratigraphic units, color, soil development, and paleomagnetic polarity.

The main eolian unit in the subsurface at the Hanford Site is referred to as the early Palouse soil. The early Palouse soil consists of up to 20 m (66 ft) of massive, brown-yellow, compact, loess-like silt and minor fine-grained sand (Tallman et al. 1979 and 1981; DOE 1988). Granule-sized grains consisting primarily of basalt are common in this unit. These deposits overlie the Plio-Pleistocene unit (Figure 1-23) in the western Cold Creek syncline around the 200 West Area but are absent in the 200 East Area. The unit is differentiated from overlying graded rhythmites (Hanford formation) by greater calcium carbonate content, massive structure, and high natural gamma response in geophysical logs (DOE 1988). The upper contact of the unit is poorly defined, and it may grade up-section into silty strata commonly found in the lower part of the Hanford formation. Because of a predominantly reversed polarity, the unit is inferred to be early Pleistocene in age.

Hanford Formation. The Hanford formation is the informal name given to all cataclysmic flood deposits of the Pleistocene. This is the main stratigraphic unit at the surface of the CSB. The Hanford formation consists of pebble to boulder gravel, fine- to coarse-grained sand, and silt. These deposits are divided into three facies: gravel-dominated, sand-dominated, and silty. These facies are referred to as coarse-grained deposits, plane-laminated sand facies, and rhythmite facies, respectively, in RHO-BW-SA-563A, *Quaternary Geology of the Pasco Basin, Washington* (Bjornstad et al. 1987). The rhythmites also are referred to as the "Touchet Beds." The Hanford formation is thickest in the vicinity of 200 West and 200 East Areas, where it is up to 65 m (200 ft) thick. Hanford deposits are absent on ridges above approximately 385 m (1,250 ft) above sea level, the highest level of cataclysmic flooding in the Pasco Basin (Bjornstad et al. 1987).

- The gravel-dominated facies generally consists of coarse-grained basaltic sand and granule to boulder gravel. These deposits display massive bedding, plane to low-angle bedding, and large-scale planar cross-bedding in outcrop. The gravel facies dominates the Hanford formation in the 100 Areas north of Gable Mountain, the northern part of the 200 East and West Areas, and the eastern part of the Site including the 300 Area. The gravel-dominated facies was deposited by high-energy flood waters in or immediately adjacent to the main cataclysmic flood channelways.

- The sand-dominated facies consists of fine- to coarse-grained sand and granule gravel displaying plane lamination and bedding and less commonly plane bedding and channel-fill sequences in outcrop. These sands may contain small pebbles and rip-up clasts in addition to pebble-gravel interbeds and silty interbeds less than 1 m (3 ft) thick. The silt content of these sands is variable, but where it is low, a well-sorted and open framework texture is common. These sands typically are basaltic, commonly being referred to as black, gray, or salt-and-pepper sands. This facies is most common in the central Cold Creek syncline and in the central to southern parts of the 200 East and 200 West Areas. The laminated sand facies was deposited adjacent to main flood channelways during the waning stages of flooding. The facies is transitional between the gravel-dominated facies and the rhythmite facies.
- The silty facies consists of thinly bedded, plane laminated, and ripple cross-laminated silt and fine- to coarse-grained sand that commonly displays normally graded rhythmites a few centimeters to several tens of centimeters thick (Myers et al. 1979; DOE 1988). This facies is found throughout the central, southern, and western Cold Creek syncline within and south of the 200 East and West Areas. These sediments were deposited under slackwater conditions and in back-flooded areas (DOE 1988).

Volcanic Ash Deposits. Volcanism in the Cascade Range has been active throughout the Pleistocene Epoch (approximately 2 million years before present to 10,000 years before present) and through the Holocene Epoch (10,000 years before present to present). The eruption history of the Holocene best characterizes the most likely types of activity in the next 100 years. Many of the volcanoes in the Cascade Range have been active in the last 10,000 years, including Mount Mazama (Crater Lake) and Mount Hood in Oregon, and Mount St. Helens, Mount Adams, and Mount Rainier in Washington State (Figure 1-24). Quaternary sediments recorded these eruptions in the form of ash deposits that are interlayered with the sediments.

The Hanford Site is approximately 150 km (95 mi) from Mount Adams, 175 km (110 mi) from Mount Rainier, and 200 km (125 mi) from Mount St. Helens, the three closest active volcanoes. At these distances, the tephra (ash) is the only volcanic product to reach the Site and, thus, the only volcanic hazard at the Hanford Site. Mount St. Helens has been considerably more active throughout the Holocene than Mount Rainier or Mount Adams, which is the least active of the three.

1.4.3.3 History of Cataclysmic Flooding in the Pasco Basin. Cataclysmic floods inundated the Pasco Basin several times during the Pleistocene when ice dams failed in northern Washington. Net erosion by these floods was minimal and probably associated with only the earliest floods; later floods only partially incised into older flood deposits before backfilling. During the three major flood episodes there were probably numerous individual flood events. Deciphering the history of cataclysmic flooding in the Pasco Basin is complicated, not only by floods from multiple sources, but also because the paths of Missoula floodwaters migrated and changed course with the advance and retreat of the Cordilleran Ice Sheet. The best preserved record is that of the last Missoula flood, which apparently came down the Columbia River.

Evidence for cataclysmic flooding in the Pasco Basin, besides the sediments, includes high-water marks and faint strandlines along the Basin margins. These were created by the hydraulic damming and formation of Lake Lewis behind Wallula Gap. Formation of this lake and its overflow may have initiated in the Columbia Gorge, as indicated by similar high-water marks both upstream and downstream of Wallula Gap. High-water mark elevations for Lake Lewis, inferred from ice-rafted erratics on ridges, range from 370 to 385 m (1,213 to 1,263 ft) above sea level. Several weak strandlines are interpreted from photolineaments between 245 and 305 m (800 and 1,000 ft) above sea level along the northeastern flank of Rattlesnake Mountain. A flood origin is inferred based on exposures in trenches that cross these features. The lack of well developed strandlines and the absence of typical lake deposits overlying flood deposits suggests that Lake Lewis was short-lived.

The course-grained flood facies is generally confined to relatively narrow tracts in or near flood channelways. The plane-laminated sand facies, on the other hand, occurs as a broad sheet over most of the central Pasco Basin. Paleocurrent indicators within beds of plane-laminated sands are unidirectional, generally toward the south and east, within the Pasco Basin. Rhythmite facies occur in slackwater areas around the margins of the Basin and were deposited as the energy of the floodwaters decreased, including upvalley currents. Individual rhythmites become finer and thinner both laterally and vertically.

1.4.3.4 Geologic Structures of the Columbia Basin and Hanford Site. The geologic structure of the Pacific Northwest is controlled by a basement rock assemblage of accreted terranes fused onto the structurally complex North American craton from the early Mesozoic to early Cenozoic. The accreted terranes form the backbone of the Cascade Range, Okanogan Highlands, and the Blue Mountains. The terranes are now mostly covered by extensive cover of Cenozoic rocks that were folded and faulted in a north-south oriented compressive regime. North-south compression is continuing today east of the Cascades portion of the Pacific Northwest and this pattern of Cenozoic deformation is expected to continue into the future.

The Columbia Basin is a structurally and topographically low area surrounded by mountains ranging in age from the late Mesozoic to Recent (Figure 1-25). The Columbia Basin has two major structural subdivisions or subprovinces: the YFB and the Palouse Slope (Figure 1-25). The YFB is a series of anticlinal ridges and synclinal valleys in the western and central parts of the Columbia Basin. The Palouse Slope forms the eastern part of the Columbia Basin and is mainly a westward-tilting paleoslope. The Hanford Site and the CSB are in the eastern part of the YFB. The western boundary of the Palouse Slope is at the eastern boundary of the Hanford Site.

The Blue Mountains subprovince of the Columbia River flood-basalt province is a northeast-trending anticlinorium that extends 250 km (155 mi) from the Oregon Cascades to Idaho and forms the southern border of the Columbia Basin and the southern part of the Columbia Plateau.

1.4.3.4.1 Major Structural Features of the Columbia Basin. The main structural features of the Columbia Basin are the YFB and two major cross-cutting structures: the Olympic-Wallowa lineament (OWL) and the Hog Ranch-Naneum Ridge anticline (HR-NR). The OWL passes along the southern boundary of

Hanford and the HR-NR anticline forms the western structural boundary of the Pasco Basin and Hanford Site.

The Olympic-Wallula Lineament. The OWL (Figure 1-25) is a major topographic feature in Washington and Oregon that crosscuts the Columbia Basin and forms the southern boundary of the Hanford Site. This alignment of structural features parallels prebasalt structural trends along the northwest margin of the Columbia Basin, but it has not been linked to any individual structure (Campbell 1989; Reidel and Campbell 1989).

The portion of the OWL that crosses the Columbia Basin is called the Cle Elum-Wallula deformed zone (CLEW) (Keinle et al. 1977). It is a 10-km- (6-mi-)wide, moderately diffuse zone of anticlines that have a N 50° W orientation. The CLEW consists of three structural parts: (1) a broad zone of deflected or anomalous fold and fault trends extending south from Cle Elum to Rattlesnake Mountain on the Hanford Site; (2) a narrow belt of topographically aligned domes and doubly plunging anticlines extending from Rattlesnake Mountain to Wallula Gap; and (3) the Wallula fault zone, extending from Wallula Gap to the Blue Mountains.

Northwest of the CRBG margin, numerous northwest- and north-trending faults and shear zones of the Straight Creek fault system lie subparallel to the OWL. The Snoqualmie batholith intrudes these faults but is not cut by them, indicating that any possible movement along the OWL at the western margin of the Columbia Basin must be older than the batholith, 17 to 19.7 Ma (DOE 1988).

The structural significance of the OWL has been called into question by two recent geophysical studies. Neither a seismic profiling survey by Jarchow (1991) nor a gravity survey by Saltus (1993) could find any obvious geophysical signature for the OWL below the CRBG.

Hog Ranch-Naneum Ridge Anticline. The NR-HR anticline is the western structural boundary of the Pasco Basin, the basin containing the Hanford Site (Figure 1-25). The HR-NR anticline is a broad south-trending anticline in the CRBG that crosses the YFB in a north-south direction. This south-plunging structure passes through five Yakima folds and the OWL. The HR-NR anticline was active in late to middle Miocene as demonstrated by thinning of basalt flows across it (Reidel et al. 1989b), but the east-trending Yakima folds show no apparent offset by the cross structure (Campbell 1989; Keinle et al. 1977; Reidel et al. 1989b), nor is the HR-NR anticline offset where the OWL-CLEW crosses it. Growth of the HR-NR anticline continued from the Miocene to Recent and is now marked by the highest structural points along the ridges that cross it.

The Yakima Fold Belt. The YFB subprovince covers about 14,000 km² (5,400 mi²) of the western Columbia Basin (Figures 1-20 and 1-25) and formed as basalt flows and intercalated sediments were folded and faulted under north-south directed compression. The reader is referred to Tables 1A-1 and 1A-2 in Appendix 1A and to the compilation of structural features for the Columbia Basin by Tolan and Reidel (1989). The Hanford Site lies in the Pasco Basin, which is one of the larger structural basins near the eastern limit of the YFB. The YFB gives the Hanford Site its principal physiographic features

and has been the primary factor influencing the geohydrologic conditions at the Hanford Site.

The YFB consists of asymmetrical anticlinal ridges and synclinal valleys. The anticlines are typically segmented and usually have a north vergence, although some folds have a south vergence. Synclines are typically asymmetrical with a gently dipping north limb and a steeply dipping south limb. Fold length is variable ranging from several kilometers to over 100 km (62 mi); fold wavelengths range from several kilometers to as much as 20 km (12 mi). Structural relief is typically about 600 m (1,970 ft) but varies along the length of the fold. The greatest structural relief along the Frenchman Hills, the Saddle Mountains, Umtanum Ridge, and Yakima Ridge occurs where these folds intersect the north-south trending HR-NR anticline (Reidel et al. 1989b).

In general, the axial trends produce a "fanning" pattern across the fold belt (Figure 1-25). Anticlines on the western side of the fold belt generally have a N 50° E trend (Swanson et al. 1979b). Anticlines in the central part of the fold belt have east-west trends except along the OWL where a N 50° W trend predominates.

Within the Hanford Site and surrounding area, the geometry of the anticlines typically consists of steeply dipping to overturned north flanks and gently dipping (< 5°) south flanks. Exceptions, however, include the doubly plunging anticlines within the Rattlesnake-Wallula alignment of the CLEW and the conjugate box-fold geometry of parts of the anticlines such as the Smyrna segment of the Saddle Mountains (Reidel 1984). The main variable in fold profiles is the width of the gently dipping limb. The widths of the gently dipping limbs vary from as little 5 km (3 mi) to as much as 35 km (22 mi).

Segmentation of the anticlines is common throughout the fold belt and is defined by abrupt changes in fold geometry or by places where regional folds die out and become a series of doubly plunging anticlines. Segment lengths are variable but average about 12 km (7 mi) (ranging from 5 to 35 km [3 to 22 mi]) near the Hanford Site; some of the larger segments contain subtler changes in geometry, such as different amplitudes, that could also be considered segment boundaries. Segment boundaries are often marked by cross or tear faults that trend N 20° W to north and display a principal component of strike-slip movement (e.g., Saddle Mountains [Reidel 1984]). Near Hanford these cross faults are confined to the anticlinal folds and usually occur only on the steeper limb, dying out onto the gentler limb.

Segment boundaries may also be marked by relatively undeformed areas along the fold trend where two fold segments plunge toward each other. For example the Yakima River follows a segment boundary where it crosses the Rattlesnake-Wallula alignment at the southeast termination of Rattlesnake Mountain (Figure 1-25).

The steep limb of the asymmetrical anticlines is almost always faulted. Near the Hanford Site the steep limb is typically the northern flank, but elsewhere, as at the Columbia Hills (Swanson et al. 1979b), the south limb is faulted. Where exposed, these frontal fault zones have been found to be imbricated thrusts as, for example, at Rattlesnake Mountain, Umtanum Ridge

near Priest Rapids Dam (Bentley in Swanson et al. 1979b), the Horse Heaven Hills (Hagood 1986), and the Saddle Mountains near Sentinel Gap (Reidel 1984).

Yakima folds have emergent thrust faults at the ground surface. The tops of the youngest lava flows at the earth's surface serve as a plane that becomes a low angle thrust fault; the structural attitude of the surface flow controls the angle of the emergent fault plane. This type of apparent structural control led many investigators to conclude that faults associated with the Yakima Folds are low-angle thrust faults with detachment surfaces either within the CRBG, in the sediments below the basalts, or at the basalt-sediment contact. Where erosion provides deeper exposures into the cores of folds, the frontal faults are observed to be reverse faults (e.g., the Columbia water gap in the Frenchman hills, 45° south [Grolier and Bingham 1978]; the Columbia Hills at Rock Creek, Washington, 50°-70° north [Swanson et al. 1979b]).

Hydrocarbon exploration boreholes provide direct evidence for the dips of these frontal faults. Reidel et al. (1989b) have shown that the Saddle Mountains fault must dip more than 60° where the Shell-ARCO BN 1-9 borehole was drilled. Drilling of the Umtanum fault near Priest Rapids Dam (DOE 1988) suggests that this fault dips southward under the ridge with a dip of at least 30° to 40° but perhaps as high as 60° (Price and Watkinson 1989).

Although it is difficult to assess, total shortening increases from east to west across the YFB. At about 120° longitude, it is estimated to be greater than 15 km (9 mi) but less than 25 km (16 mi) (Reidel et al. 1989b) or about 5% (Appendix 1A, Table 1A-1). Typically, shortening on an individual anticline caused by folding is approximately 1 to 1.5 km (0.6 to 0.9 mi). The amount of shortening on faults expressed at the surface is generally unknown. Estimates range from several hundreds of meters to as much as 3 km (1.9 mi) (Appendix 1A, Table 1A-2).

1.4.3.4.2 Structure of the Hanford Site. The Cold Creek syncline (Figures 1-26 and 1-27) lies between the Umtanum Ridge-Gable Mountain uplift and the Yakima Ridge uplift, and is an asymmetric and relatively flat-bottomed structure. The 200 Areas lie on the northern flank, and the bedrock dips gently (approximately 5°) to the south. The 300 Area lies at the eastern end of the Cold Creek syncline where it merges with the Pasco syncline.

The Wahluke syncline (Figure 1-26) is the principal structural unit that contains the 100 Areas. The Wahluke syncline is an asymmetric and relatively flat-bottomed structure similar to the Cold Creek syncline. The northern limb dips gently (approximately 5°) to the south. The steepest limb is adjacent to the Umtanum Ridge-Gable Mountain structure.

The Umtanum Ridge-Gable Mountain structural trend is a segmented anticlinal ridge extending for a length of 110 km (68 mi) in an east-west direction and passes north of the 200 and 300 Areas and south of the 100 Areas. From the west, the Umtanum Ridge plunges eastward and joins the Gable Mountain-Gable Butte segment just east of the western boundary of the Hanford Site. The easternmost segment, the Southeast anticline, trends southeast off the eastern boundary of the Gable Mountain-Gable Butte segment.

Umtanum Ridge is an asymmetrical, north-vergent-to-locally-overtuned anticline with a major thrust to high-angle reverse fault on the north side (Price and Watkinson 1989) that dies out eastward toward Gable Mountain. Gable Mountain and Gable Butte are two topographically isolated, anticlinal ridges that are composed of a series of northwest trending, doubly plunging, en echelon anticlines, synclines, and associated faults.

The Yakima Ridge uplift extends from west of Yakima, Washington, to the center of the Pasco Basin, where it forms the southern boundary of the Cold Creek syncline south of 200 West Area (Figures 1-26 and 1-27). The easternmost surface expression of the Yakima Ridge uplift is represented by an anticline that plunges eastward into the Pasco Basin (Tolan and Reidel 1989). The eastern extension of Yakima Ridge is mostly buried beneath late Cenozoic sediments and has much less structural relief than the rest of Yakima Ridge.

The 200 and 300 Areas are situated on the south flank of the Umtanum-Gable Mountain anticline where the Miocene-aged basalt bedrock dips to the southwest into the Cold Creek syncline. The 100 Areas lie north of the Umtanum Ridge-Gable Mountain anticline in the Wahluke syncline. The deepest parts of the Cold Creek syncline, the Wye Barricade depression and the Cold Creek depression, are approximately 12 km (7.5 mi) southeast of the 200 Areas and under the 200 West Area, respectively.

1.4.3.5 Geology of the 200 East Area Canister Storage Building. The geology of the CSB site, located in the 200 East Area, is summarized on Figures 1-27 and 1-28. The suprabasalt sediments consist of the Ringold Formation and Hanford formation. The Ringold Formation conforms to the basalt bedrock surface and tilts southeast toward the axis of the Cold Creek syncline. The Ringold Formation is dominated by gravel units E and A, which are separated by the Lower Mud unit. These are the main unconfined aquifers. The Ringold Formation thins from 50 m (164 ft) at the south end to nearly pinching out at the north end. The beds have been truncated and are unconformably overlain by the Hanford formation. The Hanford formation is mainly sands and gravelly sands that are between 75 and 100 m (246 and 328 ft) thick at the site.

During excavation of the pit for the CSB, geologic mapping showed that the foundation for the building is in the fine-grained, laminated sands of the Hanford formation. No faults were found cutting the unit but clastic dikes were observed along the south wall of the site.

1.4.3.6 Tectonic Development of the Hanford Site. A seismic hazards analysis of the Hanford Site (Geomatrix 1996) has shown that the geologic history of the Hanford Site from the Precambrian to the present and the resulting geologic structures significantly impact the hazards analysis. This section summarizes the principal geologic events in the development of the Site geology.

The present structure of the Columbia Basin is the product of north-south compression that began in the early Tertiary before the eruption of the CRBG and continues today. The Columbia Basin is composed of two fundamental subprovinces, the Palouse Slope and the YFB. The Palouse Slope is a stable, undeformed area overlying the old continental craton. The YFB overlies a large pre-basalt basin that has been subsiding since the early Tertiary. The pre-CRBG sedimentary basin and CRBG basin are divided by the HR-NR anticline.

The edge of the old continental craton lies at the junction of the two structural subprovinces and is presently marked by the Ice Harbor dike swarm of the CRBG.

The pattern of deformation in the Columbia Basin has been dominated by north-south compression and subsidence; the YFB is the principal product of these. Deformation has controlled the location of the Columbia River system since the late Miocene as well as the depositional pattern of the post-basalt sediments. The rates of deformation in the Columbia Basin have declined since the early Tertiary. The rate of regional subsidence of the basin and the rate of local uplift on the anticlinal ridges have both declined. The present rate of ridge growth is estimated at 0.04 mm/yr (0.0016 in/yr) and the rate of subsidence in the basin is estimated at 3×10^{-3} mm/yr (0.0001 in/yr).

Microseismicity, high in situ stress conditions, and the geometry of Quaternary-Holocene faulting indicate that the basin is still experiencing north-south compression. Although known late Cenozoic faults are found exclusively on the anticlinal ridges, earthquake focal mechanisms and strain measurements suggest that most stress release is occurring in the synclinal areas. No earthquake events have been shown to be related to known faults. The high in situ stress in the Cold Creek syncline explains the microseismicity in the region; but the absence of microseismicity associated with the anticlinal ridges may result from weakened fault zones lubricated with groundwater that have a component of aseismic or below-detection-limit seismic slip, or the fault zones may be locked up.

1.4.3.6.1 The Pre-Miocene Columbia Basin. The beginning of the development of the Pacific Northwest can be traced to the late Precambrian rifting of the Proterozoic supercontinent when plates that were to become part of either Siberia or Australia separated from North America. The western edge of the North American craton in Washington was near the present 119° longitude trending north-south in the vicinity of the present Ice Harbor Dam and near the eastern border of the Hanford Site. Between the initial rifting and early Mesozoic time, eastern Washington was a passive margin accumulating sediments along the coast through most of the Paleozoic and early Mesozoic.

When Pangea began to separate in the Triassic, the western coast of North America became an active continental margin with a subduction zone forming along the cratonic boundary. By the late Jurassic, microcontinents and exotic terranes that formed at great distances from North America began to be accreted onto the old craton, expanding the North American continent westward. Washington and the west coast of North America grew by accreting other terranes until at least the Eocene. Presently these accreted terranes form the crystalline basement of the Hanford Site.

The process of subduction and accretion resulted in suturing of these exotic terranes by the intrusion of batholiths beginning in the Cretaceous and continuing into the Eocene. At the same time, most of eastern Washington was uplifted. Streams and rivers eroded these uplands and deposited the sediments along the edge of the continental shelf. The accretion also resulted in successive westward repositionings of the subduction zone until the present position was reached.

The Cenozoic saw the initiation of extensive volcanism throughout the Pacific Northwest along north-south trending volcanic arcs and in areas where extension occurred during the Eocene. In the Columbia Basin the Eocene and early Oligocene saw rapid subsidence caused by extension accompanied by infilling of continental sediments and volcanic rocks.

Before the eruption of the CRBG in Miocene time, the Columbia Basin had two distinct parts: the eastern basin was underlain by ancient cratonic rocks that formed a stable gently dipping slope to the west; the western portion of the Columbia Basin was an area underlain by the accreted terranes of the Mesozoic, which were overlain by continental volcanic rocks and continental sediments that accumulated in a rapidly subsiding basin during the early part of the Cenozoic. The Hanford Site is along the boundary of these two parts of the Columbia Basin. The *Journal of Geophysical Research* (Catchings and Mooney 1988) interpreted the basin underlying the western part as a failed rift based on seismic refraction survey. Other studies (Rohay and Malone 1983; Rohay et al. 1985), however, question this interpretation. These studies did not find evidence for a rift basin in the deep crust or mantle.

Tertiary sedimentary and volcanoclastic rocks extend beyond the margin of the CRBG and form part of the Cascade Range (Reidel et al. 1994); in addition, there is no known fault zone along the western margin of the basin as suggested in the rift model. The pre-CRBG sediments that continue across the present Cascade Range were arched upward during intrusion and uplift of the Cascade Range beginning about 12 Ma to form the present western edge of the Columbia Basin. This supports the previously mentioned geophysical studies and suggests that the Columbia Basin is not a rift basin but perhaps simply a back-arc basin. The concept of a rift basin has a significant impact on the seismic hazards of the Site (Geomatrix 1996).

1.4.3.6.2 Miocene Columbia Basin. Beginning about 17 Ma and continuing until about 6 Ma, flood-basalt flows of the CRBG began erupting from linear vent systems in eastern Washington, northeast Oregon, and western Idaho. The greatest volume (85%) of basalt was erupted between 16.5 and 15.5 Ma with waning eruptions until 6 Ma. The basalt eruptions were huge by comparison to eruptions today; individual flows contained as much as 5,000 km³ (1,200 mi³) of basalt (Reidel et al. 1989b). The average hiatus between eruptions was as long as 20,000 years.

Borehole, geophysical, and stratigraphic data (Catchings and Mooney 1988; Reidel et al. 1989b) indicate that the CRBG is thinner on the Palouse Slope than in the YFB. The CRBG ranges from 500 to 1,500 m (1,640 to 4,920 ft) thick on the Palouse Slope but abruptly thickens to as much as 4,000 m (13,125 ft) in the Pasco Basin area under the Hanford Site (Reidel et al. 1989b). Regional thickness patterns for both the CRBG and underlying Tertiary sediments indicate that the pre-CRBG basin where the Hanford Site is located began subsiding again. By far the most significant tectonic activity was continued subsidence in the basin. The subaerial nature of the CRBG indicates that subsidence continued as long as basalt was being erupted and that basalt accumulation kept pace with subsidence (Reidel et al. 1989a and 1989b). Subsidence rates from 17 to 15.6 Ma were approximately 1 cm/yr (0.4 in/yr) initially and decreased to 3×10^{-3} cm/yr (0.001 in/yr) in the late Miocene (Reidel et al. 1989b).

During the eruption of the CRBG, the anticlinal ridges were topographic highs against which the basalt flows thinned as they were emplaced (Reidel 1984; Reidel et al. 1989b). Detailed analysis of borehole and field data (Reidel 1984; Reidel et al. 1989b) established a quantitative relationship between flow thickness and fold growth rates. During the initial eruption of the CRBG (17 to 15.6 Ma) the ridges grew at about 0.25 mm/yr (0.01 in/yr), and the rate decreased to about 0.04 mm/yr (0.002 in/yr) during the waning phases (15.6 to 10.5 Ma) (Reidel 1984; Reidel et al. 1989b).

By the end of the massive eruptions of the CRBG (8.5 Ma), most of the Columbia Basin was a shallow, bowl-shaped, nearly featureless plain. The massive eruptions had buried most of the structural and topographic relief. In the western part of the Columbia Basin, only the anticlinal ridges that were not buried by younger flows stood above the plain. Across this plain flowed the ancestral Columbia River and its main tributaries, including the Salmon-Clearwater, Yakima, and Palouse Rivers.

1.4.3.6.3 The Late-Miocene to Middle-Pliocene Columbia Basin. The post-CRBG tectonic history of the Columbia Basin and Hanford Site is recorded in the Yakima folds and post-CRBG sediments. Alluvial-lacustrine sediments deposited primarily by the Columbia River system show that the Yakima folds were growing and displacing river channels during the late Miocene and Pliocene (Fecht et al. 1987).

Progressive changes in the distribution of post-CRBG sedimentary facies provide one of the best records of the post-CRBG tectonic history of the Columbia Basin and Hanford Site. Ridge uplift and basin subsidence are recorded by progressive lateral shifts in these depositional environments over time (Fecht et al. 1987; Smith 1988; Lindsey 1991b; Reidel et al. 1994).

During the waning phases of CRBG eruptions (12.5 to 8.5 Ma), the Columbia River flowed south across the YFB. Before approximately 8 Ma, the post-CRBG pre-Ringold channel of the Columbia River flowed across the western Pasco Basin, entering at Sentinel Gap and exiting near the southwestern side of Hanford; from there it flowed southwest toward Goldendale. About 8 Ma the Columbia River began to shift eastward onto the Hanford Site flowing south through Gable Gap and occupying a water gap over the eastern end of Rattlesnake Mountain near Benton City, Washington (Fecht et al. 1987). By middle Ringold time (approximately 6 Ma), the Columbia River shifted position again, exiting the Pasco Basin at Wallula Gap as it does now (Fecht et al. 1987).

About 3.4 Ma, regional uplift in western North America caused incision of the Columbia River system that resulted in the removal of over 100 m (328 ft) of Ringold section across the Hanford Site and under the CSB site. This regional incision and erosion produced the White Bluffs along the Columbia River on the eastern boundary of the Hanford Site.

1.4.3.6.4 Quaternary Deformation in the Columbia Basin. Uplifted and faulted Ringold and coeval sediments flank most ridges in the central Columbia Basin (Reidel 1984; Reidel et al. 1989b). Deformed Pliocene-Pleistocene sediments also are found on many ridges. Younger glaciofluvial sediments of the Hanford formation locally record some of the youngest deformation in the Columbia Basin.

Evidence for continued growth of the YFB in the Quaternary is mainly restricted to the frontal fault zones. Although not common, evidence of young faulting or suspected young faulting has been found at many locations across the YFB (see Appendix 1A, Tables 1A-3 and 1A-4). Young faults have been described at Toppenish Ridge, at Union Gap in Ahtanum Ridge, on Gable Mountain along Umtanum Ridge, in the Columbia Hills anticline, and along the CLEW. Although age relationships are not fully understood, they suggest that faulting has continued since the last cataclysmic flood (approximately 13,000 years before present).

1.4.3.7 Contemporary Stress and Strain.

1.4.3.7.1 Seismicity. Seismic monitoring at Hanford began when the U.S. Geological Survey installed a small array of seismograph stations around the Hanford Site in the summer of 1969. In 1982 a closely spaced seismic network was installed at the Hanford Site to characterize the microseismicity on the Site for a possible high-level waste repository. This operated until 1988. In 1988 the number of stations in the network was reduced. Earthquakes of magnitudes 1.0 (Coda Amplitude Magnitude) and larger currently can be detected and located at the Hanford Site and earthquakes of magnitude 2.5 and larger are detected and located throughout most of eastern Washington.

Past seismic hazard studies at the Hanford Site have shown that earthquakes can be related to three crustal layers and five general sources (Tables 1-21 and 1-22). All layers and sources are monitored at the Site except the Cascadia Subduction Zone, which is monitored by the University of Washington.

Table 1-21. Depth of Earthquakes in the Columbia Basin.

Layer	Depth
Columbia River Basalt Group	0-5 km
Prebasalt sediments	5-10 km
Crystalline basement	>10 km

Table 1-22. Principal Locations of Earthquakes in the Columbia Basin.

Area	Layer
Major reverse faults on ridges	Mainly basalt, also prebasalt sediments
Secondary faults on ridges	Basalt
Swarm area	Basalt
Basement	Crystalline basement
Cascadia Subduction Zone	Lithosphere - plate tectonic boundary

Vertical Patterns. There are three horizontal layers of seismicity (seismic stratigraphy) related to the stratigraphy of the Hanford Site and vicinity (Table 1-21): the CRBG, the prebasalt sediments, and the crystalline basement. About 75% of the earthquakes have originated in the CRBG layer. The prebasalt sedimentary layer has had 8% of the events and the crystalline basement has had 17%.

Shallow Earthquakes in the Basalt. The majority of the seismicity at the Hanford Site and the surrounding area comes from the basalt layer that extends from the surface to approximately 4 km (2.5 mi) under the Site.

Earthquakes in Sedimentary Rock below the Basalt. The seismicity in the pre-CRBG sedimentary rock appears to be confined to the top 3 km (1.9 mi). The seismicity of this sedimentary layer at the Hanford Site is relatively low when compared to the basalt layer but may be related to localized detachment zones related to the growth of the anticlinal structures.

Earthquakes in the Crystalline Basement. Deep earthquakes below 10 km (6.2 mi) appear to be concentrated in the western and southwestern portions of the Hanford Site. The deepest earthquakes located below the Site are shallower than 30.0 km (18.6 mi).

Using first-motion data from the Eastern Washington Regional Network and from the Basalt Waste Isolation Project, focal mechanisms show faulting that strikes between N 30° W and N 80° W. Although the strike is consistently west-northwest, the throw on the assumed faults varies. These data indicate reverse faults or strike-slip faults.

Spacial Patterns. Past studies at the Hanford Site have concluded that there are five different tectonic environments (earthquake sources) where earthquakes can occur near the Hanford Site and in the Columbia Basin of eastern Washington (Table 1-22).

1. Reverse/thrust faults in the CRBG associated with major anticlinal ridges such as Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge
2. Secondary faults occurring on the major anticlinal ridges
3. Small geographic areas of unknown geologic structure that produce clusters of events (swarms), usually in the CRBG in synclinal valleys
4. Basement source structures, although earthquakes cannot be directly tied to a mapped fault because very little is known about geologic structures in the crystalline basement beneath the Hanford Site
5. The Cascadia Subduction Zone, which recently has been postulated to be capable of producing a magnitude 9 earthquake.

Floating Earthquakes. A "floating" earthquake within the tectonic environment covering the entire Columbia Basin, including the Hanford Site, must be assessed. A floating earthquake is one that, for seismic design

purposes, can happen anywhere in a tectonic province and is not associated with any known geologic structure. It can be floated anywhere in the province.

Earthquake Swarm Areas. The major source of earthquakes at the Hanford Site is swarm activity in the syncline of the YFB. There are three general areas of significant swarm activity: the Wooded Island swarm area, Coyote Rapids swarm area, and the Saddle Mountains swarm area (Figure 1-29).

The Wooded Island swarm area, located near the 300 Area, occurs at the eastern edge of the YFB where it abuts against the Palouse Slope. This boundary marks the suture zone between the old accreted terranes to the west and the stable Precambrian-Paleozoic craton to the east (Reidel et al. 1994). This zone also is marked by an abrupt increase in the thickness of the basalt and subbasalt sediment over the accreted terranes and abrupt thinning of the basalt and sediment over the craton.

The Coyote Rapids Swarm Area is located at the horn of the Columbia between 100 K and 100 N areas; it occurs over no known geologic structure. The swarm lies at the intersection of two paleoslopes that make a northeast-southwest trough extending from Spokane, Washington, to the Columbia Gorge. This zone may be an old basement weakness zone, but there is no known reason for the swarm to occur in its present position.

The Saddle Mountains Swarm Area is located along the north side of the Saddle Mountains. The swarm area is located north of the Saddle Mountains fault zone in an area that has no mapped geologic structures. There is evidence for recent (post-13,000 years) faulting on the Saddle Mountain fault (Appendix 1A, Table 1A-3), but there is no evidence for faults at the swarm. The cause of the earthquake swarm is not known at this time.

Magnitude of Earthquakes. Earthquake activity at Hanford and in the Columbia Basin is summarized in Appendix 1A, Tables 1A-5, 1A-6, 1A-7, and 1A-8. Since July 1982, approximately 650 earthquakes between magnitude 0 and 3.8 have been recorded on and around the Hanford Site. The pattern of earthquake activity between 1990 and 1995 is shown in Figure 1-30. The greatest seismic activity is in the low-magnitude range, with only 5 events exceeding a magnitude of 3.0. The largest magnitude earthquake on the Hanford Site was a 3.8 magnitude earthquake on October 25, 1971, in the Coyote Rapids Swarm Area (Appendix 1A, Table 1A-7). The largest recent, felt earthquake was a 3.3 magnitude earthquake on June 12, 1995, in the Wooded Island swarm area. The largest regional earthquake was the 5.7 Milton-Freewater earthquake on July 16, 1936 (Appendix 1A, Table 1A-6); this earthquake occurred 100 km (62 mi) southeast of the Hanford Site. The 1936 Milton-Freewater earthquake was estimated to have a peak acceleration of 0.03 g at the Hanford Site.

1.4.3.7.2 Contemporary Stress in the Cold Creek Syncline. Contemporary stress in the Cold Creek syncline is expressed principally as horizontal shortening and subsidence. Geodetic surveys (Prescott and Savage 1984) were performed across the Pasco Basin to determine rates of shortening. The data suggest north-south shortening; the rate of shortening is not statistically significant at the 95% confidence level, however, and the measurements are within the error limits of the recording instruments.

Contemporary stress measurements were performed at the Hanford Site as part of the Basalt Waste Isolation Project. Core diskings and spalling in boreholes drilled in the Cold Creek syncline indicate relatively high in situ stress (DOE 1988). Hydraulic fracturing tests were conducted in boreholes in the Cold Creek syncline at a depth of about 1 km (0.6 mi) (DOE 1988). The results also indicated high in situ stress. The maximum horizontal stress ranges from 52.6 to 67.4 MPa (7,630 to 9,780 lbf/in²) and the minimum horizontal stress ranges from 30.3 to 35.7 MPa (4,400 to 5,180 lbf/in²) with a mean horizontal to vertical ratio of 1.77 ± 0.20 . The mean orientation of induced fractures, and the direction of the maximum horizontal stress, is consistent with north-south compression (DOE 1988).

1.4.3.7.3 Subsidence. Subsidence has been continuing in the Pasco Basin and Hanford Site since at least the Eocene. Estimates of subsidence since the middle Miocene (17 Ma) indicate the rates of subsidence have declined. From 17 to about 15.6 Ma, the rate of subsidence was about 0.7 to 1 cm/yr (0.3 to 0.4 in/yr). This decreased to about 0.03 cm/yr (0.01 in/yr) from 15.6 to 14.5 Ma. The present rate of ridge growth is estimated at 0.04 mm/yr (0.0015 in/yr) and the rate of subsidence in the basin is estimated at 3×10^{-3} mm/yr (0.0001 in/yr).

The pattern of subsidence in the Cold Creek syncline is shown in Figure 1-31. There are two broad areas of subsidence in the Cold Creek syncline: the Wye Barricade depression and the Cold Creek Depression. Both areas have had a long slow history of subsidence (Reidel et al. 1983); both areas are away from the 200 Areas and the CSB site.

1.4.3.8 Geologic Hazards. The geologic hazards that affect the performance of the CSB have been assessed based on the geologic data addressed in previous sections. These hazards are discussed below and, where appropriate, quantified for use in the structural evaluations and safety analyses.

1.4.3.8.1 Seismic Hazard Assessment. A seismic hazard analysis was recently completed for the Hanford Site (Geomatrix 1996). Previous seismic hazard analyses were done for Supply System WNP-1, WNP-4, and WNP-2, which also are located on the Hanford Site (Power et al. 1981). The Supply System study was later applied to the DOE-held areas within the Hanford Site by Woodward-Clyde Consultants (WCC 1989).

The following discussion is based on the current seismic hazard analysis (Geomatrix 1996), which incorporates seismo-tectonic data and interpretations that postdate the Supply System's earlier assessment and are discussed in previous sections of this report. The details of the source models and attenuation relationships used in the hazard assessment are included in WHC-SD-W236-TI-002, *Probabilistic Seismic Hazard Analysis, DOE Hanford Site, Washington* (Geomatrix 1996).

The potential seismic sources determined to be the major contributors to the seismic hazard in and around the Hanford Site are crustal sources and Cascadia Subduction Zone earthquakes in western Washington State. The crustal sources are:

- Fault sources related to the Yakima folds

- Shallow basalt sources that account for the observed seismicity within the CRBG and not associated with the anticlines
- Crystalline basement source.

The mean seismic hazard curves for the 200 East Area and the CSB site are shown in Figures 1-32 and 1-33 and illustrate the contributions of individual folds to the hazard. The relative contribution of crustal and Cascadia Subduction sources at the 200 East Area is illustrated in Figure 1-34 and the relative contribution of the three crustal sources for the same location is shown in Figure 1-35.

Horizontal and vertical equal-hazard response spectra were developed for the CSB site. These are shown at 5% damping for performance category 3 in Figure 1-36 (Tallman 1996). More detail and additional damping values are presented in WHC-SD-W236-TI-002 (Geomatrix 1996).

The CSB is using the design and completed portions of the subgrade construction of the canceled Hanford Waste Vitrification Plant (HWVP). The horizontal seismic response spectrum for the HWVP was a Newmark and Hall median spectra shape anchored at 0.35 g (Newmark and Hall 1978). The vertical spectrum is two-thirds of the horizontal. The horizontal and vertical Newmark and Hall response spectra envelop the horizontal and vertical equal hazards response spectra (respectively) (Figure 1-36). Therefore, use of the HWVP response spectra fulfills the requirements of performance category 3 response spectra (Tallman 1996).

The site response characteristics of the soils underlying the Hanford Site are similar to those represented in the empirical strong motion database from California. This was determined by comparing the relative response of characteristic Hanford Site soil profiles and dynamic soil properties with those of California deep soil strong-motion recording stations. Time histories representative of the events contributing to the Hanford Site hazard were used for ground motion input (Geomatrix 1996, Appendix A).

1.4.3.8.2 Volcanic Hazard Assessment. Two types of volcanic hazards have affected the Hanford Site in the past 20 million years:

- Continental flood basalt volcanism that produced the CRBG, which underlies the Hanford Site, outcropping in the surrounding ridges
- Volcanism associated with the Cascade Range.

Several volcanoes in the Cascade Range are currently considered active, but activity associated with flood basalt volcanism has ceased.

The flood basalt volcanism that produced the CRBG occurred between 17 million and 6 million years before present. Most of the lava was extruded during the first 2 to 2.5 million years of the 11-million-year volcanic episode. Flood basalt volcanism has not recurred during the last 6 million years, suggesting that the tectonic processes that created the episode have ceased. The recurrence of Columbia River basalt volcanism is not considered to be a credible volcanic hazard (DOE 1988).

Volcanism in the Cascade Range has been active throughout the Pleistocene Epoch (approximately 2 million years before present to 10,000 years before present) and through the Holocene Epoch (10,000 years before present to present). The eruption history of the Holocene best characterizes the most likely types of activity in the next 100 years. Many of the volcanoes in the Cascade Range have been active in the last 10,000 years, including Mount Mazama (Crater Lake) and Mount Hood in Oregon and Mount St. Helens, Mount Adams, and Mount Rainier in Washington state (Figure 1-24). The Hanford Site is approximately 150 km (95 mi) from Mount Adams, 175 km (110 mi) from Mount Rainier, and 200 km (125 mi) from Mount St. Helens, the three closest active volcanoes. At these distances, the tephra (ash) is the only hazard. Mount St. Helens has been considerably more active throughout the Holocene than Mount Rainier or Mount Adams, which is the least active of the three. Ashfall at the Hanford Site during the May 18, 1980, eruption of Mount St. Helens ranged from a trace in the southern part of the Site to about 1 cm (0.5 in.) in the 100 Areas.

Probabilistic volcanic hazard studies of the Cascade Range have been completed by the U.S. Geological Survey (Hoblitt et al. 1987; Scott et al. 1995). Figure 1-24 illustrates the annual probability of exceeding 1 cm (0.4 in.) of volcanic ash accumulation in Washington and Oregon following the eruption of a major Cascade Range volcano and Figure 1-24 illustrates the annual probability of exceeding 10 cm (4 in.) of volcanic ash accumulation. Figure 1-37 presents this information as a volcanic ash hazard curve for the Hanford Site.

1.4.3.8.3 Subsurface Stability. The CSB is constructed in flood sediments, the youngest sediments being approximately 13,000 years old. There are no areas of potential surface or subsurface subsidence, uplift, or collapse except for the low geologic deformation discussed in Section 1.4.3.6. With the exception of the loose, surficial, wind-deposited silt, soils are competent and form good foundations. Several geotechnical studies have been completed in and around existing tank farms. Liquefaction of soils beneath the tank farms is not a credible hazard because the water table is greater than 65 m (215 ft) below ground surface. Liquefaction cannot occur in dry sediments.

A geotechnical investigation was performed at the site in 1989 (Dames and Moore 1989) to evaluate subsurface conditions for the design and construction of the HWVP. The HWVP Project was canceled and the site is being used for the CSB. Subsurface conditions were investigated by 17 borings ranging in depth from 6 to 30.5 m (20 to 100 ft) at the site and in the surrounding area. Geophysical tests, including a series of downhole seismic tests, were conducted in boring VP-8, approximately 122 m (400 ft) from the CSB. Borehole VP-15 (Figure 1-38) is at the CSB site.

The 17 geotechnical investigation borings were advanced without drilling fluid by driving a 15.2-cm- (6-in.-) diameter, steel "core barrel" with a "split jar" downhole hammer. As the borings were advanced, a 20.32-cm- (8-in.-) diameter steel casing was driven to prevent caving of soils above the sampling depth. Water was occasionally poured into the hole to prevent caving of the loose, dry soils and to aid in recovering samples. Slightly disturbed soil samples were taken at 1.5-m (5-ft) intervals by driving a sampler using either a 320-kg (705-lb) hammer falling through a distance of 0.46 m (18 in.)

or a 374-kg (825-lb) hammer falling through a distance of 0.71 m (28 in.). During the sampling process, resistance to penetration of the sampler, in blows per foot, was recorded.

The soil profile in the upper 30.5 m (100 ft) consists essentially of the three strata shown in Figure 1-39. Borehole VP-14 is approximately 70 m (230 ft) west of the CSB. The stratigraphy in VP-15 (Figure 1-38) is the same as at VP-14 (Figure 1-39). The dynamic soil properties of the site are summarized in Figure 1-40. More detailed descriptions of the geotechnical investigations and interpretations are found in *Report of Geotechnical Investigations for the Proposed Hanford Waste Vitrification Plant, Hanford Washington* (Dames and Moore 1989).

1.5 NATURAL PHENOMENA THREATS

Table 1-23 summarizes the natural phenomena and the criteria to be used for the design of safety-class (performance category 3) SSCs for the CSB. Safety-significant (performance category 2) SSCs will be designed to the *Uniform Building Code* Zone 2B, and follow "essential facility" and "standard occupancy" rules, respectively (ICBO 1994). These SSCs also will be designed to codes, standards, regulations, and orders as listed in Section 1.2. Each of these phenomena and the bases for the analysis values have been discussed in Section 1.4.

1.6 EXTERNAL HUMAN-GENERATED THREATS

This section identifies and investigates specific potential human-generated threats to CSB operation. Threats to the CSB from human activities that are not known or well characterized at this time will be evaluated by the Unreviewed Safety Question process. This also applies to those activities that have been identified, such as airport usage, but that may change significantly in terms of a potential increased risk to the facility.

1.6.1 Aircraft Activity

Three commercial airports and four private airports are located within 50 km (30 mi) of the CSB site. The closest commercial airport is the Richland Airport, 32 km (20 mi) southeast of the facility. This airport has two 1,220-m (4,000-ft) runways, one with a 010°/190° orientation and the other with a 070°/250° orientation. Runway capability is about 13,600 kg (30,000 lb) per point of contact. Visual flight rule landings are standard Federal Aviation Administration non-control-tower patterns. In April 1996, approximately 65 aircraft were based at the airport. The projected number of operations for 1996 is 19,600. Except for two scheduled freight flights, all operations in 1996 were by general aviation aircraft (Hosler 1996).

The Tri-Cities Airport is 45 km (28 mi) to the southeast near Pasco. The Federal Aviation Administration operates the air traffic control tower and airport radar approval control facility. The airport has two 2,350-m (7,700-ft) crossing runways with 120°/300° and 030°/210° orientations. The latter has a 1,350-m (4,430-ft) parallel runway. Runway 30 has a

Table 1-23. Canister Storage Building Safety-Class Natural Phenomena Design Loads.

Hazard	Load	Design guidance
Seismic	Median response spectra: ^a 0.35 g horizontal 0.23 g vertical	DOE Order 5480.28 ^b DOE Standard 1020-94 ^c
Straight wind	129 km/h (80 mi/h), fastest mile at 9 m (30 ft)	ASCE 7-93 ^d DOE Standard 1020-94 ^c (including missiles)
Tornado	Wind speeds 322 km/h (200 mi/h) total 257 km/h (160 mi/h) rotational 64 km/h (40 mi/h) translational	NRC Standard Review Plan ^e 3.3.2 Tornado Loading
Volcanic ash	117 kg/m ² (24 lb/ft ²) ground ash load	NRC Standard Review Plan ^e 3.8.4 Other Seismic Category Structures
Flooding	Dry site for river flooding Site drainage basin: 19 cm (7.4 in.) for 6-hour probable maximum precipitation Site drainage: 23 cm (9.2 in.) for 6-hour probable maximum precipitation	ANSI/ANS-2.8-1992 ^f NRC Standard Review Plan ^e 2.4.2 Floods
Lightning	Lightning protection shall be provided for facility as required by NFPA 780 ^g .	NFPA 780 ^g
Snow	98 kg/m ² (20 lb/ft ²) ground load	ASCE 7-93 ^d

^aNeumerk, N. M., and V. J. Hall, 1978, Development of Criteria for Seismic Review of Selected Nuclear Power Plants, NUREG/CR-0098, U.S. Nuclear Regulatory Commission, Washington, D.C.

^bDOE Order 5480.28, Natural Phenomena Hazards Mitigation, U.S. Department of Energy, Washington, D.C.

^cDOE Standard 1020-94, Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities, U.S. Department of Energy, Washington, D.C.

^dASCE, 1993, Minimum Design Loads for Buildings and Other Structures, ASCE 7-93, American Society of Civil Engineers, New York, New York.

^eNRC, 1981, Standard Review Plan, NUREG-0800, U.S. Nuclear Regulatory Commission, Washington, D.C.

^fANSI/ANS, 1992, Determining Design Basis Flooding at Power Reactor Sites, ANSI/ANS-2.8-1992, American Nuclear Society, La Grange Park, Illinois.

^gNFPA, 1992, Lightning Protection Systems, NFPA 780, National Fire Protection Association, Quincy, Massachusetts.

very-high-frequency omnirange instrument approach and Runway 21R has an instrument landing system and is an instrument approach runway. In April 1996, about 94 aircraft were based at the airport. Total operations for 1995 were 79,000, with 66% general aviation, 28% commercial aviation (air taxis, air carriers), 4% military aircraft, and 2% other operations (Hosler 1996). Four commercial carriers with a total of about 26 flights per day were serving the airport in April 1996.

The Vista Airport, operated by the Port of Kennewick, is a general aviation airport located 45 km (28 mi) to the southeast. It has a 1,220-m (4,000-ft) runway with a 20°/200° orientation. All operations are under visual flight rules. In April 1996, it was estimated that about 40 aircraft were based at the airport and operations averaged approximately 40 to 50 per day (Hosler 1996).

Four privately owned airstrips are within 40 km (25 mi) of the CSB. These are McWhorter (26 km [16 mi] south-southeast), Kent Farms (37 km [23 mi] southeast), Hathaway Ranch (39 km [24 mi]), and Hanford (4 km [2.5 mi] west-northwest).

NUREG-0800, *Standard Review Plan*, Section 3.5.1.6, "Aircraft Hazards" (NRC 1981), provides guidance to ensure that the risks from aircraft hazards are low enough for nuclear power plants. If the distance at which aircraft activity occurs meets all the criteria provided below, the probability of an aircraft accident resulting in radiological consequences greater than the exposure guideline in Title 10, *Code of Federal Regulations*, Section 100, "Reactor Site Criteria" (10 CFR 100), can be considered to be less than 10^{-7} per year and no additional analysis is required (Standard Review Plan 3.5.1.6 [NRC 1981] defines the criteria using English rather than Standard International units):

1. The plant-to-airport distance (D) is between 5 and 10 statute miles, and the projected annual number of operations is less than $500 D^2$, or D is greater than 10 statute miles and the number of operations is less than $1,000 D^2$
2. The plant is at least 5 statute miles from the edge of military training routes, including low-level training routes, except for those associated with a usage greater than 1,000 flights per year or where activities (such as practice bombing) may create an unusual stress situation
3. The plant is at least 2 statute miles beyond the nearest edge of a federal airway, holding pattern, or approach pattern.

There are no active airports within 10 statute miles of the CSB site, but there are three commercial airports and three active private airports within 48 km (30 mi) of the site. Table 1-24 shows that the first criterion regarding the annual number of operations of less than $1,000 D^2$ is satisfied with a margin of more than a factor of ten. The impact of airport growth that would erase this margin would involve changes that cannot be predicted at this time.

Table 1-24. Airports Near the Canister Storage Building Site.

Airport	Distance (D) from CSB* (miles)	Flights per year	1,000 D ²	Orientation from CSB	Type of operation
Richland	20	19,600	400,000	Southeast	Commercial
Tri-Cities	28	79,000 5,000/V187	784,000	Southeast	Commercial
Vista	28	18,250	784,000	Southeast	Commercial
McWhorter	16		256,000	South- southwest	Private
Kent Farms	23		529,000	Southeast	Private
Hathaway Ranch	24		576,000	East	Private
Hanford	2.5	0	4,000	Northwest	Closed since 1976

*Metric values for D are not provided as the criterion is based upon D in miles.

The airspace over the Hanford Site is periodically used as a marshaling area for military aircraft participating in training missions at the Yakima Training Center (Section 1.7.1.5). A low-level military training route associated with this training passes above the western edge of the Hanford Site about 14 km (8.7 mi) west of the CSB site. The traffic on this route is about 1,800 sorties per year according to the military authority responsible for the route. Military air operations may occasionally overfly the 200 East Area, but because of the proximity of Rattlesnake Mountain (1,106 m [3,629 ft]), a low approach is not routine. Aircraft tend to maintain significant altitude over the Hanford Site because of a request by the Federal Aviation Administration and because of safety considerations around the mountain (Muhlestein 1994).

Figure 1-41 shows the airports, low-level federal airways, and airport instrument approaches in the vicinity of the CSB site. Airway V187 (located close to the CSB site with a minimum altitude of 1,065 m [3,500 ft] mean sea level) is the only airway that can pose a potential threat to the CSB.

The Federal Aviation Administration provided a conservative estimate of 5,000 flights per year that can be expected through airway V187 (Hosler 1996). The number obtained for airway V187 is for flights by aircraft that file instrument-flight-rule flight plans. Aircraft that leave the airport in the general direction of V187 and that are under visual flight rules do not have to file a flight plan and are not required to follow the airway. For the purpose of this evaluation, the total number of aircraft flying through airway V187 is assumed to be those constrained to the airway (i.e., 5,000 per year). Other flight paths shown on Figure 1-41 are either sufficiently far away (more than 3 km [2 mi]) with sufficiently low volume or are not currently active.

According to the Richland airport manager, the 12 NM and 14 NM arc shown on Figure 1-41 is no longer used except on a rare occasion.

Standard Review Plan 3.5.1.6 (NRC 1981) provides the probability per year (P_{py}) of an aircraft crashing into the plant as

$$P_{py} = C \times N \times A_{eff}/W$$

where

C = In-flight crash rate per mile for aircraft using airway
($4.0 \times 10^{-10}/mi$)

N = Number of flights per year along the airway (5,000, from Tri-Cities airport data)

W = Width of airway in miles (5.9 mi, see below)

A_{eff} = Effective area of the plant in square miles (0.068 mi^2 , see below).

The width of a federal airway includes the airspace within parallel lines spaced 4 mi each side of the centerline (14 CFR 71.75). However, Federal Aviation Administration regulations require aircraft operating under instrument flight rules to fly along the centerline of the federal airway (14 CFR 91.181) and permit a maximum error of $\pm 6^\circ$ in the equipment used to determine the position of the aircraft. For the CSB, located 45 km (28 mi) from the airport, this results in an airway width of 9.5 km (5.9 mi) at the CSB site.

The effective area of the facility is the ground surface area covered by all flight crash trajectories that could impact the surface structure. This area is larger than the facility itself because of the possibility of the aircraft skidding across the ground before hitting the facility as well as the possibility of a direct hit on the structure before striking the ground. The effective area is the sum of the structure's area, the shadow area (behind the structure), and the aircraft skid area (in front of the structure). In UCRL-118793, *Aircraft Accident Data Development for Aircraft Risk Evaluation to Ground Facilities Through the Use of a G.I.S.* (Kimura et al. 1995), the components of the effective area are defined as

$$A_{eff} = A_{skid} + A_{structure} + A_{shadow}$$

where

$A_{structure}$ = Ground footprint of building, $259 \times 136 = 35,220 \text{ ft}^2$ for the CSB with Hot Conditioning System (HCS) Annex

$$A_{skid} = (L + A_w) \times S_k$$

L = Facility maximum dimension, 259 ft for the CSB with the 26 ft HCS Annex

A_w = Aircraft wingtip-to-wingtip dimension, conservatively assumed for the Tri-City Airport to be a Boeing 757 with a wing span of 125 ft (current Tri-City Airport air carrier jet activity is primarily 737s with wing spans of 95 ft)

S_k = Aircraft skid distance, 3,206 ft for air carriers (Kimura et al. 1995)

$$A_{\text{shadow}} = [(L^2 + W_f^2)^{0.5} + A_w] \times Z \times \cot \phi$$

L and A_w as defined above

W_f = Facility width, 136 ft for the CSB

Z = Facility height, 56 ft for the CSB

ϕ = Angle of approach (from aircraft accident data, most accidents occur when the pilot flies the aircraft into the ground; during normal landing approach, the glide slope is usually 3° with some approaches as high as 6° because of nearby terrain (Kimura et al. 1995); for conservatism, a 3° angle of approach is assumed).

As noted in Table 1-25, the CSB shadow area has been increased to include one exhaust stack that extends 75 ft above the CSB roofline with a diameter of 7 ft for this portion of the stack. The intake stack has very little extension above the roofline, and as such, is not addressed separately.

The effective area for the CSB for air carrier use of V187 is 0.068 mi^2 . See Table 1-25. The probability per year, estimated by using the above equation with the input data noted, is 2.3×10^{-8} , which is sufficiently low as to screen this airway from further evaluation.

In the NRC acceptance of reduced windspeeds for design basis tornadoes (Clifford 1996), the NRC pointed out that there has been an assumption made by the NRC that protection for tornado-generated missiles provided adequate protection for general aviation light aircraft crashes and nearby explosions. However, with the reduced windspeeds, the NRC stated that new structures built to the reduced tornado criteria should be analyzed for minimum wall thickness for protection against other postulated site-specific events.

As use of the Hanford air space by general aviation is very light, it is appropriate to first investigate the potential for a crash of a general aviation light aircraft into the CSB before establishing the need to perform such analyses. The threat from general aviation, aerial applicators, aerial surveying, and military training can be estimated by assuming a certain number of aircraft in the vicinity of the CSB site, but without regard to airways, as follows:

$$P_{py} = C \times N \times A_{\text{eff}}$$

Table 1-25. Canister Storage Building Aircraft Risks.

Aircraft	A_w (ft)	S_k (ft)	A_{skid} $ft^2 \text{ E-06}$	A_{shadow} $ft^2 \text{ E-06}$	A_{eff} (mi^2)	C	N	P_{PY}
Air carrier on V187	125 (Boeing 757)	3,206	1.23	0.635	0.068	4 E-10/mi	5,000	2.3 E-08
General aviation	54 (Cessna Citation III)	317	0.0922	0.458	0.021	1.2 E-08/ mi^2	50	1.3 E-08
Military	64 (F-14)	1,000	0.323	0.483	0.03	0.4 E-08/ mi^2	50	6.0 E-09

A_w = aircraft wingtip-to-wingtip dimension.

S_k = aircraft skid distance.

$$A_{skid} = (L + A_w) * S_k.$$

L = facility maximum dimension, 259 ft for CSB (includes 26 ft for HCS).

$$A_{shadow} = A_{shadow_bldg} + A_{shadow_stack}$$

$$A_{shadow_bldg} = [(L^2 + W_f^2)^{0.5} + A_w] * Z * \cot\phi.$$

W_f = facility width, 136 ft for CSB.

Z = facility height, 56 ft for CSB.

ϕ = angle of approach, 3°.

$$A_{shadow_bldg} = 446,200 \text{ ft}^2 \text{ for a Boeing 757 on V187.}$$

$$A_{shadow_stack} = (\text{stack diameter} + A_w) * \text{stack height} * \cot\phi = 188,900 \text{ ft}^2 \text{ for a Boeing 757 on V187.}$$

Stack height is the stack height above the building roofline (75 ft) and stack diameter is the diameter of this portion of the stack (7 ft).

$$A_{structure} = L * W_f, 35,220 \text{ ft}^2 \text{ for CSB.}$$

$$A_{eff} = A_{skid} + A_{structure} + A_{shadow}$$

C = In-flight crash rate (per mile when applied to airways and per square mile when applied to airspace).

N = Number of flights per year along the airway on trajectory that would put the facility at risk.

P_{PY} = Probability per year of an aircraft impacting the facility.

where

P_{py} = Probability per year of an aircraft impacting the facility

C = In-flight crash frequency per square mile ($1.2 \times 10^{-8}/mi^2$ for general aviation and $0.4 \times 10^{-8}/mi^2$ for military 4 mi or more from the end of the runway [NRC 1981])

Note that Standard Review Plan 3.5.1.6 (NRC 1981) does not provide data specific to rotary wing aircraft. Such aircraft do overfly the Hanford Site. On an "accident per statute mile" basis, the accident rate for rotary and single engine fixed wing aircraft are about the same; the accident rate for reciprocating rotary wing is higher (Kimura et al. 1995):

Aircraft	Accident per statute mile
Fixed wing, single engine, reciprocating	6.22×10^{-7}
Rotary wing, reciprocating and turbine	6.54×10^{-7}
Rotary wing, reciprocating only	1.73×10^{-6}

N = Number of flights per year in the vicinity of the CSB on a trajectory that puts the CSB at risk (very conservatively assumed to be 100, evenly split between military and others)

A_{eff} = Effective area of the CSB in square miles as defined above.

$P_{py} = 1.3 \times 10^{-8}$ events/yr for general aviation

$P_{py} = 6.0 \times 10^{-9}$ for military.

With these low frequencies of potential damage to the CSB, further consideration for light aircraft impact is not warranted.

DOE is currently completing a standard to address accident analysis for aircraft crash into hazardous facilities. This standard will provide a value to be used in the risk analysis as events/yr/ A_{eff} . This value will be used to assess the risk of aircraft crash for facilities away from airports independent of the use of federal airways. This standard will be addressed in the final CSB SAR.

1.6.2 Other Transportation Accidents

Accidents that might occur on State Highway 240, such as explosions or toxic chemical releases, are judged to present a negligible risk to the CSB because of the distance between the facility and the highway. At its closest approach, the distance is about 8 km (5 mi). NRC Regulatory Guide 1.78, *Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release* (NRC 1974a), provides useful guidance on evaluating chemicals stored or situated at distances greater than 8 km (5 mi) from the facility. It states that they need not be considered because, if a release occurs at such a distance, atmospheric dispersion will dilute and disperse the incoming plume to such a degree that

there should be sufficient time for the operators to take appropriate action. In addition, the probability of the plume remaining within a given sector for a long time is quite small.

Regulatory Guide 1.78 (NRC 1974a) also provides useful guidance for the evaluation of potential accidents involving hazardous chemicals that might be shipped past the CSB on Route 4, the Hanford Site railroad, and the Columbia River. Regulatory Guide 1.78 (NRC 1974a) does not require control room habitability analysis for shipments less frequent than 10 per year for truck traffic, 30 per year for rail traffic, or 50 per year for barge traffic. Neither the truck nor rail guidelines are exceeded for shipments of a quantity that could present a risk to the CSB. Section 1.7.1.1 discusses the process that will be used to establish whether there are critical operator actions that would require a more in-depth assessment of CSB habitability. Barge shipment on the Columbia River does not routinely occur above the Port of Benton barge facility discussed in Section 1.3.1.

Regulatory Guide 1.91, *Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants* (NRC 1978), describes a method for determining distances from critical plant structures beyond which any explosion that might occur on a railway, highway, or navigable waterway is not likely to have an adverse effect on plant operation or to prevent safe shutdown. The method is based upon an NRC staff judgement that for structures of concern, an acceptable overpressure limit from such explosions can be conservatively chosen at 7 kPa (1 lb/in²). Although not stated in the Regulatory Guide, it is assumed that the 7 kPa (1 lb/in²) value was established for structures that are designed to withstand the severe natural phenomena loadings that are typical for safety-related structures of nuclear power plants.

For the purposes of this evaluation, the CSB critical plant structures of concern, which are similar to those in a nuclear power plant that are required for safe plant operation and shutdown, are the below-grade structure (i.e., the base slab, interior and exterior vault walls, and the intake and exhaust plenums), operating deck, and the intake and exhaust foundation bases and stacks. As described in Section 4.3.4.4, "System Evaluation," these are all reinforced concrete structures that are designed to withstand the tornado pressure drop of 6.2 kPa (0.9 lb/in²). It is reasonable to assume that they would also withstand a 7 kPa (1 lb/in²) overpressure.

The CSB operating shelter is not considered a critical plant structure relative to the need to maintain the integrity of its shell as it is not credited for limiting offsite releases. However, as described in Section 4.3.4.4, it is also designed to withstand the tornado differential pressure of 6.2 kPa (0.9 lb/in²) as failure of the shelter may adversely impact safety-class SSCs.

Regulatory Guide 1.91 (NRC 1978) defines the safe distance, R , in meters, as

$$R \geq 18 \times W^{\frac{1}{3}}$$

was obtained for Hanford Site two-lane roads such as Route 4 (H&R 1995). This risk reduction factor also would be appropriate for shipment of large quantities of explosive materials. For this analysis, it is conservatively assumed that the conditional probability that an explosion will result as a consequence of an accident is 0.1. Therefore, the explosion rate, n , is 8.86×10^{-9} explosions/km (5.5×10^{-9} explosions/mi).

There are currently no routine shipments of explosives on Route 4 of a quantity that would place the CSB at risk. However, such shipments could occur during the facility's lifetime. For this analysis, the number of such shipments per year, f , was conservatively assumed to be six. The exposure distance, s , for the CSB and Annex was calculated to be 0.820 km (0.51 mi) based upon a building length of 78 m (257 ft), a setback from Route 4 of 350 m (1,155 ft), and a safe distance of 510 m (1,683 ft).

With these data, the exposure rate, r , was conservatively calculated to be 4.36×10^{-8} events/yr. As this is less than 10^{-6} events/yr, no additional analysis is required.

Based upon the above analyses, it is concluded that explosive shipments on roadways and railways, controlled and not controlled by DOE, do not represent a risk to the CSB.

1.7 NEARBY FACILITIES

Accidents in certain facilities in the 200 East Area (Figure 1-8) have the potential to impact the CSB facility and its operations, as discussed in Section 1.7.1. Conversely, certain nearby facilities can potentially be affected by accidents in the CSB, as discussed in Section 1.7.2.

Threats to the CSB from nearby facilities that are not known or well characterized at this time will be evaluated by the Unreviewed Safety Question process. This also applies to those activities that have been identified but that may change significantly in terms of a potential increased risk to the facility.

1.7.1 Potential Effects from Nearby Facilities

Potential hazards to the CSB from onsite or offsite hazardous operations or facilities are examined under three general classifications:

- Nonreactor nuclear and nonnuclear industrial facilities within 8 km (5 mi) of the CSB including all activities conducted in and near the 200 East Area
- Nuclear reactors within an 80-km (50-mi) radius of the CSB
- Military activities.

1.7.1.1 Hazards to the CSB from Nonreactor Nuclear Facilities. Because SARs are being developed simultaneously for the CSB and for the Tank Waste

Remediation System, much of the information provided in this section was prepared for both the Tank Waste Remediation System SAR and the CSB SAR.

Facilities currently operating, recently operating, or with potential to operate at the 200 East and 200 West Areas were screened along with the area between the 200 East and 200 West Areas. For the CSB SAR, selected facilities were those believed to pose the most risk to safe operations at the CSB. Safety analysis reports and accident analyses prepared for these facilities were reviewed to determine possible hazards, such as radiological doses to personnel resulting from direct radiation, release of airborne radioactivity, or exposure to toxic chemicals.

Considered, but not included in the SAR, were the 200 East Area Burial Grounds, the Liquid Effluent Retention Facility, and the 200 Areas Effluent Treatment Facility in the 200 East Area. In the 200 West Area, the T Plant, U Plant, Reduction-Oxidation Plant, and the 222-S Laboratory were considered, but not included. These facilities have insufficient radiological or toxicological inventories in a dispersible form to represent a risk to the CSB operation.

The specific facilities discussed here include the Plutonium-Uranium Extraction (PUREX) Facility, the Grout Treatment Facility, B Plant, the Waste Encapsulation and Storage Facility (WESF), 242-A Evaporator/Crystallizer, Plutonium Finishing Plant (PFP), and the Low-Level Waste Disposal Site. The worst-case scenarios for each of these facilities may challenge CSB habitability. This hazard is identified in Appendix 3A. Section 3.4 of the final SAR will document whether there are CSB operator prevention or mitigation actions required to satisfy onsite and offsite hazardous material and radiological acceptance limits. If such actions are required, CSB habitability will be addressed in the CSB emergency response procedures. During much of the CSB's 40-year life, the facility will not be particularly sensitive to these hazards as it will be simply a storage facility and will require little human supervision.

Plutonium-Uranium Extraction Facility. The PUREX Facility is located in the 200 East Area, 2.4 km (1.5 mi) east-southeast of the CSB. It is the most recently constructed of the irradiated fuel separation facilities and was used for processing N Reactor fuel. The principal product was a solution of plutonium nitrate that was transferred to the PFP for further processing. Another product was uranyl nitrate solution, which was processed at the Uranium Oxide Plant. The facility is shut down and in preparation for eventual decontamination and decommissioning.

The postulated PUREX accidents having the most severe radiological consequences to a maximally exposed individual are associated with a cooling coil leaking into the 216-A-25 Pond and a fission product release from the PUREX pipe and operating gallery. After a review of these accidents and associated consequences, it was found that none of the postulated PUREX Facility accidents should impair CSB personnel in the performance of required safety actions.

Grout Treatment Facility. The Grout Treatment Facility is located on the eastern perimeter of the 200 East Area approximately 4.3 km (2.7 mi) east of the CSB. The Grout Treatment Facility combines tank wastes with

grout-forming solids to form a grout slurry. The waste feed stream constituent of this slurry consists of low-level fractions of radioactive wastes. The slurry ultimately is pumped into near-surface, concrete-lined vaults for permanent disposal. Only one vault has been filled with grout (completed in 1987) even though additional vaults have subsequently been designed and constructed. This facility is currently not operational but has the potential to operate again in the future.

The maximum credible accident release postulated involves a double-ended jumper leak on the grout feed line with the pit cover blocks left off (pending a maintenance inspection) during which the Grout Treatment Facility resumes operation. This postulated release would spray low-level waste as an aerosol for a maximum period of 24 hours before detection by a visual inspection.

B Plant Facility. The B Plant is located approximately 455 m (1,500 ft) east of the CSB. Until 1952, B Plant was operated as a fuel separation facility. In 1968 it was converted to a waste fractionation plant to remove ¹³⁷Cs and ⁹⁰Sr from radioactive waste streams. This had the effect of reducing heat loads in the double-shell tanks. The B Plant now provides essential support to WESF and currently is preparing for a transition to shutdown status.

The most credible accident at B Plant, postulated in WHC-SD-WM-TI-385, *B Plant Preliminary Accident Analysis* (Marusich 1991), results from the simultaneous occurrence of (1) a solvent fire in which hot gases from the fire heat filters, driving off material on the filters, and (2) a blowback of process solution into the pipe gallery caused by tank pressurization. Such a scenario may result in evacuation of CSB operating personnel.

Waste Encapsulation and Storage Facility. The WESF is distinct from B Plant, even though it is located on the west end of B Plant and shares a common wall with the plant. Historically WESF was involved in converting cesium and strontium into cesium chloride and strontium fluoride salts. These materials then were encapsulated in double-walled metal containers and stored in a water-filled cooling basin. Strontium fluoride and cesium chloride capsules are still being stored in this fashion at WESF, but no new capsules are being produced.

The worst-case credible accident postulated involves a truck with a leaking gas tank that catches fire in the truck port (WHC 1996). It is assumed that this accident will result in the breaching of the truck port door and that packaged solid waste will be consumed by the fire. Radionuclides then will be transported directly to the environment via the breached truck port door.

242-A Evaporator/Crystallizer. The 242-A Evaporator/Crystallizer is located 2.4 km (1.5 mi) east of the CSB. The 242-A Evaporator/Crystallizer uses evaporative concentration to reduce the volume of liquid wastes (low-heat-generating tank wastes). The concentrated slurry, reduced in volume, is transferred and stored in an underground waste storage tank. The process condensate is routed to the Liquid Effluent Retention Facility for storage and treatment at the Effluent Treatment Facility.

There were five design basis accidents (DBAs) analyzed in the 242-A Evaporator/Crystallizer SAR (Lavender 1992). Of the five accidents analyzed, the worst-case scenario involved a release from a spray leak in the pump room and a failure of the exhaust system's high-efficiency particulate air (HEPA) filters. Although this event is considered extremely unlikely, the event was analyzed for safety-class determinations at the 242-A Evaporator/Crystallizer. The release from a spray leak is comprised of a liquid component and an aerosol component. The analysis assumed that the liquid component would remain in the pump room (safety class 2); however, the aerosol component would be released to the environment via the K1 exhaust stack. The dose consequences to both the onsite maximum individual and offsite maximum individual were calculated and found to be within the risk acceptance guidelines provided in WMC-EM-4-46 Letter 96-SFD-318, *Contract No. DE-AC06-96RL13200: Proposed Spent Nuclear Fuel Project Division (SFD) Risk Acceptance Guidelines (RAGs)* (Sellers 1996a). Such a scenario would require the temporary safe shutdown of CSB operations. However, this accident would not affect the intrinsic safety of CSB operations.

Plutonium Finishing Plant. The PFP is located near the western boundary of the Hanford Site in the 200 West Area, 8 km (5.0 mi) west of the CSB. It converts plutonium nitrate solution to plutonium metal and performs plutonium handling and storage operations. Contaminated liquid waste streams from the PFP are routed to the tank farms. This facility is currently in a stand-by mode and may operate again in the future.

The worst-case PFP accident scenario is associated with a fire having a postulated airborne release of 1.2 g ^{239}Pu (Marusich 1990). The credible radiological hazard is defined as a consequence of respirable plutonium dispersed to the air from a fire and other material transport mechanisms. After a review of this accident and associated consequences, it has been found that an accident at this facility may require an evacuation of nearby Tank Farm facilities to reduce the consequences to tank farm personnel. Because of the distance separating the CSB from PFP, such a scenario would not adversely affect CSB operations and would not require evacuation of onsite personnel.

Low-Level Waste Disposal Site. The commercial low-level waste disposal site operated by U.S. Ecology, Inc., is the only non-DOE industrial facility within 8 km (5 mi) of the CSB (Figure 1-4). The disposal site is on land leased from Washington State located 1.7 km (1 mi) southwest of the CSB. The low-level waste is buried in lined containers. Monitoring of groundwater and vegetation is performed as required by the facility's NRC operating license and environmental impact statement. This facility is not likely to have a significant accidental airborne radioactive release that could adversely affect the CSB.

1.7.1.2 Hazards to the Canister Storage Building from Nonnuclear Hanford Site Facilities. A number of nonnuclear industrial facilities operating in the 200 Areas pose the potential for accidental fires, explosions, or releases of toxic fumes. These include the Essential Materials Warehouse (Building 275-EA), oil and paint storage buildings, fabrication shops, gas cylinder storage buildings, the spare parts and electrical warehouse, B Plant storage buildings, maintenance facilities, gasoline service stations, and the powerhouse complexes in each area (284-E and 284-W). Considering its

location, Building 275-EA may have the potential to pose a risk to CSB operations and personnel and is detailed below.

Building 275-EA. Building 275-EA, the Essential Materials Warehouse, was constructed in 1955 and is located 2.4 km (1.5 mi) east-southeast of the CSB. It is classified as an unprotected wood frame structure and is susceptible to collapse as a result of an external event (e.g., earthquake, wind, snow, or ash loading) or an internal event (e.g., forklift collision with a bearing wall, or fire). Building 275-EA currently stores more than 100 different types of potentially hazardous solids and liquids including acids, bases, solvents, fluorides, pesticides, and herbicides. Radioactive materials are not stored in this building.

The worst-case chemical release postulated in the safety analysis occurs following a building collapse whereupon 2,450 kg (5,445 lb) of 1,1,1-trichloroethane evaporates under adverse atmospheric conditions. The maximum concentration at the PUREX Facility gatehouse and environs is calculated to be 187 ppm, which is below the time-weighted average threshold limit value of 350 ppm (i.e., the concentration for this chemical that an industrial worker may be repeatedly exposed to without adverse effects) as given in *Threshold Limit Values and Biological Exposure Indices for 1989-1990* (ACGIH 1989). Concentration levels at the CSB would be significantly less than this because of the 2.4-km (1.5-mi) separation.

1.7.1.3 Hazards to the CSB from Nuclear Reactors. Three recently operating reactors, the N Reactor, FFTF, and the Critical Mass Laboratories, no longer pose a threat to the CSB. The N Reactor and FFTF are undergoing decontamination and decommissioning, and the Critical Mass Laboratories in the 200 East Area north of the PUREX Facility are currently being used as tank farm office areas. The N Reactor was a 4,000 MW, dual-purpose, pressure tube, light-water cooled, graphite-moderated reactor (UNI 1978). It is located in the 100 N Area and is about 8.8 km (5.5 mi) from the nearest northwest Hanford Site boundary. The N Reactor began operating in 1964 producing plutonium for the defense program and steam for electrical power generation. It was shut down in 1987 for safety improvements and then subsequently defueled and placed in cold standby in 1988. It is currently being decontaminated and decommissioned.

It is planned to remove the reactor building structures for the production reactors down to the reactor block and then cocoon the reactor block for 75-year safe storage. A preliminary hazard analysis (PHA) completed for a demonstration of this process for the C Reactor Building (105-C) did not identify any new hazards that would result from this activity (Delphinus 1996).

The FFTF is a 400 MW, sodium-cooled, mixed-oxide-fueled, breeder reactor that is currently shut down and in the process of being defueled. It is located in the 400 Area and is approximately 7.2 km (4.5 mi) from the nearest Hanford Site boundary, which is to the east of the facility (Figure 1-4).

The only operating nuclear reactor on the Hanford Site is WNP-2. The location of this reactor is shown in Figure 1-4. WNP-2 is an operating commercial nuclear power plant using a boiling-water reactor steam supply system. The design power level was increased to 3,486 MW in 1995 (Supply

System 1995). The reactor was designed by the General Electric Company and is designated as a BWR/5 with a Mark II containment.

By the requirements of 10 CFR 100, the following are the maximum allowable doses for WNP-2:

Location	Duration	Whole body dose	Thyroid
Exclusion area boundary	2 hours	250 mSv (25 rem)	3,000 mSv (300 rem)
Low population zone	30 days	250 mSv (25 rem)	3,000 mSv (300 rem)

The exclusion area boundary for WNP-2 is 1,950 m (1.2 mi) and the low population zone distance is 4,827 m (3 mi). The CSB is located approximately 17.6 km (11 mi) from WNP-2. Using the atmospheric diffusion guidance provided in NRC Regulatory Guide 1.3, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors* (NRC 1974b), to estimate the dose reduction as a function of distance, it was determined that the 2-hour and 30-day doses at the CSB would be reduced by a factor of 20. Review of the site-specific meteorology provided in the WNP-2 Final Safety Analysis Report (Supply System 1995) shows there would be no significant reduction for the change in wind direction. The factor of 20 reduction for distance would result in a whole body dose of 12.5 mSv (1.25 rem) and a thyroid dose of 150 mSv (15 rem).

The expected dose that would be received at the CSB should a loss of coolant accident occur would be significantly less than this. Regulatory Guide 1.3 (NRC 1974b) requires an assumption that 25% of the radioactive iodine and all of the noble gases are released to the containment. In fact, the emergency core cooling system would prevent most of these releases as little fuel damage would occur as a result of the loss of coolant accident.

In 1998 the Supply System plans to add an independent spent fuel storage installation (ISFSI) on their leased property. The ISFSI would be licensed following the requirements in 10 CFR 72. According to 10 CFR 72.106, an individual located at the ISFSI's controlled area boundary shall not receive a dose greater than 5 rem. At the CSB, this would result in a dose not exceeding 0.25 rem.

1.7.1.4 Hazards to the Canister Storage Building from Industrial Facilities off the Hanford Site. There are no oil or gas pipelines in the vicinity of the CSB. The nearest major natural gas pipeline to the CSB site is about 47 km (29 mi). A 20-in. gas transmission line of the Northwest Pipeline Corporation is located east and essentially parallel to U.S. Highway 395 between Pasco and Ritzville, Washington. A second pipeline system consisting of parallel 36-in. and 42-in. lines, owned by Pacific Gas Transmission Company, passes through Wallula, approximately 53 km (33 mi) from the site (Hosler 1996). These distances eliminate any potential hazard to plant operations from a natural gas fire or explosion.

The nearest petroleum product storage tanks are located 61 km (38 mi) from the site. These are 23-million-gallon capacity tanks at the Chevron Pipeline Company, and 21-million-gallon capacity tanks at the Tidewater Barge Lines. There are no plans to use a third petroleum storage facility at the Port of Pasco (Hosler 1996).

Located within the Richland city limits is the Siemens Power Corporation's Richland Engineering and Manufacturing Facility. All operational steps for the manufacture of nuclear fuel for light water reactors are conducted within the facility including the conversion of UF_6 to UO_2 . The most limiting postulated accident at this facility is a fire in the UF_6 cylinder storage area (Siemens 1994). Fusible plugs in twelve cylinders are assumed to melt causing the release of UF_6 that reacts with moisture in the air to form UO_2F_2 (solids in the form of uranyl fluoride hydrates) and $4HF$ (as hydrogen fluoride gas). UF_6 is a radiological hazard by inhalation. However, UF_6 is also a concern because of its chemical toxicity and the associated HF that can cause skin and eye burns and lung impairment. This accident results in a dose that exceeds 10 mSv (1 rem) out to 1.9 km (1.2 mi). The accident also exceeds the Emergency Response Planning Guide-2 (ERPG-2) toxicology limits out to 14.1 km (8.8 mi) (ACGIH 1989). The ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. The CSB is located 30 km (19 mi) from the Siemens facility. Therefore, CSB operators would not be placed at risk by an accident at the Siemens facility.

No other nonnuclear industrial facilities or operations have been identified that may impact CSB operations.

1.7.1.5 Hazards to the Canister Storage Building from Military Facilities.

The Yakima Training Center is a subinstallation under the command of Fort Lewis (Tacoma, Washington). Further information is given in the *Final Environmental Impact Statement - Ft. Lewis Military Installation* (DOA 1979). The southeastern boundary of the Yakima Training Center is located about 23 km (14 mi) from the CSB (see Figure 1-2 or 1-42). The Yakima Training Center is used for military maneuvers and weapons training and is the only significant military activity in the vicinity of the Hanford Site.

The only weapon currently in use at the Yakima Training Center known to present a hazard to the Hanford Site is the Multiple Launch Rocket System (MLRS). With a range of approximately 26 km (16 mi), the MLRS could potentially impact the CSB site. However, the MLRS is only fired from the perimeter of the Yakima Training Center into a centrally located impact zone. The safety fan for the MLRS is shown in Figure 1-42. The MLRS is fired away from the Hanford Site and is only fired with dummy warheads. Given this information, additional safety features, and the administrative controls in place at the Yakima Training Center, a weapons accident having an impact on the Hanford Site is very improbable.

A more probable hazard to Hanford Site facilities is a scenario in which a fire started within the Yakima Training Center boundary spreads to the Hanford Site. Exploding artillery shells, sparks from tracked vehicles or other machines, and careless smoking by troops might start brush fires that,

under adverse meteorological conditions, could spread rapidly beyond the Yakima Training Center boundaries. The hazards associated with range fires are discussed in Chapter 3.0.

1.7.2 Potential Effects to Nearby Facilities

CSB accidents with the potential to affect the maximum onsite individual (which may include persons at some of the facilities discussed above) are discussed in Section 3.4.2.3.

1.8 VALIDITY OF EXISTING ENVIRONMENTAL ANALYSES

No significant discrepancies have been identified between the site characteristic assumptions made in this chapter and those made in the SNF Project Environmental Impact Statement (DOE 1996).

1.9 REFERENCES

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- 10 CFR 100, "Reactor Site Criteria," *Code of Federal Regulations*, as amended.
- 14 CFR 71, "Designation of Class A, Class B, Class C, Class D, and Class E Airspace Areas; Airways; Routes; and Reporting Points," Section 71.75, "Extent of Federal Airways," *Code of Federal Regulations*, as amended.
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Figure 1-1. Location of the Hanford Site in the State of Washington.

Figure 1-2. The Hanford Site, Counties, and the Regional Highway Network.

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Figure 1-3. Hanford Site and Surrounding Area.

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CVDS-1

Figure 1-5. Hanford Site Topographic Map and Cross Section.

Figure 1-6. Population of Cities and Counties Near the Hanford Site.

Note: If population is not listed, it is less than 1,000.

HMS = Hanford Meteorological Station.

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CSB-1

Figure 1-7. Distribution of Transient Population.

Key

midway between WNP-1, -2, and -4

migratory agricultural workers

recreational

To convert miles to kilometers, multiply by 1.6093.

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SRP-1

Figure 1-8. Onsite Population Distribution in the 200 East Area by Zone.

Figure 1-9. Hanford Meteorological Network.

Note: All network stations are 9.1 m unless otherwise indicated.
To convert meters to feet, multiply by 3.281.

7G96030009.15
CSB-1

Figure 1-10. Hanford Site in Relation to Surrounding Terrain.

Figure 1-11. Six-Hour Precipitation Hazard Curves for the Hanford Site.

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11/5/96 CSB-1

Figure 1-12. Greatest Depth of Snow on the Ground
at Hanford from 1946-47 to 1980-81.

Figure 1-13. Wind Hazard Curves with Design Windspeeds
(Windspeeds are Fastest Mile).

Coats, D.W., and R.C. Murray, 1985, *Natural Phenomena Hazards Modeling Project: Extreme Wind/Tornado Hazard Models for Department of Energy Sites*, UCRL-53526, Rev.1, Lawrence Livermore National Laboratory, Livermore, California.

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2G96100235.2
CSB-1

Figure 1-14. Wind Rose and Wind Speed Histogram for the 200 East Area.

7G96030009.14
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Figure 1-15. Location of Surface Water on the Hanford Site.

Figure 1-16. Location of Dams on the Columbia River.

Figure 1-17. Extent of Probable Maximum Flood in Cold Creek Area.

Figure 1-18. Characteristic Stratigraphy, Lithology, and Hydrogeologic Conditions on the Hanford Site.

To convert meters to feet, multiply by 3.281.

WHC-SD-ER-TI-0003, 1991, *Geology and Hydrology of Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents*, Rev. 6, Westinghouse Hanford Company, Richland, Washington.

703600000.25
CSB-1

Figure 1-19. Water Table Contours for the
200 East Areas Based on Well Data.

Figure 1-20. Location of the Hanford Site, Pasco Basin, and Columbia Plateau.

Figure 1-21. Physiographic Provinces of the Pacific Northwest, with the Columbia Intermontane Province Shown in White.

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CVDS-1

Figure 1-22. Generalized Stratigraphy of the Pasco Basin.

Period	Epoch	Group	Formation	Member (formal and informal)	Sediment stratigraphy or basalt flows
Tertiary	Quaternary	Holocene	Surficial Units		Loess Sand dunes Alluvium and colluvium Land slides Talus Colluvium
Tertiary	Pliocene	Pliocene	Ringold Formation		member of Savage Island member of Taylor Flat member of Wooded Island
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		
Tertiary	Pliocene	Pliocene	Ringold Formation		

Figure 1-23. Idealized Suprabasalt Subsurface Stratigraphy of the Hanford Site.

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Figure 1-24. Annual Probability of Volcanic Ash Accumulation on the Hanford Site.

Greater than 1.0cm (0.4 in.)

Greater than 10.0cm (4.0 in.)

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Figure 1-25. Structural Map of the Yakima Fold Belt.

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CSB-1

Figure 1-26. Generalized Geologic Map of the Pasco Basin.

Figure 1-27. Geology of the 200 East and West Areas.

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Figure 1-28. Stratigraphy of the 200 East Area.

Note: Stratigraphy is for the north-south cross section shown in Figure 1-27.

Figure 1-29. Generalized Location of Earthquake Swarms in the Pasco Basin.

BEN	=	Benson Ranch	OT3	=	Othello Three
BRV	=	Black Rock Valley	PRO	=	Prosser
BVW	=	Beverly	RC1	=	Royal City One
CRF	=	Corfu	RED	=	Red Mountain
ET3	=	Eltopia Three	RSW	=	Rattlesnake Mountain
GBL	=	Gable Butte	SNI	=	Snively Ranch
H ₂ O	=	Gable Mountain	WA2	=	Wahluke Slope
LOC	=	Water	WG4	=	Wallula Gap Four
MDW	=	Locke Island	WIW	=	Wooded Island
MJ2	=	Midway	WRD	=	Warden
	=	May Junction Two			

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SRP-1

Figure 1-30. Earthquakes at the Hanford Site 1990 through 1995.

Magnitude 0.0 to 0.99

Magnitude 1.0 to 1.99

Magnitude 2.0 to 2.99

Magnitude greater than 3.0

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CSB-1

Figure 1-31. Top of Basalt Structure Contour Maps for 200 Areas.

Figure 1-32. Seismic Hazard Curves for the
Canister Storage Building Location.

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CSB-1

Figure 1-33. Contribution of the Various Folds to the Mean Hazard from the Yakima Fold.

Figure 1-34. Contributions of the Crustal and Cascadia to the Mean Hazard at the 200 East Area.

Figure 1-35. Contributions of the Three Crustal Sources to the Mean Hazard from Crustal Sources at the 200 East Area.

Figure 1-36. Canister Storage Building Response Spectra Compared to the Performance Category 3 Response Spectra.

7G9605005.4
CSB-1

Figure 1-37. Cascade Range Volcanic Ash Hazard.

Hoblitt, R. P., C. D. Miller, and W. E. Scott, 1987, *Volcanic Hazards with Regard to Siting Nuclear-Power Plants in the Pacific Northwest*, Open-File Report 87-297, U.S. Geological Survey, Cascades Volcano Observatory, Vancouver, Washington.

Scott, W. E., R. E. Iverson, M. Vallance, W. James, and W. Hildreth, 1995, *Volcano Hazards in the Mount Adams Region, Washington*, Open-File Report 95-492, U.S. Geological Survey, Washington, D. C.

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Figure 1-38. Log of Borings: Boring VP-15.

Figure 1-39. Cross Section B - B': Subsurface Profile.

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CSB-1

Figure 1-40. Dynamic Soil Properties of the Canister Storage Building Site.

* Estimated using data from previous investigations.

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CSB-1

Figure 1-41. Federal Airways and Instrument Approaches and Departures.

Figure 1-42. The Location of Yakima Training Center with Respect to the Hanford Site.

2.0 FACILITY DESCRIPTION

2.1 INTRODUCTION

The Canister Storage Building (CSB) is being constructed in the 200 East Area of the Hanford Site to provide dry staging and interim storage for spent nuclear fuel (SNF) that will be removed from water-filled basins in the 100 K Area. The CSB's structures and processes-activities are described in this chapter to facilitate understanding of the hazard and accident analyses described in Chapter 3.0. The CSB facility's structures have a 40-year design life.

The CSB safety analysis report (SAR) is being has been developed in phases. Phase 1 of the CSB SAR included only the below-grade concrete structures: the interior and exterior vault walls, the intake and exhaust plenums, and the base slab. Phase 2 of the CSB SAR began where the below-grade construction ended at elevation 214.5 m (704 ft). It covered the concrete operating area deck floor, the intake structure and exhaust stack foundation bases, and the foundations of the load-in/load-out area, Hot Conditioning System (HCS) Annex, and support building foundations. The Phase 2 concrete structures end at elevation 216 m (709 ft) for the operating area deck floor and the load-in/load-out area, HCS Annex, and support building foundations; at elevation 219.8 m (721 ft) for the three exhaust stacks; and at elevation 223.5 m (766 ft) for the intake structure at vault 1. Phase 2 also included the steel storage tube assemblies, operating floor deck embeds, impact absorbers, tube plugs, and plug or embed covers. Phase 3 of the CSB SAR covers the CSB's above-grade steel structures, including the operating and support buildings, the intake structure, and exhaust stack. The safety support, utility distribution, and auxiliary systems also are included in Phase 3.

2.2 REQUIREMENTS

This section lists the design codes, standards, regulations, and U.S. Department of Energy (DOE) orders that are required for establishing the safety basis of the facility. The intent is to provide only the requirements that are specific for this chapter and pertinent to the safety basis.

2.2.1 U.S. Department of Energy Orders and Standards

The following DOE rule, orders, and standard are applicable to the safety basis for the facility.

- 10 CFR 835, "Occupational Radiation Protection," *Code of Federal Regulations*. The shielding requirements for the CSB shall meet the ALARA (as-low-as-reasonably-achievable) guidelines established in this document. The overall source term is derived from the radionuclide composition of the SNF contained in a nominal multicartridge overpack (MCO); however, local shielding is provided for a single maximum MCO (Swenson 1996, Table 3.2.2.1.2.2-1).

- DOE Order 6430.1A, 1989, *General Design Criteria*. The main reference standards and guides for facility design are presented in Division 13, "Special Facilities." Section 1320, "Irradiated Fissile Material Storage Facilities," contains additional requirements for irradiated fissile material storage facilities. In particular, paragraph 1320-4, "Special Design Features," requires that the passive cooling air system that ensures an acceptable temperature for the stored material be designed as a safety-class system.
- DOE Order 5480.28, 1993, *Natural Phenomena Hazards Mitigation*. This order establishes mitigation requirements for natural phenomena hazards (NPHs) and target probabilistic performance goals based on the facility performance category. Additional discussion of the NPH performance criteria is provided in Section 1.5.
- DOE Order 5480.7A, 1993, *Fire Protection*. This order provides design criteria requirements for fire protection systems for new DOE facilities. In particular, Section 9.b(3) of this order requires automatic fire suppression systems in all new structures with over 465 m² (5,000 ft²) of floor area. Because of the detrimental effects of inadvertent sprinkler activation on the SNF in the MCOs, the contractor has requested and received an exemption from this order for the operating area over the vault, the load-in/load-out area, and HCS Annex (Sellers 1996).
- DOE Order 5480.24, 1992, *Nuclear Criticality Safety*. This order establishes DOE's nonreactor nuclear facility nuclear criticality safety program.
- DOE Order 5400.1, 1988, *General Environmental Protection Program*.
- DOE-RL-HPS-SDC-4.1, 1993, *Standard Architectural-Civil Design Criteria, Design Loads for Facilities*. This Hanford Site plant standard provides criteria for the design of the CSB. Section 3.1 and Section 3.3 of this standard provide structural design criteria loads and load combinations for safety class 1 structures, systems, and components (SSCs). These include nominal dead, live, snow, and soil loads; normal operating loads; and NPH loads for extreme wind, earthquake, ashfall, and flood.

2.2.2 U.S. Nuclear Regulatory Commission Rules and Regulations

The following U.S. Nuclear Regulatory Commission (NRC) rule and guidance are applicable to the safety basis for the facility.

- 10 CFR 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," Subpart F, "General Design Criteria," and Subpart H, "Physical Protection," *Code of Federal Regulations*. This rule provides general design criteria for a spent fuel storage facility. Selected sections of the rule have been invoked by the Regulatory Requirements Team as a means to comply with NRC equivalency criteria. These criteria are

given in WHC-SD-SNF-DB-003, *Spent Nuclear Fuel Project Path Forward, Additional NRC Requirements* (Garvin 1996a). An evaluation of the application of NRC equivalency requirements to the CSB is given in Letter 9652883, *SNF CSB Application of NRC Equivalency Criteria* (Bazin et 1996). FDF 012, *SNF CSB NRC Equivalency Evaluation* (Bedell 1996).

- NUREG 0554, 1979, *Single Failure Proof Cranes for Nuclear Power Plants*.

2.2.3 Industry Consensus Standards and Other Documentation

The following rule and industry standards are applicable to the safety basis for the facility.

- 29 CFR 1910, "Occupational Safety and Health Standards," *Code of Federal Regulations*.
- ANSI/ANS-57.9-1992, 1992, *Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)*. This standard includes requirements for the design of major buildings and structures, including physical security features for independent spent fuel storage installations (ISFSIs).
- ANSI/ANS-57.1-1992, 1992, *Design Requirements for Light Water Reactor Fuel Handling System*.
- ANSI/ANS-8.3-1979, *Criticality Accident Alarm System*. This standard provides the performance criteria for detecting nuclear criticality accidents.
- ANSI/ACI 349-85, 1985, *Code Requirements for Nuclear Safety Related Concrete Structures*. ANSI/ACI 349-85 (ANSI/ACI 1985) provides the requirements for safety class 1 and 2 design for nuclear reinforced concrete structures. These requirements are incorporated into the design of safety class 1 and 2 structures in the design basis document, FRP-112, *SNF Canister Storage Building* (Bedell 1996).
- ANSI/AISC N690-94, 1994, *Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities*. ANSI/AISC N690-94 (ANSI/AISC 1994) specifies requirements that are invoked by the Design Basis Document FRP-112, *SNF Canister Storage Building* (Bedell 1996) for the design of safety class 1 and 2, 3-over-1, and 3-over-2 design for steel structures.
- ANSI/ASME 30.17, 1995, *Overhead and Gantry Cranes (Top Running Bridge, Single Girder, Underhung Hoist)*. This standard applies to the construction, operation, inspection, and maintenance of power-operated cranes, monorails, crane runways, and power- and manually-operated derricks and hoists.

- ANSI/ASME B30.16, 1995, Overhead Hoist (Underhung). This standard applies to manually, electric, and air powered hoists for vertical lifting service involving freely suspended (unguided) loads.
- ANSI/ASME HST-1M, 1995, Performance Standard For Overhead Electric Wire Chain Hoists. This standard applies to electric hoists for vertical lifting service involving freely suspended (unguided) loads.
- ANSI/ASME B30.10, 1995, Safety Standard for Hooks. This standard applies to the design, operation, and safety considerations for lifting hooks.
- ANSI/NFPA 30, 1996a, Flammable and Combustible Liquids Code. NFPA 30 (NFPA 1996a) applies to the storage, handling, and use of flammable and combustible liquids.
- ASCE-7-88, 1988, Minimum Design Loads for Building and Other Structures. ASCE-7-88 (ASCE 1988) provides material loads and minimum dead, live, snow, and wind loads.
- ASME B30.20-1993, 1993, Below-the-Hook Lifting Devices. ASME B30.20-1993 (ASME 1993a) provides requirements for the design, and fabrication of lifting devices that attach to a crane lifting hook, and erection of overhead cranes used in nuclear facilities. This specification is used to establish the requirements for the receiving crane, transport cask lifting yoke and the MM's MCO and shield plug grapples and the MCO handling machine (MHM) crane gantry and hoists. This specification also is used for seismic analysis and design of the MHM and receiving crane.
- ASME, 1995, Boiler and Pressure Vessel Code. The configuration, material design details, attachments, and connections for tanks, vessels, heat exchangers, and other items that contain fluids at pressures of 103 kPa gauge (15 lb/in² gauge) or more will be in accordance with the requirements of Section VIII, Division 1, of the Boiler and Pressure Vessel Code (ASME 1995a). Safety class (safety class 1) vessels that contain fluids at pressures of 103 kPa gauge (15 lb/in² gauge) or more will be designed in accordance with the requirements of Section III, Class 3, of the Boiler and Pressure Vessel Code.
- ASME NOG-1-1995, 1995, Rules for Construction of Overhead and Gantry Cranes (Top-Running Bridge, Multiple Girder). ASME NOG-1-1995 (ASME 1995c) provides requirements for the design, and fabrication, and erection of overhead cranes used in nuclear facilities of lifting devices that attach to a crane lifting hook. This specification is used to establish the requirements for the receiving crane and the MHM crane gantry and hoists transport cask lifting yoke and the MM's MCO and shield plug grapples.
- ASTM D 2261, 1983, Standard Test Method for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant-Rate-of-Extension Tensile Testing Machine). This standard is used in the

design specification of the service station enclosure. Specimens are gripped in the clamps of a recording tensile testing machine and pulled to simulate a rip. The force to continue the rip is recorded.

- ASTM D 2262, 1983, *Standard Test Method For Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant-Rate-of-Traverse Tensile Testing Machine)*. This standard is used in the design specification of the service station enclosure. Specimens are gripped in the clamps of a recording tensile testing machine and pulled to simulate a rip. The force to continue the rip is averaged from five recorded tests.
- ASTM C1055, 1992, *Standard Guide for Heated System Surface Conditions that Produce Contact Burn Injuries*. This guide is used in the design specification of the service and instrument air systems, and the emergency diesel generator system. This guide determines the acceptable surface operating conditions for heated systems to prevent serious injury from contact with the exposed surfaces.

2.2.4 Contractor Requirements

The following contractor requirements are applicable:

- WHC-CM-4-46, *Safety Analysis Manual*, Revision 1, as modified by Letter 96-SFD-318, *Contract No. DE-AC06-96RL13200: Proposed Spent Nuclear Fuel Project Division (SFD) Risk Acceptance Guidelines (RAGs)* (Sellers 1996). Chapter 9.0 of WHC-CM-4-46 (Revision 1) identifies the methodology for determining the safety classification of SSCs and the applicable design criteria. The safety class 1 requirements in Chapter 9.0 of WHC-CM-4-46 (Revision 1) implement the criteria established in DOE Order 6430.1A for safety-class items and the requirements for 10 CFR 72 important-to-safety SSCs. The CSB SAR was originally written under a waiver to Revision 2 of Chapter 9.0 of WHC-CM-4-46. The current revision of the SAR has begun incorporating the safety class/safety significant terminology of Revision 2. Both sets of terminology are used in the text of this chapter.
- WHC-SD-SNF-DB-003, 1996, *Spent Nuclear Fuel Project Path Forward, Additional NRC Requirements*. WHC-SD-SNF-DB-003 (Garvin 1996a) provides guidance on the use of NRC equivalency. The major additional NRC equivalency items related to the CSB design and construction are the seismic criteria contained in WHC-SD-SNF-DB-004, *Spent Nuclear Fuel Project Seismic Design Criteria, NRC Equivalency Evaluation Report* (Garvin 1996b). The other NPHs that are required from WHC-SD-SNF-DB-003 (Garvin 1996a) are contained in WHC-SD-SNF-DB-009, *Canister Storage Building Natural Phenomena Hazards* (Tallman 1996). Other major additions to design caused by the additional NRC requirements are the use of ANSI/ANS-57.9-1992 (ANSI/ANS 1992a) for the application of 5% dead load contingency and the use of ANSI/ANS-57.1-1992, *Design*

Requirements for Light Water Reactor Fuel Handling System (ANSI/ANS 1992b), for lifting requirements for the receiving crane and MHM.

- WHC-SD-SNF-DB-004, 1996, *Spent Nuclear Fuel Project Seismic Design Criteria, NRC Equivalency Evaluation Report*. WHC-SD-SNF-DB-004 (Garvin 1996b) provides seismic design criteria.
- WHC-SD-SNF-DB-009, 1996, *Canister Storage Building Natural Phenomena Hazards*. WHC-SD-SNF-DB-009 (Tallman 1996) supplements previous Hanford Waste Vitrification Plant (HWVP) loads for use in the design and construction of the CSB. With the exception of seismic criteria, the compliance to both NRC and DOE requirements is accomplished with this document. The supplemental loads are those associated with tornados and flooding. WHC-SD-SNF-DB-009 (Tallman 1996) allows tornado-driven missiles for safety-class and important to safety SSCs to be eliminated on a probabilistic risk assessment basis.
- WHC-S-0425, 1996, *Performance Specification for the Spent Nuclear Fuel Canister Storage Building*. WHC-S-0425 (Swenson 1996) requires that the CSB implement the spectra given in DOE-RL-HPS-SDC-4.1 in designing the facility for a design basis earthquake (DBE). Earthquake time histories for the safety class 1 (safety-class) DBE may be used to satisfy these loading requirements for design and analysis of safety class 1 nonreactor nuclear systems and components as defined in DOE-RL-HPS-SDC-4.1. Safety class 2 (safety-significant) items shall be designed to withstand wind loading and wind-generated missiles according to DOE-RL-HPS-SDC-4.1. Features necessary to protect the offsite and onsite personnel shall be designed to withstand design basis wind and windborne missiles, with the criteria for high-hazard usage applicable to safety class 1 (safety-class) items and moderate hazard usage applicable to safety class 2 (safety-significant) items.

2.3 FACILITY OVERVIEW

2.3.1 Facility Description-Overview

The SNF CSB consists of a steel operating area shelter, which encloses the load-in/load-out area and the HCS Annex, and three equally sized below-grade concrete vaults covered by a concrete operating deck. Support functions and equipment are housed in the a steel support building located at the north side of the operations building. Only the northernmost vault (vault 1) is equipped with steel tubes for staging and storage of the MCOs. The storage tubes are supported from the foundation base slab of the vault and are accessed through tube plugs in the operating deck. The tube plugs provide shielding, confinement, and process connections for purge and evacuation. The operating deck and other operations areas, including the load in/load out area and HCS Annex, will be enclosed in a steel building. The MCO storage vault (vault 1) is cooled by natural convection through the above-grade, dedicated concrete and steel inlet structure and exhaust air stack and the below-grade

reinforced concrete plenums, a dedicated inlet structure, exhaust air stack, and plenums. The CSB floor plan and interior elevations are shown in Figure 2-1, sheets 1 through 3.

The MCO is—MCOs are received into a trailer truck vestibule on the northwest side of the CSB where the transport cask, containing one MCO, is unlatched from the trailer. A gantry-type receiving crane is used to transfer the casks from the transporter trailer to a below-grade service station pit in the load-in/load-out area located at the north end of the operating area. After the cask MCO has arrived at the CSB, but before the cask lid is removed, the pressure in the cask annulus is tested. If a high pressure is detected, the cask can be evacuated using a temporary connection to the service station purge and vent system and returned to the Cold Vacuum Drying System (CVDS) for recertification. This ensures worker safety during removal of the cask lid. Following cask lid removal, process lines are attached to the MCO process ports to measure MCO pressure. If necessary the MCO is evacuated to a vacuum and refilled with inert gas. If the MCO is received with the pressure relief valves and/or rupture disk blanked off, the blank will be removed and the valve will be tested after the MCO is evacuated and refilled. This step ensures worker safety and prevents the service area confinement tent from being subjected to pressures greater than design pressure. The rupture disk blank is then removed and the MCO readied for movement into the MCO handling machine (MHM). MCOs are The MCO is removed from the casks and are either placed into a vertical steel tubes housed in the vault and accessed through the operating deck by the MHM or moved directly to the HCS Annex on the south side of the CSB operating area. The MHM will also be used to transfer the MCOs from the cask to the storage tube for staging, from the tubes to the HCS Annex for conditioning, and from the HCS Annex back and return them to the CSB storage tubes for interim storage. An unused MCO is placed into the empty cask using the auxiliary hoist, and the cask-MCO is transported to the K Basins for loading with SNF.

[The following has been moved to the introduction] The portion of the SNF CSB that is covered by this document is referred to as Phase 2 of the CSB SAR. Phase 1 of the CSB SAR included only the below grade concrete structures: the interior and exterior vault walls, the intake and exhaust plenums, and the base slab (see Figures 2-2 and 2-3). Phase 2 of the CSB SAR begins where the below grade construction ends at elevation 214.5 m (704 ft). It covers concrete structures and steel structures as described below.

[The following has been moved to the introduction] The concrete structures covered by Phase 2 of the CSB SAR are the operating area deck floor, intake structure and exhaust stack foundation bases, the load in/load-out area, the HCS Annex, and the support building foundation. The concrete structures end at elevation 216 m (709 ft) for the operating area deck floor, load in/load-out area, HCS Annex, and support building foundation; at elevation 219.8 m (721 ft) for the three exhaust stacks; and at elevation 223.5 m (736 ft) for the intake structure at vault 1. The concrete operating area deck floor completely encloses the below grade vault at the 216 m (709 ft) level. *[The following has been moved to Section 2.4.2]* The operating area deck floor is bounded to the north by the load in/load-out area (trailer vestibule and MCO service station) and support building foundations, and to the south by the HCS Annex. *[The following is covered in*

~~Section 2.4.2] The perimeter of the operating area deck has a 1 m (3 ft) high curb on top of which rests the steel shelter.~~

~~[The following has been moved to the introduction] The steel structures covered by Phase 2 of the CSB SAR include the carbon steel storage tube assemblies (including bellows), operating floor deck embeds, tube base assemblies, impact absorbers, tube plugs and plug or embed covers. The storage tube plug and bellows are discussed in Section 2.4.3] The storage tube plug is a composite carbon steel and concrete component. The bellows portion of the storage tube assemblies is stainless steel. [The following information has been moved to Section 2.4.3] Storage tubes are located in the operating floor by the floor embeds and supported from the basement by a tube base assembly. Each of the 220 standard storage tube assemblies in vault 1 will include two impact absorbers (one at the bottom of the storage tube, the other in between the two MCOs), a tube base, and a tube plug. Each storage tube location will receive a plug cover plate. In vaults 2 and 3 the operating floor embed locations will not include storage tube assemblies. Embed covers will be placed at the floor level in these embed openings until a future mission is identified that requires utilization of these openings.~~

~~[The following has been moved to Section 2.3.3] The safety classification of the CSB vault structure is covered on pages 3-7 and 3-8 of WMC SD HWV PSE 001, Hanford Waste Vitrification Plant Canister Storage Building Preliminary Safety Analysis Report Addendum (WHC 1992), which designated all of the structures contained in the below grade structure as safety class 1. Portions of the vault that were completed prior to suspension of the HWVP project in 1993 were reviewed, approved, accepted, and incorporated into the present design. These include the base slab and portions of the walls. The current SNF CSB vault is structurally similar to the HWVP CSB vault with a few exceptions. These differences are discussed below.~~

~~[The following has been moved to Section 2.3.3] Each of the three vault areas is now physically separate instead of sharing common intake and exhaust plenums, which was the case for the original HWVP CSB. The interior walls have been extended the full east west length of the vaults including the intake and exhaust plenums. Separation of the vault areas allows the storage tubes to be installed in vaults 2 and 3 at a later date. The separation of the vault areas also improves the convective cooling. The heat load density for one vault containing SNF MCOs is less than it would have been with the vitrified high level waste canisters. Lower vault temperatures allowed elimination of the requirement for insulating the concrete in vault 1 as was the case in the HWVP CSB. This is discussed further in Section 2.4.5.~~

~~[The following has been moved to Section 2.3.3] The below grade vault changed from the HWVP concept as a result of the SNF Project mission. The major change to the concrete deck is an increase in the number of intake structures and exhaust stack bases. The stack bases for vaults 2 and 3 will be capped until needed to support future missions. Vaults 2 and 3 are also similar to the HWVP design in that 25 cm (10 in.) of insulating concrete is provided to the deck and exhaust plenum ceiling, and 15 cm (6 in.) to the interior surfaces of the below grade vault walls.~~

~~[The following has been moved to Section 2.3.3] Figure 2-2 shows surface drains in the basemat that connect to a sump located at the northeast corner. These drains, as well as the sloped basemat floor and sump, remain from the original construction of the HWVP basemat. This system of surface drains and sump has no identified purpose in the SNF CSB mission.~~

~~[The following has been moved to Section 2.3.3] Extension of the interior walls to create separate vault areas achieves physical separation of vault 1 from vaults 2 and 3. This modification contributes to reducing the radiation streaming around and scattering up through the air intake structure. With partial interior walls in the HWVP design this radiation streaming and scattering were mitigated through the use of a set of heavy concrete louvers. The separate vaults and reduced source term in the SNF CSB design allow for removal of the louvers from the design. The architect engineer undertook high level waste canister studies (with a somewhat lower specified source for the high level waste glass canisters than the HWVP canisters) and found that the concrete louvers were not needed to meet the exposure criteria. The main reason for this is that the CSB vault inlet and exhaust plenums have been redesigned from the original HWVP configuration. The redesign features separate plenums for each vault and a wall in front of the plenums in each vault, which tends to mitigate the direct scattering of radiation from the stored canisters. Documentation of the shielding analysis can be found in Appendix A of Letter FFR 034, *Canister Storage Building (CSB) High Level Waste (HLW) Implementation Study* (Jacobs 1996b). This design revision reduces the construction complexity and results in savings as compared to the HWVP CSB.~~

~~[The following information has been moved to Section 2.3.3] Fully isolating vault 1 from vaults 2 and 3 provides sufficient shielding to permit personnel to install storage tubes in vaults 2 and 3 at a future time while vault 1 is operating. Shielding analysis conservatively assumes that vault 1 is homogeneously loaded with maximum source term MCOs. The results of shielding analysis are further discussed in Section 2.4.5. This change eliminates the need to completely furnish all three vaults with tubes and plugs before placing MCOs in vault 1 of the CSB. Extension of the interior walls provides for increased flexibility, as compared with the HWVP CSB design, and results in a significant near term construction time and cost savings as well as a capital cost deferral until missions are approved for the other two vaults.~~

2.4.3 Facility Mission

~~Initially the MCOs containing SNF are will be staged and stored in an inerted sealed condition in the storage tubes. Because of the potential for hydrogen generation and buildup from both radiolytic and chemical reactions of the bound and free water in the MCO after cold vacuum drying and hot conditioning, the operating deck design provides for will have provisions to periodically pressure purging or evacuation, and reinerting of each storage tube. Storage tube vent and purge carts are used for these operations. The design provisions include the tube plug covers (which allow access to tube plug service connections), service connections in the tube plugs, and electrical power outlets in the floor. Eventually the MCOs will be processed in the HCS Annex. Current planning calls for the MCOs to be stored in a sealed configuration upon completion of HCS processing.~~

Vault 1 contains will contain 220 storage tubes, each capable of staging or storing two MCOs. Six additional tubes locations are available to accommodate overpacked MCOs. Each standard storage tube will contains both a bottom and an intermediate impact absorber to mitigate the consequences of a concentric MCO dropped MCO. Overpack storage tubes contain only bottom impact absorbers. The storage tubes are safety class 1, and along with the impact absorbers, they are designed to withstand all credible DBAs discussed in Section 3.4.2 of this document including dropping of MCOs. The bottom impact absorbers are will be designed to prevent damage to the breach of the storage tube and the MCO in the event of a drop. Intermediate impact absorbers protect the pressure relief devices, other port valving, and filters of the bottom MCO and protect the top MCO from internal damage in the event of a drop. Standard storage tube plugs contain connections for sampling, purging and evacuating, and relieving of tube atmosphere. The initial overpack storage tube plugs are designed for shielding only, do not contain purge and evacuation connections, and are not bolted to the tube flange.

2.3.2 Site Grading and Storm Drains

The CSB storm drain and flood control facilities have been designed to accommodate both the 25-year storm and the probable maximum precipitation (PMP) event. The site civil grading and drainage plan is shown on Figure 2-2. The normal civil engineering design practice is to design the system for a specific design basis storm event, such as a 25- or 50-year return frequency storm, and to take into account storms larger than the one used for design by evaluating the path overflows (larger-than-design flows) will take when the system capacity is exceeded.

The CSB criterion for the overflow path assessment is to maintain safety of property and personnel during the PMP event. The design storm used for culverts, drainage ditches, and general storm drainage is the 25-year, 6-hour storm. The Design Basis Document (Bedell 1996) specified that "Culverts will be sized to flow with an unsubmerged inlet during the 25 year return 6 hour duration storm." The CSB Performance Specification (Swenson 1996) states that the prevailing environmental condition for rain is "1.52 cm/hr (0.60 in/hr) maximum." This corresponds roughly to a 25-year storm. WHC-SD-SNF-DB-009 (Tallman 1996) requires that the "local 1-mi², 6-hour storm" of 9.2 in. in 24 hours be used for the CSB design. This PMP is estimated to be a "1 million-year return period storm."

In the present design of the CSB site, the existing culverts installed during HWVP construction have been reused. These culverts had been sized to accommodate the 25-year storm in accordance with HWVP criteria, which are similar to the 25-year storm criteria given in WHC-SD-SNF-DB-009 (Tallman 1996). The new culverts that will be installed under the access road to the CSB from the site entry gate northwest of the CSB are similarly designed to the 25-year storm.

The site and its surrounding tributary areas were analyzed and evaluated using the PMP criteria to determine the impact on the safety of the facility and facility workers. No offsite, non-CSB area contributed PMP drainage in a manner that would affect the CSB. Onsite, runoff water from the southern portion of the CSB site flows in an easterly direction in a drainage swale

that is adjacent to the patrol road slope along the south edge of the CSB site. This water flows in an easterly direction around the south end of the site, then north along the east side of the site to the 0.9-m (36-in.) culverts that pass under the ramp road immediately northeast of the CSB. These two culverts are the only ones that could have any impact on the CSB itself. In an extremely unlikely case, both 0.9-m (36-in.) culverts could be plugged with debris at the time the PMP storm occurred and pond up to the lowest elevation of the road immediately north of the CSB, which ramps from an elevation of approximately 214 m (704 ft) next to the CSB to an elevation of approximately 215 m (707 ft) at the road's intersection with the access road coming in from the north. The rest of the site drains away from the CSB, which has a floor elevation of 216 m (709 ft). Additional rainfall would increase the depth of flow over the ramped access road, but at no time would the water level build up to the 216-m (709-ft) elevation that would threaten the CSB, affect its structural integrity, or allow water into the building.

2.3.32-4.5 Facility Modifications to Hanford Waste Vitrification Plant Canister Storage Building

The SNF CSB incorporates portions of the design and the completed below-grade sections of the canceled HWVP CSB. The safety classification of the CSB vault structure is covered on pages 3-7 and 3-8 of WHC-SD-HWV-PSE-001, Hanford Waste Vitrification Plant Canister Storage Building Preliminary Safety Analysis Report Addendum (WHC 1992), which designated all of the structures contained in the below-grade structure as safety class 1. Portions of the vault that were completed prior to suspension of the HWVP project in 1993 were reviewed, approved, accepted, and incorporated into the present design. These include the base slab and portions of the walls. The current SNF CSB vault is structurally similar to the HWVP CSB vault with a few exceptions. These differences are discussed below.

The conversion of the CSB from the HWVP mission to the current SNF mission resulted in two structural revisions made possible by the lower radiation source term and lower heat load associated with the SNF MCOCs as compared with the HWVP canisters. One is the removal of the intake plenum louvers in all three vaults. The other is the deletion of insulating concrete on the interior walls and underside of the operating deck in vault 1.

The below-grade vault changed from the HWVP concept as a result of the SNF Project mission. The major change to the concrete deck is an increase in the number of intake structures and exhaust stack bases. The stack bases for vaults 2 and 3 will be capped until needed to support future missions. Vaults 2 and 3 are also similar to the HWVP design in that 25 cm (10 in.) of insulating concrete is provided to the deck and exhaust plenum ceiling, and 15 cm (6 in.) to the interior surfaces of the below-grade vault walls.

The CSB design for the HWVP mission had partial-length, below-grade interior walls and common intake and exhaust plenums. The SNF ~~current~~ CSB configuration, as shown in Figures 2-3 and 2-42-2 and 2-3, extends the below-grade walls to isolate the individual vaults and creates individual intake and exhaust plenums for each vault. ~~This design change also aided in the deletion of the intake shielding louvers.~~

~~Extension of the interior walls to create separate vault areas achieves physical separation of vault 1 from vaults 2 and 3. This modification contributes to reducing reduces the radiation streaming around and scattering up through the air intake structure. With partial interior walls in the HWVP design this radiation streaming and scattering were mitigated through the use of a set of heavy concrete louvers. The separate vaults and reduced source term in the SNF CSB design allow for removal of the louvers from the design. The architect engineer undertook high level waste canister studies (with a somewhat lower specified source for the high level waste glass canisters than the HWVP canisters) and found that the concrete louvers were not needed to meet the exposure criteria. The main reason for this is that the CSB vault inlet and exhaust plenums have been redesigned from the original HWVP configuration. The redesign also features separate plenums for each vault and a wall in front of the plenums in each vault, which tends to mitigate the direct scattering of radiation from the stored canisters. For documentation of the shielding analysis, see can be found in Appendix A of Letter FRF-034, Canister Storage Building (CSB) High Level Waste (HLW) Implementation Study (Jacobs 1996b). This design revision reduces the construction complexity and results in savings as compared to the HWVP CSB.~~

~~Fully isolating vault 1 from vaults 2 and 3 provides sufficient shielding to permit personnel to install storage tubes in vaults 2 and 3 at a future time while vault 1 is operating. Shielding analysis conservatively assumes that vault 1 is homogeneously loaded with maximum source term MCOs. The results of shielding analysis are further discussed in Section 2.4.5. This change eliminates the need to completely furnish all three vaults with tubes and plugs before placing MCOs in vault 1 of the CSB. Extension of the interior walls provides for increased flexibility, as compared with the HWVP CSB design, and results in a significant near term construction time and cost savings as well as a capital cost deferral until missions are approved for the other two vaults.~~

~~Each of the three vault areas is now physically separate instead of sharing common intake and exhaust plenums, which was the case for the original HWVP CSB. The interior walls have been extended the full east-west length of the vaults including the intake and exhaust plenums. Separation of the vault areas allows the storage tubes to be installed in vaults 2 and 3 at a later date. The separation of the vault areas also improves the convective cooling. The heat load density for one vault containing SNF MCOs is less than it would have been with the vitrified high-level waste canisters. Lower vault temperatures allowed elimination of the requirement for insulating the concrete in vault 1 as was the case in the HWVP CSB.~~

The total activity for one MCO is given as 309,883 Ci versus 891,000 Ci (5.4×10^3 Ci/gal $\times$ 165 gal) for a vitrified waste canister. This information can be obtained from Table 3.2.2.1.2.2-1 of WHC-S-0425 (Swenson 1996) and Table 8.2-2 of WHC-SD-HWV-PSAR-001, Hanford Waste Vitrification Plant Preliminary Safety Analysis Report (WHC 1994). Shielding analysis results indicate that the dose rate at the base of the intake stack is less than 5.0×10^{-4} mSv/h (0.05 mrem/h), and in the adjoining below-grade vault, the dose rate is less than 4.0×10^{-3} mSv/h (0.4 mrem/h) (Sienko 1996).

On page 3-32 of the WHC-SD-HWV-PSE-001 (WHC 1992), the heat loads for the HWVP canisters in the three vaults are given as 800 canisters at 0.4 kW and

1,200 canisters at 1 kW for a total CSB heat load of 1,520 kW (507 kW per vault). In Section 3.2.2.1.2.2 of WHC-S-0425 (Swenson 1996), the SNF MCO heat load for one vault is given as 80% at 401396 W and 20% at 852 W for a total of 192 kW for 390 MCOs. Based on these conservative assumptions, results of the thermal analysis (FDI 1996, Calculation CSB-HV-0001) indicate that the maximum air-concrete temperature inside the vault (deck underside) is 56 °C (133 °F) coincident with a steady state intake air temperature of 46 °C (115 °F). This result is below the ANSI/ACI 349-8590 (ANSI/ACI 1990) limit of 65 °C (150 °F) for reduction of concrete strength. See Chapter 4.0, Section 4.3.1.4.3 for further information. Under these conditions the wall temperature of the MCO is conservatively estimated to be 118122 °C (244251 °F) (for the maximum MCO), which is well below the performance specification (Swenson 1996) limit of 132 °C (270 °F) wall temperature required to ensure the fuel centerline temperature of not exceeding 204 °C (400 °F) is not exceeded (Phillips 1996) for fuel centerline temperature. The design of the cooling system limits the MCO external surface temperature to a maximum of 132 °C (270 °F) using any of the three gases argon, helium, or nitrogen to inert the storage tubes. The design of the cooling system does not include MCOs in overpacks.

The below-grade portion of the HWVP CSB was designed to carry the loads associated with a large, wheeled, shielded canister transporter that was to be used for the HWVP mission. The SNF current CSB configuration assumes a large heavy crane, the MHM, is used to transport the MCOs. The MHM is designed to ride on steel rails that run north to south and are located at the 216.1-m (709-ft, 0-in.) floor elevation. Anchor bolts are will be installed in the deck at the east and west sides of the operating floor for the installation of MHM runway rails. The MHM rails will be installed during construction of the operating area superstructure. The MHM rails are will be installed in trenches that will run north to south and cut across the receiving crane rails. The receiving crane rails are will be installed in trenches that run east to west in the northernmost portion of the operating floor. The reinforced concrete construction of that northernmost portion of the operating floor includes known as the load-in/load-out area is included in this Phase 2 of the CSB SAR. The receiving crane rails will be installed during construction of the operating area superstructure. Special rail crossover components called "frogs" are will be provided in the locations where the MHM runway rails cross the receiving crane runway rails. Details of the MHM and other MCO-related handling equipment will be provided in a later submittal Phase 3 of the CSB SAR.

DOE Order 6430-1A, Section 1300 3.2, considers safety class items as those whose failure would result in exposures exceeding DOE 5400 series limits for the public at the Site boundary or nearest point of public access. For the Hanford Site's 200 Area, this distance is 15,000 m (9.3 mi). The Regulatory Requirements Team's application of NRC equivalency has resulted in the requirement to identify SSCs that should be designated as important to safety in accordance with 10 CFR 72, Section 72.3, as implemented through Section 72.106 (Garvin 1996a). Once SSCs "important to safety" have been identified, the requirements for safety class 1 SSCs are imposed on them as required by WHC SD SNF DB 003 (Garvin 1996a) defined in Revision 1 of WHC CN 4 46, Section 9.0, "Safety Classification of Structures, Systems and Components."

The facility design has been evaluated for the natural phenomena loads listed on Table 1-23 of Section 1.5, "Natural Phenomena Threats." NPH wind loads associated with a reactor design basis tornado were evaluated using the tornado wind load from Table 1-23, given as 322 km/h (200 mi/h) total, versus the SDC 4.1 wind load of 145 km/h (90 mi/h) (DOE RL 1993). This higher wind load on the operating area superstructure and support building was incorporated into the appropriate analysis and load combination for the operating deck and below grade vault (FDI 1996, Calculations CSB-S-0023, CSB-S-0025, and CSB-S-0026).

The intake structure and exhaust stack bases of vault 1 of the operating deck structure were re-designed to withstand tornado wind loads to meet the NRC tornado criteria for reactors as discussed in Section 1.4.1.1.4. The analysis and design of the superstructure for tornado generated missiles is discussed further in Section 4.3.4.4.

The architect engineer has performed a review of the performance requirements and design criteria imposed by ANSI/ANS 57.9 1992 (ANSI/ANS 1992a). Section 6.17.1.1 of ANSI/ANS 57.9 1992 requires that the most adverse dead load loading condition be increased by 5% from the estimated value. The effects of an increase in the dead load have been included in the CSB design. The substructure walls, piers, and basemat continue to provide the strength needed to meet the criteria. The major difference between the CSB and the generic requirements of ANSI/ANS 57.9 1992 (ANSI/ANS 1992a) is that in ANSI/ANS 57.9 1992 transportation package washdown, decontamination facilities, and safety class electrical power for instrumentation, lighting, communications, and physical security systems are assumed to be necessary. The technical justifications for not implementing these particular requirements demonstrated that nuclear safety of the facility is was not impaired by their exclusion and that these functions are requirements could be met by other facilities (Jacobs 1996a). Radioactive waste treatment facilities are not included in the CSB design because the volume of radioactive waste expected to be generated from CSB operations is very small and does not require an onsite dedicated radioactive waste treatment facility. Liquid radioactive waste from the CSB can be shipped by truck to the Effluent Treatment Facility in the 200 East Area. Emergency communications equipment is not provided as part of the CSB design because no dedicated emergency communication center is required; such communications will be handled through systems that interface with the Central Alarm Station. Two independent diesel emergency generators provide backup power to designated safety significant electrical loads. The generators and electrical distribution system are designed to meet the requirements of NRC 10 CFR 50.46 associated with their safety classification including the requirement that the system have sufficient redundancy to power safety significant loads if one of its components fails to operate.

Note that Figure 2-32-2 shows surface drains in the basemat that connect to a sump located at the northeast corner. These drains, as well as the sloped basemat floor and sump, remain from the original construction of the HWVP basemat. This system of surface drains and sump has no identified purpose in the SNF-CSB mission.

~~2.3.42.4.6 Construction Restart Issues~~

~~A readiness for construction task force of key project participants identified open issues that needed to be addressed before the restart of construction. These issues are documented in Report No. 951108-001, Canister Storage Building Construction Restart Readiness Assessment (Ares 1996). One of the requirements was to document the acceptability of the existing basemat before the resumption of CSB construction. Detailed inspections and evaluations of the acceptability of the existing basemat foundation were performed and documented, including a review of the adequacy and completeness of the construction quality assurance records. The review is further discussed in Section 14.6.5.1.4.~~

~~The architect engineer prepared a statement of work document for the construction management organization to use as guidance for the inspection walkdown and report. This ensured that the report would contain sufficient information for the architect engineer to adequately evaluate the acceptability of the existing basemat. Detailed instructions to prepare the existing concrete for the resumption of construction were provided on the architect engineer's construction drawings and specifications.~~

~~Following the submittal of the architect engineer's statement of work for the inspection walkdown, the construction management organization performed a detailed inspection of the below grade vault basemat and partially completed walls (Islam 1996). The results were categorized and submitted by the construction management organization for disposition by the architect engineer. Category 1, 2, and 3 deficiencies are from CSB construction errors. Environment affected deficiencies are in category 4. To date all category 1, 2, and 3 deficiencies have been dispositioned. Category 4 deficiencies dealing with rebar, rust stains, and basemat embed surface rust have been dispositioned (Mortimer 1996). Deficiencies dealing with couplers have been dispositioned. The information on disposition is contained in RFI:PM-T3-001, Engineering Assessment Inspection (FDI 1996a).~~

2.4 FACILITY STRUCTURE

2.4.2 Facility Description

2.4.2.1 Below-Grade Reinforced Concrete Structures

As shown in Figures 2-3 and 2-42-2 and 2-3, the CSB consists of a below-grade reinforced concrete structure, with approximate dimensions of 55 m x 51 m x 15 m deep (181 ft x 166 ft x 48 ft deep). The dimensions of the floor plan encompassing the load-in/load-out area, operating area, and HCS Annex are approximately 70 m x 42 m (230 ft x 137 ft). The operating floor ~~is~~ will be enclosed by the a-steel-framed shelter, or operating area building. The reference elevation of the facilities at the top of the operating deck is 216 m (709 ft) above mean sea level. The CSB basemat foundation is constructed at an elevation of 201.5 m (661 ft, 3 in.) above mean sea level, or approximately 14.2 m (46 ft, 9 in.) below the grade elevation of 215.8 m (708 ft). The basemat is nominally 1.7 m (5 ft, 6 in.) thick; its surface elevation is 203.2 m (666 ft, 9 in.). The distance from the basemat floor to the underside of the operating deck is 11.4 m (37 ft, 3 in.). The exterior

walls and air inlet and outlet plenums are 1.4 m (4 ft, 6 in.) thick. Interior partition walls between vaults are 0.9 m (3 ft) thick.

~~[This material has been moved to Section 4.3.1.4.]~~ The CSB basemat foundation is constructed at an elevation of 201.5 m (661 ft, 3 in.) above mean sea level, or approximately 14.2 m (46 ft, 9 in.) below the grade elevation of 215.8 m (708 ft). ~~[The following has been moved to Chapter 4]~~ This coincides with a soil profile identified as stratum 3 in Section 3.6.1.9 of WHC SD HWV PSAR 001, *Hanford Waste Vittrification Plant Preliminary Safety Analysis Report* (WHC 1994). This layer exhibits light cementation and is typically in a dense to very dense condition. The formation extends to a depth of approximately 76 m (250 ft) below grade. Geotechnical investigations reported in WHC SD HWV PSAR 001 (WHC 1994) characterized the soil properties at the elevation of interest as having high strength and low compressibility. Stratum 3 has a vertical static subgrade modulus value of $8.1 \times 10^4 \text{ kN/m}^2$ (518 kip/ft²) based on a 1 ft² plate. This is adjusted for the actual foundation size by the equation given in the geotechnical report (Dames and Moore 1989).

The mass of the portion of the CSB above the basemat or foundation slab is greater than that in the HWVP design because of has increased due to the extension of the below-grade interior walls. The weight of the canisters in the storage tubes has also increased from 6,300 kg (13,900 lb) with vitrified waste (three canisters), to 17,240 kg (38,000 lb) with SNF (two MCOs). ~~[This material has been moved to Section 4.3.1.4.]~~ The live loading associated with canister transport equipment has doubled from the HWVP design, but the new loading is a live load along the east and west exterior vault walls versus that of the HWVP transporter travelling over the full deck. The structural loading to the foundation, assuming all vaults fully loaded with SNF, is well within the allowable soil bearing values. Details of the analysis of the adequacy of the soil to carry the anticipated foundation loading are documented in CSB S 0023 (FDJ 1995b). The soil bearing pressures beneath the vault are less than $3.8 \times 10^5 \text{ N/m}^2$ (8 kip/ft²), which is well within the allowable bearing capacity of $6.7 \times 10^5 \text{ N/m}^2$ (14.0 kip/ft²). The factor of safety against sliding during a design basis earthquake (DBE) event is approximately 1.8 (CSB S 0024).

Only vault 1, the northernmost vault, will be provided with carbon steel storage tubes and an individual intake structure and exhaust stack at this time. This will expedite the receipt of MCOs containing SNF. Storage tubes and shield plugs are not provided for the other two vaults. The intake structures and exhaust stacks for the other two vaults will not be constructed at this time, except the exhaust stack bases for vaults 2 and 3.

The below-grade walls and basemat carry the loads associated with handling and transporting the MCO (i.e., the transporter with cask, receiving crane, and the MHM). As described further in Section 3.4, "Accident Analysis," the below-grade portion of the CSB has been determined to be safety class (safety class 1) in accordance with Revision 1 of WHC CM 4 46, *Safety Analysis Manual*.

The CSB subsurface structure provides shielding for the inlet and outlet plenums and for possible future work in adjacent vaults or for excavation next to the vaults. The SNF CSB subsurface structure design includes 1.4-m-

(4-ft, 6-in.-) thick reinforced concrete exterior walls and 0.9-m- (3-ft, 0-in.) thick reinforced concrete interior walls. These wall thicknesses are the same as in the original HWVP CSB design. The subsurface structure with 0.9-m- (3-ft, 0-in.) thick interior walls provides shielding from the source term associated with SNF storage. This source term is substantially less than the source term that would have been present in the HWVP CSB, as discussed in Section 2.3.34-5.

The exterior walls of the subsurface structure were designed to meet the criteria given in Title 10, *Code of Federal Regulations*, Part 835, "Occupational Radiation Protection" (10 CFR 835), for uncontrolled access. The radiation field at the exterior surface of the below-grade vault areas when loaded with HWVP CSB sources was calculated to be 1.0×10^{-3} mSv/h (0.1 mrem/h). ~~This makes future excavation possible next to vault 2 for installation of additional vaults, such as for high level waste, if desired.~~

Shielding calculations have assumed that each MCO contains the maximum activity value associated with Mark IV (MKIV) fuel listed in Table 3.2.2.1.2.2.1 and described in Section 3.2.2.1.6 of WHC-S-0425, Performance Specification for the Spent Nuclear Fuel Canister Storage Building (Swenson 1996, Section 3.2.2.1.6 and Table 3.2.2.1.2.2.1). The shielding calculations indicate that the radiation field at the intake stack base will be less than 5.0×10^{-4} mSv/h (0.05 mrem/h) (Sienko 1996), of which less than 1% is attributed to neutron scatter for SNF as the source term. Originally, the interior walls were designed for structural purposes only; shielding calculations now show that the full-length SNF CSB walls they provide shielding from the SNF for workers in the presently unused vaults 2 and 3. Interior radiation levels in the presently unused vaults will be about 4.0×10^{-3} mSv/h (0.4 mrem/h) at the wall surface plane (within 1 cm [0.4 in.]). Because of the large source configuration, the dose rate inside adjacent vaults (e.g., vault 2) does not decrease very rapidly with distance, remaining at about 4.0×10^{-3} mSv/h (0.4 mrem/h) for the first meter or so away from the interior wall of vault 2 that is shared with vault 1. Heating of the concrete by the radiation field inside the vault has been estimated to be insignificant at approximately (2×10^{-8} Btu/h/ft²). Neutrons and gammas effects from the spontaneous fission of californium ~~were was not included in the shielding calculations or concrete heating calculations because their contribution is negligible and since it was not identified in the CSB Performance Specification source term.~~

2.4.2-2 At-Grade Reinforced Concrete Structures

The operating deck is a 1.5-m- (5-ft-) thick reinforced concrete structure that forms the at-grade portion of the CSB. The operating deck is shown in plan view on Figure 2-52-4. The dimensions of the operating deck are approximately 70 m (230 ft) north-south by 42 m (137 ft) east-west. ~~The operating area deck floor is bounded to the north by the load-in/load-out area (truck trailer vestibule and MCO service station) and support building foundations, and to the south by the HCS Annex foundation.~~ The operating deck structure contains numerous through-thickness steel sleeves (embeds) that receive the storage tubes and tube plugs for both the standard MCO and overpack MCO locations in vault 1, and that provide a location for the tube plug cover plates in vault 1 or deck embed cover plates in vaults 2 and 3.

These embeds are offset and arranged at a center-to-center distance of 1.42 m (4 ft, 8 in.) east to west and 1.37 m (4 ft, 6 in.) north to south, as shown in Figure 2-52-4.

This distance between MCOs has been evaluated for criticality and found to be appropriate (see Chapter 6.0). Two hundred twenty standard and six overpack embeds are provided for each of the three vaults. Each of the standard embeds is stepped down from a diameter of 1.07 m (3 ft, 6 in.) at the upper surface of the operating deck. The overpack embeds are similarly stepped down from 1.2 m (4 ft) at the operating deck. Details of the standard tube, embed, and plug at the deck level are shown on Figure 2-62-5 along with the overpack tube plug assembly. Overpack embeds, tubes, and plugs are nominally 5 cm (2 in.) ~~15 cm (6 in.)~~ in diameter larger than the standard.

Each vault ~~also~~ is provided with penetrations through the operating deck to accommodate a rectangular intake structure, 3.3 m x 4.9 m x 0.6 m thick (10 ft, 8 in. x 16 ft x 2 ft thick) and a circular exhaust stack foundation 3.5 m (11 ft, 6 in.) in diameter and 1.4 m (4 ft, 6 in.) thick. Each of the three exhaust stack bases is furnished with 44 57-mm (2.25-in.) diameter anchor bolts to which the steel exhaust stacks will be fastened. The intake structure and exhaust stack bases are designed for the ~~safety class-NPHS~~ loads given in Table 1-23.

The HCS Annex is an extension to the south of the operating deck. Its ~~foundation~~ is a reinforced concrete structure that houses process module mounting plates and seven process pits for HCS equipment. The dimensions of the HCS Annex ~~foundation~~ are 10.7 m (35 ft, 3 in.) by 42.3 m (138 ft, 11 in.) by 1.5 m (5 ft) thick; the reinforced concrete slab is supported at grade. A loading-staging vestibule is located on the west side of the HCS Annex for egress and ingress of HCS equipment. The dimensions of the loading-staging vestibule ~~foundation~~ are 7.6 m (24 ft, 11 in.) by 8.3 m (27 ft, 4 in.). An outer and inner door in the loading-staging vestibule serve as an air-lock for area ventilation confinement.

The load-in/load-out area is an extension to the north of the operating deck. It houses an MCO service station ~~pit~~ and ~~process~~-lines and provides trenches and anchor bolts for receiving crane, service ~~station enclosure tent~~, and ~~tent~~-gantry rails. The load-in/load-out area's reinforced concrete slab is 42.2 m (138 ft, 4 in.) by 9.1 m (29 ft, 9.5 in.) by 1.5 m (5 ft) thick supported at grade. A truck vestibule forms an extension to the west of the load-in/load-out area. The dimensions of the truck vestibule slab are 13.0 m (42 ft, 7 in.) by 15.5 m (50 ft, 9.5 in.) by 1.5 m (5 ft) thick. ~~The~~ reinforced concrete slab is supported at grade. An outer and inner door in the truck vestibule serve as an air-lock for operating area ventilation confinement. ~~A second service pit is~~ ~~Two additional service pits~~ are provided in the CSB load-in/load-out area for MHM maintenance and future transloading of Fast Flux Test Facility (FFTF) fuels. Details of ~~this~~ ~~these~~ service pits can be seen on Figure 2-72-6, sheets 1 and 2.

Surrounding the operating area on the south, east, and west is a 1.3-m (4-ft, 4-in.) thick by 1.0-m (3-ft) high concrete perimeter curb. The curb is 0.6 m (2 ft) wide and 2.4 m (8 ft) high at the north wall of the load-in/load-out area for shielding of support building personnel from the MCO transport cask. Doors ~~are will be~~ provided for personnel traffic through this shield

wall. ~~The other portions of the perimeter curb are required to provide shielding. The operating area steel superstructure is will be attached to anchor bolts set at column locations throughout this perimeter curb.~~

2.4.2-3 Steel Structures

Storage tubes are located in the operating floor by the floor embeds and supported from the basemat by a tube base assembly. Each of the 220 standard storage tube assemblies in vault 1 will include two impact absorbers (one at the bottom of the storage tube, the other in between the two MCOS), a tube base, and a tube plug. Each storage tube location will receive a plug cover plate. In vaults 2 and 3 the operating floor embed locations will not include storage tube assemblies. Embed covers will be placed at the floor level in these embed openings until a future mission is identified that requires utilization of these openings.

The storage tubes are restrained from lateral movement at the basemat by the tube base assemblies into which they are inserted. These are shown on Figure 2-82-7. The tube base assemblies are carbon steel, welded structures designed to the requirements of ANSI/AISC N690-94 (ANSI/AISC 1994). They are affixed to embedded plates in the basemat slab. The tube base assemblies are designed with cooling passages to ensure that the temperature at the basemat slab will not exceed the 66 °C (150 °F) concrete temperature limit. The basemat slab embeds serve as alignment and horizontal seismic restraint points for the storage tube base assemblies. The basemat slab embeds were designed and installed to the standards in ANSI/ACI 349-85, ~~Code Requirements for Nuclear Safety Related Concrete Structures~~ (ANSI/ACI 1985), and were part of the existing HWVP CSB construction.

The standard and overpack storage tubes ~~also are provided with a stainless steel expansion bellows to complete the assembly. These are shown on Figure 2-92-8.~~ Bellows permit unrestricted thermal growth of the storage tube, accommodate differential movement of the operating deck in relation to the basemat slab, and seal the operating area from the vault. The standard bellows assembly is 0.94 m (37 in.) in diameter and 17.8 cm (7 in.) tall. The bellows are constructed of 0.91-cm- (0.036-in.-) thick stainless steel in accordance with ASTM SA-240, Type 304 series or Type 321. Bellows weld ends are furnished in accordance with ASME SA-36/36M or ASME SA-516. The bellows are shown on Figure 2-9.

The standard storage tubes, which are 12.1-m- (39-ft, 7-in.-) long, are carbon steel pipes, 0.7 m (28 in.) in diameter, closed at the bottom. When the bellows are in place at the top, the storage tube assembly is 12.6 m (41 ft, 4 in.) long. The overpack storage tubes are SA-36 carbon steel plate pipes of the same length, thickness, and design as the standard storage tubes but 0.8676 m (3430 in.) in diameter. Overpack storage tube assemblies are provided in vault 1 for potential future use. These standard and overpack storage tube assemblies are safety-class (safety class 1) and storage tubes are designed and fabricated to the requirements of the Boiler and Pressure Vessel Code (ASME 1995a), Section VIII, Division 1 as modified by the conclusions in the ASME tube material evaluation report (Williams 1997). Supporting analyses are in accordance with ANSI/AISC N690-94, ~~Specification for the Design, Fabrication, and Erection of Steel Safety Related Structures for Nuclear Facilities~~ (ANSI/AISC 1994). Bellows assemblies are designed to

the Boiler and Pressure Vessel Code (ASME 1995a), Section III, Class MC, Subsection NE. Standard storage tubes are specified as API Specification 5L, *Specification for Line Pipe* (API 1995), Grade BCS material with a wall thickness of 12.7 mm (0.5 in.). Overpack tubes are will be SA 36 carbon steel plate of the same thickness. Ongoing evaluations are expected to show that this material is equivalent to ASTM A 36 by a commercial grade dedication process. As an alternative, the API 5L plate material is may be recertified by the tube manufacturer to SA 36, an acceptable ASME Code material according to Section UC 10 of Section VIII of the Boiler and Pressure Vessel Code (ASME 1995a). Code stamping of the tubes is not required.

The working pressure of the standard storage tube pipe material's working pressure is 5,170 kPa gauge (750 lb/in² gauge) at 21 °C (70 °F). The maximum calculated service pressure will be 524 kPa gauge (76 lb/in² gauge) (FDI 1996, Calculation CSB-PR-008) when an MCO rupture disk bursts; the normal service pressure is 5528 kPa gauge (84 lb/in² gauge). The pressure-retaining function of the standard storage tube is accomplished by tube plugs that bolt to the tube flange below the bellows assembly. There is sufficient clearance tolerance between the tube wall and impact absorbers to prevent lateral loads from contacting the tube wall during staging or storage or in the event of an MCO drop.

Standard storage tubes are provided with impact absorbers at the bottom inside the base of the tubes (lower impact absorber) and between each MCO (intermediate impact absorber). Specifications for the lower impact absorbers require that they limit the deceleration of a dropped MCO to 35 g, and the radial load on the storage tube to 3,450 kPa gauge (500 lb/in² gauge) or less. To account for uncertainties in the final MCO design, the storage tube impact absorber has been designed assuming a maximum MCO weight of 9,120 kg (20,100 lb) as compared with the maximum value of 8,869 kg (19,512 lb) given in WHC-S-0425 (Swenson 1996, Table 3.2.2.1.2.2-2). In specifying the lower impact absorber, the results contained in Letter SCS-W-96-576, *Drop Analysis of Multi-Canister Overpack in Canister Storage Building* (Hyde 1996a) were used. The report (Hyde 1996a) indicates that the impact absorbers should be designed to limit the MCO deceleration to 35 g. Further analysis shows that an intermediate impact absorber is required between MCOs to prevent local damage to the MCO shield plug top and to protect the MCO mechanical seal from damage. The design of the intermediate absorber bottom will need to accommodate the MCO venting and pressure relief functions. In the event of an overpressurization, the released gas would travel to the annulus between the MCO and storage tube. The bottom impact absorber is specified to limit its sideward thrust on the storage tube during deformation to that of the tube's working pressure. The bottom and intermediate impact absorbers are shown on Figure 2-102-9. Impact absorbers for standard and overpack storage tubes are shown on Figure 2-9.

[The following has been moved to Section 4.3.5.4.] Analyses have shown that the MCO shell when fully loaded will not yield when exposed to accelerations below 150 g and will not buckle (become unstable) until the accelerations reach 700 g (Hyde 1996b). By review of the analysis results, it is apparent that the MCO wall does not expand to values greater than 1.3 cm (0.5 in.) until exposed to more than 300 g. Analysis of the postulated MCO drops into the storage tubes shows that the accelerations on the MCO when dropped into the CSB storage tube with impact absorbers is well below 100 g

(Hyde 1996b). Thus the MCO will not impose any lateral loads on the storage tube.

The standard tube plug assembly provides radiation shielding, holds gas pressure in the storage tube, and allows access to the tube interior for gas inerting, gas pressure monitoring, pressure relief, and high-efficiency particulate air (HEPA) filtering of released gases released from MCOs. The standard tube plug body is designed, fabricated, inspected, and tested in accordance with the Boiler and Pressure Vessel Code (ASME 1995a), Section III, Subsection NE, Class MC. Standard tube plug valves and piping are designed, fabricated, inspected, and tested in accordance with ASME B31.3, *Chemical Plant and Petroleum Refinery Piping* (ASME 1995b). Piping material is in accordance with ASTM A53, *Standard Specification for Pipe, Steel, Black and Hot Dipped, Zinc-Coated, Welded and Seamless* (ASTM 1995c). The standard plug has a cast steel top (in accordance with ASTM A27/A27M [ASTM 1993], Grade N2, Class 1, and ASTM A781/A781M [ASTM 1995b]) and concrete lower portion. The concrete barrel of the standard plug is constructed of SA36 material. The tube interior is accessed through two 5-cm (2-in.) holes drilled into the casting that connect to two 3.8-cm- (1.5-in.-) diameter tubes. ~~The following has been moved to Section 4.3.5.4.]~~ All structural welds on the plug are full penetration welds and will withstand a 2.9 m (9.5 ft) drop of the plug onto the storage tube.

The 45° sealing surface section of the standard tube plug is mated sealed to the upper 45° sealing surface section of the storage tube. The sealing is done using two O-ring seals constructed of ethylene propylene in accordance with the requirements of ASTM D2000, *Standard Classification System for Rubber Products in Automotive Applications* (ASTM 1995a). The O-rings are fully compressed by the plug's weight and the 45° surfaces make metal-to-metal contact that attenuates radiation exposure to the O-rings. The O-ring seals are tested by pressurizing between the seals through a built-in test connection located in the plug. The uplift force on the plug, caused by gas pressure, is held by the weight of the plug and eight hand-tightened hold down clamps that connect to the by-bolts on to the 45° upper section of the tube. The bolts are specified to be in accordance with ANSI B18.3, *Socket Cap, Shoulder and Set Screws (Inch Series)* (ANSI 1995), and ASTM A574, *Standard Specification for Alloy Steel Socket Head Cap Screws* (ASTM 1992b). The eight hold down clamps are held in position by retaining points on the clamp tips that grip the bolt heads and the engagement of the clamp screws in a 0.3-cm (0.125 in.-) retaining groove machined into the top surface of the plug. The clamps are connected by steel cable to a flat steel ring plate to ensure that all the clamps are removed before the plug-MCO is lifted by the MHM. The plate rests on the plug's lifting lug and will not allow the plug grapple to engage the lug until the hold down clamp and ring plate assembly (spider) are removed. The standard tube plug lifting lug is in accordance with ASME B30.20-1993 (ASME 1993a).

Standard tube plugs are shown on Figure 2-62-5. The dose rate estimate, based on the Monte Carlo, three-dimensional geometry MCNP-4A code's streaming and scattering calculations (Breisemeister 1993), is about 2.0 mSv/h (200 mrem/h) near the top of the plug-tube gap (top of the bottom straight plug section). At the surface of the operating deck, the upper limit of the dose rate caused by the radiation from this gap is less than 2.0×10^{-3} mSv/h (0.2 mrem/h). The radiation fields will be confirmed as a result of routine

monitoring by health physics technicians during operations and filling of the vault. The operating deck dose rate can only be approximated, based on the analysis performed, since the complicated geometry and low dose rate make it difficult to achieve adequate Monte Carlo statistics for a precise answer. This analysis was performed on the earlier (low pressure) concrete and steel composite plug. Details of the shielding analysis can be found in calculation number CSB-SH-2002, *Floor Plug/Deck Interface Analysis* (Kidd 1996a). Overpack storage tube plugs were similarly analyzed. ~~Additional calculations are being performed with the new 1.0 MPa gauge (150 lb/in² gauge) plug design. Only minor changes in dose rates are expected since the source terms are the same. The results will be included in the next phase.~~

The tube plug leak rate will be tested each time the tube is refilled with inert gas, using the same criteria as for construction acceptance. The current tube plug acceptance specification includes a test procedure to verify that the leak rate through the double seal is less than 1×10^{-4} standard cm³/s (3.5×10^{-2} standard ft³/sec) at a test pressure of 27 kPa gauge (4 lb/in² gauge). This test pressure ensures retention of inerting gas in the tubes during normal operations. Since this test measures leakage from the middle (out through both seals at once), the in-service leakage rate through one seal at a time will be lower (one-fourth on average). This leakage rate was chosen to minimize the release of contamination from the tube in the event of a burst MCO rupture disk.

Pressure relief valves in the standard tube plug are designed to lift at 62 kPa (9 lb/in²), thus providing a means for the inerted storage tubes to maintain a normal operating pressure of 7 kPa to 28 kPa gauge (1 to 4 lb/in² gauge). The pressure relief valves meet the requirements for Class 2 components in accordance with the Boiler and Pressure Vessel Code (ASME 1995a), Section III, Subsection NC, and the seat leakage requirements of API STD 527, *Seat Tightness of Safety Relief Valves* (API 1991). Allowable leakage is not to exceed 9.4×10^{-4} standard m³/s (2×10^{-4} standard ft³/min) up to 90% of set pressure. The storage tube plug must be fastened to the tube to prevent the plug from lifting at the tube system design pressure of 524 kPa (76 lb/in² gauge). The approximate weight of the standard size storage tube plug is 2,406 kg (5,300 lb). During an MCO overpressurization accident as described in Section 3.4.2.1, the MCO pressure will reach 1.0 MPa (150 lb/in² gauge) above the tube pressure before the MCO rupture disk bursts and releases particulate into the storage tube. ~~Should the resultant rise in tube pressure exceed the HEPA filtered plug's venting capabilities, the lifting forces on the tube plug could result in the release of unfiltered storage tube gases past the seals and into the operating area. The design of the storage tube plug seals, relief valves, HEPA filters and lock down devices, as described in Section 4.3.5.2, mitigates against this release.~~

~~A steel cask pedestal is provided in the MCO service station load-in/load out area for elevation alignment of the cask with the top of the operating decks.~~

Tube plug covers protect the tube plug connections and devices and fit flush with the operating deck. They are 76.2-mm- (3-in.-) thick carbon steel disks provided with lifting lugs and a concentric inspection port for tube servicing operations and tube pressure monitoring. The deck embed covers in vaults 2 and 3 are 12.7-mm- (0.5-in.-) thick carbon steel plates designed with

tube steel reinforcement and with gaskets at deck embed contact surfaces. They provide for personnel safety and maintain a level floor surface. Both the plug and embed covers are shown on Figure 2-112-10.

A steel cask pedestal is provided in the MCO service station load in/load-out area for elevation alignment of the cask with the top of the operating decks.

~~2.4.2.4 Mobile Containment Service Tent and Gantry Crane. [This section has been moved to Section 2.5.1.2.]~~ The mobile containment service tent is wheeled and travels on rails in the load in/load out area of the CSB. Positive restraints are provided between the base of the tent and the support rail to prevent the tent from lifting up or moving off the rail during a seismic event and resulting in a potential loss of function.

The mobile containment service tent will be staged in an area adjacent to and to the east of the MCO service station. The tent will be staged over the MCO service station pit after receiving a transport cask loaded with an MCO. The tent will be pushed manually away from the MCO service station pit after the servicing of the MCO has been completed and the shielding hatch assembly has been placed over the pit.

The mobile containment service tent is equipped with a HEPA filtered exhaust unit with a built in standby exhaust fan. One fan is in standby while the other is in operation. The exhaust system will maintain a negative 125 Pa (0.5 in. water gauge) pressure within the tent enclosure during the servicing operations. The exhaust unit discharges to the operating area exhaust stack. On a loss of normal power, the emergency generator system will provide power to the mobile containment service tent exhaust system.

The tent and the filtered exhaust system form the confinement envelope for the zone 2 ventilation area around the MCO service station. The confinement atmosphere is supported by maintaining a 125 Pa (0.5 in. water gauge) negative pressure inside the tent. To achieve and maintain this negative pressure, the tent is sealed to the floor, and the openings and joints in the material of the tent are designed to efficiently maintain the seal.

The tent material is a fire resistant nuclear grade fabric with a specific weight of 425 g/m² (18 oz/yd²) minimum. The tent material meets or exceeds all the requirements of MIL C 4306G, *Cloth and Strip, Laminated or Coated, Vinyl Nylon or Polyester High-Strength, Flexible* (MIL 1989), Type I specifications. The tent material is also in accordance with NFPA 701, *Standard Methods of Fire Tests for Flame Resistant Textiles and Films* (NFPA 1996), Chapter 12, and has a maximum tearing strength that is in accordance with ASTM D 2261, *Standard Test Method for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant Rate of Extension Tensile Testing Machine)* (ASTM 1983a), and ASTM D 2262, *Standard Test Method for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant Rate of Traverse Tensile Testing Machine)* (ASTM 1983b).

The tent is equipped with a lighting system to provide an illumination level of not less than 75 lx (70 footcandle) for a distance of 2.7 m (9 ft) from the top of the MCO. The tent has enough capacity to house the cask lid,

the shield ring, the shield hatch assembly, the 5 ton gantry crane and hoist, and the storage rack. The tent is equipped with service sleeves, 7.6 cm (3 in.) diameter minimum, to bring services into the tent as needed to support ventilation, to supply power, and to introduce tools.

The 5 ton motorized gantry crane has an underhung electrical wire rope hoist. The crane does not exceed 2.4 m (8 ft) in total height and has a maximum lift of 4.6 m (15 ft). The underhung electrical wire rope hoist is equipped with brakes, end stops, and a free rotating hook. The wheels of the gantry crane are designed to withstand a minimum loading of 2,270 kg (5,000 lb) each and are provided with locking devices to prevent movement while in use. The gantry crane has an acceleration control, and its travelling speed does not exceed 10.7 m/min (35 ft/min). The wire rope hoist has a lift speed of 3.0 m/min (10 ft/min) maximum, and the motorized trolley has a 7.6 m/min (25 ft/min) maximum speed.

The MCO service station gantry crane and hoist are designed in accordance with ANSI/ASME B30.10, *Safety Standard for Hooks* (ANSI/ASME 1995d), ANSI/ASME B30.16, *Overhead Hoist (Underhung)* (ANSI/ASME 1995b), ANSI/ASME 30.17, *Overhead and Gantry Cranes (Top Running Bridge, Single Girder, Underhung Hoist)* (ANSI/ASME 1995a), and ANSI/ASME HST 1M, *Performance Standard for Overhead Electric Wire Chain Hoists* (ANSI/ASME 1995e).

2.4.2.5 Multicanister Overpack Handling Machine. [This section has been moved to Section 2.5.1.5] The MHM as provided by Foster Wheeler Environmental Corporation is a fully shielded machine whose purpose is to remove MCOs from the service station pit in the receiving area of the CSB, place the MCOs in the vault storage tubes (having first removed and subsequently replaced the storage tube plug), and transfer and retrieve MCOs to and from the hot conditioning ovens. The MHM can be used to reverse the operation and remove the MCOs from the vault and, in addition, can handle the storage tube impact absorbers.

The MHM consists of two main units that operate simultaneously as a single machine: the gantry crane system and the shielded turret system. The gantry crane system is a 125-ton capacity, equal leg gantry with a top running trolley. The crane system includes the trolley and control panel, girders, end ties, wheel trucks, and seismic clamps. The shielded turret system includes the cask body, MCO hoist, ventilation system, shield plug hoist, television navigation cameras, shield skirt, and turntable.

The MHM gantry crane system is mounted on rails that run north south in recessed troughs in the operating deck. The span between rails is 38.6 m (126 ft, 6 in.). The shielded turret system is mounted on the trolley, which runs in the east west direction. The cask trolley can travel 31.6 m (103 ft, 10 in.) east west and 58.06 m (190 ft, 6 in.) north south (see Figures 2-11 and 2-12). Specifications for the gantry and main trolley systems require that they be designed and fabricated to meet the requirements of ASME NOG-1 1995, *Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)* (ASME 1995b), Type 1, and NUREG 0554, *Single Failure Proof Cranes for Nuclear Power Plants* (NRC 1979).

The MMH gantry and trolley and the CSB support structures are designed with seismic restraints that will prevent damage to an MCO if a seismic event were to occur during handling.

The MMH controls are provided with east-west and north-south motion interlocks with the cask motion. The interlocks are designed to prevent damage to the MCOs during handling if a seismic event or MMH trolley control system failure were to occur. The MMH main girders are located at a height of 2.75 m (9 ft) above the operating deck to clear the MCO service station, the tube vent and purge carts, and the HCS process enclosures.

The turret consists of a rotating upper assembly and a stationary bottom nose assembly. A retractable shield skirt mounted to and concentric with the nose assembly is lowered to complete the shielding when the MMH is engaged with a storage tube or when the shield hatch is positioned over the MCO service station pit. The skirt is connected to a nose tube and is sealed with elastomeric O-rings to the operating station where it is positioned (storage tube or service station).

When the MMH is located over the MCO service station and the shield skirt is lowered and sealed, the turret is rotated into position to remove the center shield plate. The center shield plate is removed with the MMH's shield plug grapple and hoist. The turret is then rotated to position the cavity over the operating station, and the MCO is removed using the MCO hoist and grapple. After the MCO has been raised to the transporting position, the turret is again rotated, and the center shield plate is replaced in the shield hatch. The shield skirt is raised and locked into position, and the MMH then transports the MCO to the designated storage tube.

Upon arrival at the storage tube station, the shield skirt is lowered into place and sealed to insure proper confinement and shielding. The turret is rotated to position the shield plug cavity over the storage tube, and the shield plug is removed using the shield plug grapple and hoist. When the shield is in its stored position, the turret is rotated to align the cavity over the storage tube and the MCO is lowered into position using the MCO grapple and hoist. After the MCO is in place, the turret is again rotated to position the tube plug and it is reinserted into the tube opening. The shield skirt is then raised and the MMH taken to a designated staging or storage position. MCO retrieval and replacement operations are carried out in a similar manner for transfer of MCOs to and from the HCS ovens.

The dose criterion "shielding goal" for the MMH is 2.0×10^{-3} mSv/h (0.2 mrem/h) at contact (1 cm [0.4 in.]) with the MMH. The 10 CFR 835 design objective for controlling personnel exposure from external sources of radiation in areas of continuous occupational occupancy (2,000 h/yr) is to maintain exposure levels below an average of 0.5 mrem (5 microsieverts) per hour and as far below this average as is reasonably achievable. The 2.0×10^{-3} mSv/h (0.2 mrem/h) at contact goal considers the possibility of multiple other sources associated with the CSB.

The slant angle concrete path and the gap between the MMH and deck surface needs to be taken into account when estimating the dose rate at the floor surface of the operating deck. The dose rate including streaming should be less than the shielding goal of 2.0×10^{-3} mSv/h (0.2 mrem/h). The dose

rate was reduced by adding an extended shield gate skirt that extends at least 91 cm (36 in.) beyond the edge of the floor embed. Based on the preliminary specification scoping shielding analysis (Kidd 1996b), this distance is judged to be adequate. In addition, the MMH deck gap radiation streaming was mitigated by the use of a steel below deck insert into the embed on the bottom of the shield gate that blocks the direct line of sight radiation as the MGO is withdrawn into, or out of, the MMH (there is approximately 13 cm [5 in.] of steel blocking the path in addition to the very narrow and extended gap based on the extended skirt described above).

The air from the MMH cavity is monitored by a tritium monitor, which also monitors for ^{85}Kr activity, and by an alpha beta continuous air monitor that monitors for breakthrough of the MMH ventilation system's HEPA filters. The probes are located adjacent to the exhaust of the MMH ventilation system.

2.4.2.6 Receiving Crane. *[This section has been moved to Section 2.5.1.1.]* The receiving crane is a 60-ton capacity gantry crane with one 60-ton main and one 10-ton auxiliary wire rope hoist supported on a top running trolley (Figure 2-13). The crane operates in a chemically clean indoor environment in the load in/load out area of the CSB. The crane is equipped with a shielded operator station together with remote accessories such as a powered rotating hook, local control panels, and a radio controlled operator station. The various tasks performed with the receiving crane are mainly associated with off loading MGO shipping casks in preparation for the MGO's transfer to the storage vault.

The receiving crane gantry has a span of 8.4 m (27 ft, 6 in.) and can travel 50 m (164 ft) in an east-west direction. The crane runs on runway rails that are recessed and flush with the operating floor. The runway travel of the receiving crane intersects with that of the MMH, which is also a gantry crane system. The intersecting runway rails are coplanar and therefore have been provided with movable rail sections that match the bridge wheels on both cranes. The limits of gantry travel are established by bridge stops that have been accommodated in the east and west building walls. These stops are designed to be contacted by bumpers mounted on the gantry trucks to absorb the energy of a kinetic impact.

The receiving crane is considered de-coupled from the runway rails (e.g., no mechanical rail clamps). Lateral displacement is restrained by the wheel flanges and longitudinal displacement is restrained by the crane wheel brakes during a seismic occurrence. The receiving crane is stable against overturning during a seismic occurrence with a safety factor of 1.1, in accordance with ASME-NOG-1 (ASME 1995b).

The receiving crane is provided with a hook coverage capability that extends beyond the CSB load in/load out area. The maximum hook elevation of the main hoist hook is based on the need to lift a transportation cask containing FFET fuel from the road truck.

The receiving crane system is designed, fabricated, manufactured, inspected and tested in accordance with the requirements of NUREG 0554 (NRC 1979); CMAA Specification No. 70, *Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes* (CMAA 1994); ASME-B30.20, *Below the Hook Lifting Devices* (ASME 1993); and

ASME NOG 1 (ASME 1995b), Type I with the exception of NOG 5420(a) (reeving is in accordance with CMAA Specification No. 70 [CMAA 1994]), and NOG 5428.1 (a single hook is used rather than a double hook).

The receiving crane is expected to receive some radiation exposure when the shipping cask is being moved. Based on an analysis of the side exposure to the receiving crane, a maximum rate of about 11 mR/h is obtained, or about 4×10^3 Rad for a 40 year lifetime total integrated dose. This is a conservative value because it is unlikely that the receiving crane will experience a 40 year continuous work schedule.

The receiving crane has a shielded operator station mounted on the north bridge truck. The shielding is 9 cm (3.5 in.) thick carbon steel with viewing windows that have a shielding equivalency of 9 cm (3.5 in.) of iron or 1-MeV photons reduced by a factor of 50.

The receiving crane, including its load blocks, will not be exposed to temperatures, pressures, or chemicals that would require special design considerations.

2.4.2.7 Tube Vent and Purge Carts. *[This section has been moved to Section 3.5.1.6]* The tube vent and purge cart (Figure 2-14) is designed to monitor storage tube gas pressure and composition, evacuate air, pressurize and dilute tube gas with inert gas, and provide for controlled venting of gases emitted from the MCOCs. The gases are monitored and vented to the operating area through HEPA filters on the cart. The cart also can maintain and replenish the inert gas atmosphere in the storage tubes. An inert pressurized atmosphere is maintained in the tubes, which contain staged MCOCs, to prevent an accumulation of explosive mixtures of hydrogen and oxygen. Periodic tube venting also keeps the pressure from rising high enough to activate the relief valves in the plug.

The cart is connected to process piping on each tube plug. The process piping allows monitoring and purging of the tube atmosphere without removing the plug. The air in the accessed tube is evacuated using the vacuum pump, and the inert atmosphere is supplied from high pressure inert gas bottles on the cart. Pressurization with inert gas is controlled through a pressure regulator, and overpressurization of the tube is prevented by a relief valve. A restrictive flow path from cart to tube also makes rapid overpressurization unlikely. The inert gas pressure in the tube is left slightly positive after inerting, and hydrogen, periodically relieved from the MCOC, gradually increases the pressure within the tube.

The schedule for venting, purging, and inerting the tubes is determined from initial operating experience. The interval between scheduled visits is set so the hydrogen concentration will be below 4% (the lower flammability limit for pure hydrogen in air). Temperature variations in the vault will affect the tube pressures; therefore pressure is not a sensitive indication of hydrogen concentration. Instead, the hydrogen concentration is measured each time the cart makes a scheduled visit to a tube. The measurement result is used to adjust the schedule as necessary. Should the hydrogen concentration exceed 4%, the tube gas will be diluted to below 4% before using the vacuum pump. The cart includes a function to automatically dilute pressurized gas that is higher than 4% hydrogen with inert gas as the pressure is vented from

the tubes through the cart and into the operating area. Several carts will be required in order to meet the contemplated schedule when vault 1 staging capacity is reached. One cart will be reserved as a spare during normal operations.

The currently conceived operations scenario assumes that when gas generation from the first MCO in a tube has declined to very low rates, a second MCO is added to the tube; the purging and inerting process is repeated at that time. Periodically (up to 18 times per day), the tubes will be vented through the cart system and reinerted at the original slightly positive tube pressure. Tubes that contain only sealed MCOs, or no MCOs, do not require servicing by the tube vent and purge cart. The operating philosophy will be developed to accommodate actual conditions expected after the MCO design and hydrogen generation modelling are complete.

During the time the cart is being used to perform venting, purging, and inerting, the portion of the connected system that is between the cart mounted HEPA filters and the tube atmosphere fills the same secondary confinement role as the storage tubes. Under accident conditions this confinement provides mitigation of radionuclide releases from the MCOs.

2.4.2.8 Emergency Diesel Generators. *[This section has been moved to Section 2.8.1.2]* The emergency generator system is housed in the support building at the north end of the CSB. The system is composed of two identical and redundant units, each rated at 100 kW output (3 phase, 480 V) and powered by a V 6 turbocharged diesel engine with air starter. The engine generator sets are positioned on vibration isolators to minimize transmission of vibration. The system has been designed in accordance with *Engine Driven Generator Sets Guideline Specifications for Emergency or Standby (EGSA 1992)*; *IEEE 446, Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE 1987)*; *NFPA 70, National Electrical Code (NFPA 1993)*; and *NFPA 110, Standard for Emergency and Standby Power Systems (NFPA 1996)*.

The two units are located in different rooms separated by a 2 hour firewall in accordance with *ANSI/NFPA 30, Flammable and Combustible Liquids Code (ANSI/NFPA 1993)*. Each room houses the diesel generator set; a 190 L (50 gal), double walled, diesel fuel day tank; and a 1.5 m³ (55 ft³) starting air receiver, operating at 759 kPa gauge (110 lb/in² gauge), that is capable of providing six consecutive starts of the diesel generator. Each room also houses an automatic transfer switch that will initiate the startup of the diesel unit on sensing a loss of offsite power.

When a loss of offsite power occurs, each of the automatic transfer switches will send a start signal to its dedicated generator, power the emergency busses, and thus transfer the safety class 2 loads to its generator within 15 seconds of the occurrence. The automatic transfer switch is programmed in such a manner that after two unsuccessful starting attempts, it will activate the second emergency generator to start and carry the safety class 2 loads. The generator will come up to speed within 6 seconds of receiving the signal to start. The two automatic transfer switches also are programmed in such a way that one is a lead and will receive the starting signal first, and if for some reason it fails to operate, the second transfer switch will take over and initiate the starting procedure.

Each generator will have a load bank permanently installed on the exhaust side of the engine radiator, on the generator skid extension on the north side of the diesel engine. This 100 kW load bank will allow generator load testing as needed.

Rotating equipment exposed to the outside contact is protected by metallic guards to prevent contact. The protection provided is in accordance with OSHA Instruction Standard 112.14, *Guards for Rotating Equipment* (OSHA 1978). Hot surfaces of 49 °C (120 °F) or more exposed to human reach are insulated to prevent burns. This is in accordance with ASTM C1055, *Standard Guide for Heated System Surface Conditions that Produce Contact Burn Injuries* (ASTM 1992).

Two 1,900 L (500 gal) diesel fuel storage tanks are located outside the north wall of the support building at a distance of 3 m (10 ft). Each tank is a double walled, insulated, aboveground tank with a leak detection system. Overfill protection compartments can contain up to 95 L (25 gal) of overfill. When full each tank contains enough fuel to run one diesel generator unit for 48 hours at full power. Each tank has a positive displacement pump mounted on the top of the tank. This pump is to react to the level control on the 190 L (50 gal) day tank and keep the day tank filled with diesel fuel. The top of the storage tank is equipped with a walkway and ladders for access and maintenance. The two diesel fuel storage tanks are to be filled by a dispenser nozzle from a diesel fuel truck.

2.4.42-9 Canister Storage Building Above-Grade Structures (Intake Structure, Exhaust Stack, Operating Area Shelter, and Support Building)

2.4.4.1 Intake Structure and Exhaust Stack. The CSB intake structure is a 5.2 m x 5.5 m x 6.7 m high (17 ft x 18 ft x 22 ft high) steel structure mounted on top of a 4.6 m x 6.1 m x 17.4 m high (15 ft x 20 ft x 57 ft high) reinforced concrete tower that is constructed monolithically with the CSB vault. The steel portion of the intake structure is a combination of a braced tubular steel frame with steel shear panels at the base. The tower is analyzed and designed as an integral part of the CSB vault structure (FDI 1996, Calculation CSB-S-0028A). The intake structure contains an inlet that increases static wind pressure by reducing the wind velocity at the windward side. A canopy is provided for increased wind pressure efficiencies. Intake structure drawings, H-2-119294 and H-2-119298, are included in Appendix 4A.

The exhaust stack is a self-supporting 49.2-m (161.5-ft) tall cantilevered structure. The diameter at the base of the stack is 4.0 m (13 ft); the diameter at the top of the stack is 2.1 m (7 ft). The bottom section of the 4.0-m- (13-ft-) diameter stack base rises 16.8 m (55 ft) and is constructed of 16-mm- (5/8-in.-) thick carbon steel plate. The middle section continues upward 10.1 m (33 ft) and tapers from 4.0 m to 2.1 m (13 ft to 7 ft) in diameter. The middle section is constructed of 16-mm- (5/8-in.-) thick carbon steel plate. The 2.1-m- (7-ft-) diameter top section of the stack continues upward another 17.4 m (57 ft) and is constructed of 9-mm- (3/8-in.-) thick carbon steel plate. The upper 13.4-m (44-ft) section of the stack is provided with vertical wind spoilers that are each 0.2 m tall by 3.4 m long (7 in. tall by 11 ft long). The spoilers are also made of 9-mm- (3/8-in.-)

thick carbon steel plate and are designed to ASCE-7-88 guidance (ASCE 1988). Stack material is ASTM-242 or ASTM-A588 Grade A (345 MPa [50,000 lb/in²] yield). Thermal gradients across the stack are of minimal design concern for the materials and temperatures involved. The stack is topped by a wind deflector tip as shown on drawing H-2-1-119300 (sheet 2). This drawing and the drawing showing the entire exhaust stack, H-2-1-119300 (sheet 1) are included in Appendix 4A.

2.4.4.2 Operating Area Shelter. The operating area shelter is a steel-framed enclosure that covers the vault operating deck, the load-in/load-out area on the north, and the HCS Annex on the south. The building is approximately 70.1 m long, 41.5 m wide, and 16.8 m high (230 ft long, 136 ft wide, and 55 ft high) and sits on a 0.9-m- (3-ft-) high concrete curb around the vault deck. The structural system consists of load-carrying roof trusses spanning the east-west direction and supported by columns spaced typically at 6.2 m (20 ft, 4 in.) centers. The weight of the operating shelter is approximately 425,000 kg (938,000 lb) for the structure and 554,300 kg (1,222,000 lb) for roofing, siding, girts, and miscellaneous weights, for a total of 979,800 kg (2,160,000 lb) (FDI 1996, Calculation CSB-S-0029).

The truck vestibule and loading and staging areas extend out from the western edge of the operations area and provide controlled transfer of equipment and materials into and out of the operating area shelter. The HCS Annex opens directly into the southern end of the operations area and uses the same MCO handling bridge crane.

The CSB has a structural system, roof, and exterior wall system made of noncombustible materials. This gives the building a construction type of Uniform Building Code Type II-N (nonrated) (ICBO 1994). Interior finishes have a flame spread index less than 25 when tested in accordance with ASTM-E84, *Test for Surface Burning Characteristics of Building Materials* (ASTM 1989), in any areas that have finishes. The CSB operating area was originally designed to the *Uniform Building Code* (ICBO 1994) classification F-2, Type II-N, (noncombustible construction). A subsequent review of WHC-SD-SNF-FHA-002, *Phase 2 Preliminary Fire Hazard Analysis for the Canister Storage Building* (Sadanaga 1996), by the Authority Having Jurisdiction (DOE-RL) determined that an H-7 occupancy classification was more appropriate. A deviation request was submitted to DOE-RL to allow the application of NFPA 101, *Safety to Life from Fire in Buildings and Structures* (NFPA 1991), and NFPA 220, *Standards on Types of Building Construction* (NFPA 1995b), in lieu of the Uniform Building Code requirements for definitions, occupancy classification, fire ratings, and types of construction (Williams 1996). Fluor Daniel Hanford, Incorporated (FDH), has received approval of the deviation request (Sellers 1996).

The roof system provides an impervious weatherproof barrier over the entire CSB structure. All roofing consists of a standing seam metal system attached to clip angles, connected to metal subpurlins, then screwed down to a structural steel deck attached to the top of the roof framing system. This deck does not provide weatherproofing; however, it is designed to resist tornado wind loads. Between the deck and roof panel, the building has 23 cm (9 in.) of batt insulation, for the equivalent of an R-30 insulation rating.

The roof for the operating area shelter has a single gable with a main ridge running north-south along the midline. All roofs slope down toward the eaves at 4.2 cm/m (0.5 in./ft). Water runs off to the outer edges of the roofs where continuous gutters catch and send the water to downspouts. The two receiving vestibules have gable roofs with main ridges running east-west along their midlines. The gable roofs have ridge flashing and the shed has counter flashing along the ridge at the common wall.

Galvanized steel gutters (18 gauge) and downspouts (26 gauge) channel the flow of water from the roofs down to a controlled runoff channel on the CSB site. The PMP is 15 cm (6 in.) per hour. For the largest typical tributary area, this would require only 15-cm- (6-in.-) wide gutters with 13-cm- (5-in.-) wide downspouts 12 m (40 ft) apart. However, the CSB is designed for 20 cm (8 in.) of rain per hour in 5-minute bursts to establish a 50% safety factor. This results in gutters 20 cm (8 in.) wide by 15 cm (6 in.) deep with 15 cm by 20 cm (6 in. by 8 in.) rectangular downspouts.

The exterior siding encloses the CSB structure in a continuous, airtight, weatherproof shell. Air leakage is less than 0.018 m³/min per square meter (0.06 ft³/min per square foot) at 1.4 kPa (30 lb/ft²) differential pressure in accordance with ASTM E283, *Standard Test Methods for Determining the Rate of Air Leakage through Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen* (ASTM 1991). Water penetration is zero at 0.3 kPa (6.24 lb/ft²) differential pressure in accordance with ASTM E331, *Test for Water Penetration of Exterior Windows, Curtain Walls and Doors by Uniform Pressure Differences* (ASTM 1986). All areas of the CSB have the same siding design, consisting of a 8-cm- (3-in.-) deep metal liner panel screwed to structural girt framing. The 8-cm- (3-in.-) deep sheet metal zee sub-girts attach horizontally to the liner panel. Fifteen centimeters (6 in.) of fiberglass batt insulation fits into the cavity of the liner panel and sub-girts providing the CSB with an R-20 exterior thermal barrier. The metal siding will resist tornado wind loads and pressure drop. Fasteners will resist both pull-out and pull-over stresses induced by the specified wind load, as well as seismic and other forces, such as construction loads, roof loading, and thermal changes. The greater cross-sectional depth of this particular siding, coupled with additional structural members for closer fastener installation, provides assurance that the design basis tornado wind loads are resisted and the siding remains on the building.

All exterior joints, whether siding or roofing and miscellaneous flashing, provide airtight and watertight sealing up to 3×10^{-4} m³/s per square meter (0.06 ft³/min per square foot) at 1.4 kPa (30 lb/ft²) differential pressure. All counter flashing, eaves, and edges have sealant mastic and tape to form a continuous barrier impervious to air infiltration. All interface points have flexible sheet metal flashing that continuously connects both adjacent surfaces and, in conjunction with the sealants, provides continuous air and water infiltration resistance. Typical interfaces include roof to wall intersections, wall to foundation intersections, wall corners, eaves, ridges, gables, expansion joints, and reveals.

Exterior siding and roofing has a factory-applied coating with a 25-year design life. Suitable refresher coatings can extend the building life indefinitely. Doors and frames have field-applied paint finishes. Hardware has a brushed stainless finish, also known as a 626 finish. The roof and the

upper section of all buildings have a teal-colored finish coat. The lower sections have a beige finish coat. All trim, doors, and frames have charcoal-gray coatings and finishes.

The operating area shelter contains a 1.2-m- (4-ft-) wide dedicated circulation way all around the perimeter walls. This passageway connects all of the emergency exits, and personnel working in the deck area can directly access the exits via the dedicated circulation way.

From the operating area shelter, two radiation shield doors allow ingress to and egress from the support building. Special exit-only doors, spaced around the exterior walls, provide the only emergency exiting from the operating area shelter. The truck vestibule and loading and staging area also have exit-only doors. The operating area shelter has eight personnel emergency exits. Personnel enter and exit the main corridor in the support building through one personnel entry door.

A large (11.4 m by 11.6 m [37 ft by 38 ft]) fabric panel "megadoor" acts as an inner airlock door large enough for the receiving crane to pass through when travelling between the truck vestibule and service pit load-in/load-out area. An overhead metal "telescope" door (6.1 m by 6.1 m [20 ft by 20 ft]) encloses the outer opening of the truck vestibule at the northwest entrance to the CSB. Two more telescoping doors (4.3 m by 4.3 m [14 ft by 14 ft]) serve as inner and outer airlock doors for receiving the hot conditioning equipment at the southwest entrance to the CSB.

The CSB has primarily a single floor level at 216.1 m (709 ft, 0 in.) elevation. Hand-held fire extinguishers are provided within the operating area as defined by NFPA 10, *Portable Fire Extinguishers* (NFPA 1994). A 2-hour fire wall separates the operations area from the support building.

Seismic and tornado lateral forces are resisted through truss-column frame interaction in the east-west direction and through a vertical bracing system along the east and west walls in the north-south direction. Building plan and elevation drawings, H-2-119311, H-2-119312, H-2-119313 (sheets 1 and 2), and H-2-119314 (sheet 1), are included in Appendix 4A.

2.4.4.3 Support Building. The CSB support building is a single story, steel-framed structure approximately 45.7 m long, 16.2 m wide, and 4.9 m high (150 ft long, 53 ft wide, and 16 ft high) located to the north of the CSB vaults and operating area shelter.

The support building abuts the north edge of the operating area shelter and contains several rooms: equipment spaces (including heating, ventilating, and air conditioning [HVAC], filters, and instrument air), electrical room, two generators, control room and security control space, health physics office, count room, regulated change room, operations office, and airlocks. The equipment areas have dedicated circulation for equipment access and servicing. These areas exit either via the main corridor or, in the electrical and generator rooms, directly to the outside.

The support building has a shed roof with the ridge along the common wall between it and the operating area shelter. A structural steel deck is attached to the top of the roof framing system. The support building roof

slopes downward at 4.2 cm/m (0.5 in/ft) to the north eave where water is collected in a gutter and downspout system equivalent to that provided for the operating area shelter. The support building roof has an occasional-use access ladder that extends up from the HVAC equipment area through a roof hatch. From the lower roof of the support building, another ladder with safety cage extends up to the high roof of the operating area shelter.

Exterior siding and roofing for the support building is of equal grade and finish appearance to the operating area shelter. The siding and exterior wall design for the support building, including exterior joints and interface points, also is the same as described above for the operating area shelter. A relatively small telescoping door (3 m by 3 m [10 ft by 10 ft]) opens to receive supplies into and discharge waste from the support building.

The primary personnel entrance for the CSB is at the northeast corner of the support building near the health physics office, control room, and operations office. A main corridor crosses the entire support building between the primary personnel entrance on the east and the loading dock on the west. This corridor provides an exit path to the primary support building exits. Operating personnel enter the primary personnel entrance, don clothing, and enter the operating area shelter from an airlock in the support building. They return by a similar path for doffing, decontamination, and egress. Personnel may access the health physics office and the operations offices, change and control rooms, and various compartments through 12 single-wide interior personnel doors, and 1 double-wide interior pair of doors. All doors have air seals around the jams and are rated for at least 1.0 kPa (20 lb/ft²) pressure; 1.4 kPa (30 lb/ft²) in the operating area. The health physics office has a view window to the personnel decontamination area.

The CSB office spaces have painted gypsum board ceilings and the control room has acoustic lay-in ceiling. The gypsum board ceilings have access hatches. Interior partitions consist of steel studs with painted gypsum board cladding. Typical walls have one layer of 1.6-cm (5/8-in.) gypsum board on each side providing a 1-hour fire rating. Typically these walls extend to the ceiling of the room. However, walls requiring higher ratings have additional layers of cladding with staggered joints and extend to the roof deck above.

Flooring in office areas consists of vinyl tile with cove base over concrete slabs. The personnel decontamination areas have a depressed floor level with an access floor aligned with the surrounding finished floor. The flooring in these access floor areas has perforations to allow sprinkler discharge to accumulate in the depressed areas until it can be decontaminated and removed. These depressed areas have coved corners and seamless sheet vinyl covering on the slab surface. Equipment areas have sealed exposed concrete floors.

Entry to the electrical room is through one tall exterior double door (1.8 m by 2.7 m [6 ft by 9 ft]) with a removable top transom that allows equipment installation and servicing. Three similar, though shorter, standard height (1.8 m by 2.1 m [6 ft by 7 ft]) pairs of exterior service doors provide access to the two generator rooms. The generator rooms also have wall louvers. The room containing the continuous airborne effluent monitor (CAEM) and the safeguards and security equipment is accessible from inside.

The support building has sprinklers throughout. Each individual area in the support building has hand-held fire extinguishers located as defined by NFPA 10 (NFPA 1994).

The foundations and superstructure of the support building are structurally isolated from the CSB vaults and operating shelter. The building houses safety-significant (safety class 2 and 3) equipment for electrical, HVAC, continuous air effluent monitors, facility operations monitoring, and change rooms. A 0.7-m (28-in.) diameter, 22.9-m (75-ft) high steel HVAC exhaust stack, supported at grade and guided at the roof, penetrates through the building roof. The structural system consists of roof beams spanning the east-west direction and supported by girders and columns spaced typically at 8.3 m (27 ft, 1 in.) on center. Seismic and tornado lateral force resistance is achieved by girder-column frame interaction in the north-south direction and through a vertical bracing system along the north and south walls. The building is brace-framed in the east-west direction. The foundations for the building and equipment are spread footings located below the frost depth. (FDI 1996, Calculation CSB-S-0019.) Support Building plan and elevation drawings, H-2-119320 and H-2-119321, are included in Appendix 4A.

2.4.3 Facility Mission

~~[This section has been moved to Section 2.3.1.] Vault 1 will contain 220 storage tubes, each capable of staging or storing two MCOs. Six additional locations are available to accommodate overpacked MCOs. Each standard storage tube will contain both a bottom and an intermediate impact absorber to mitigate the consequences of a dropped MCO. The storage tubes are safety class 1, and along with the impact absorbers, they are designed to withstand all credible DBAs discussed in Section 3.4.2 of this document including dropping of MCOs. The impact absorbers will be designed to prevent the breach of the storage tube and the MCO.~~

~~Initially the MCOs containing SNF will be staged in an inerted sealed condition in the storage tubes. Because of the potential for hydrogen generation and buildup from both radiolytic and chemical reactions of the bound and free water in the MCO after cold vacuum drying, the operating deck design will have provisions to periodically evacuate and reinert each storage tube. The design provisions include the tube plug covers (which allow access to tube plug service connections), service connections in the tube plugs, and electrical power outlets in the floor. Eventually the MCOs will be processed in the HCS Annex. Current planning calls for the MCOs to be stored in a sealed configuration upon completion of HCS processing.~~

2.4.4 Facility Design Assumptions

~~[The following was moved to Section 2.4.1.] Shielding calculations have assumed that each MCO contains the maximum activity value associated with Mark IV (MKIV) fuel listed in Table 3.2.2.1.2.2.1 and described in Section 3.2.2.1.6 of WNC S 0425, Performance Specification for the Spent Nuclear Fuel Canister Storage Building (Swenson 1996). [The following information is covered in Section 2.3.3] Vault thermal analyses have assumed that 20% of the MCOs contain the maximum heat value associated with MKIV fuel~~

and 80% contain the average value, as directed by the design authority in WHC S-0425 (Swenson 1996), Section 3.2.2.1.2.2, "Design Feed," and Table 3.2.2.1.2.2.2, "MCO General Attributes." ~~[The following information is in Section 2.5.2] Evaluations of hydrogen generation rates and MCO pressurization were based on WHC SD-SNF-TI-029, Multi-Canister Overpack (MCO) Pressurization Analysis (Bergsman 1996).~~

~~[The following information has been moved to Section 2.5.1] The presence of water in an MCO will increase the rate of hydrogen generation and the rate at which MCO pressure increases. The hydrogen pressure control strategy includes the following steps:~~

- ~~— Cold vacuum drying to remove all of the free water, significantly reducing the reaction rate~~
- ~~— Independent testing to confirm that the fuel is dry by measuring the rate at which the pressure increases while the fuel (MCO) is heated to 75 °C (167 °F)~~
- ~~— Selection of an appropriate normal condition of transport time (TBD)~~
- ~~— Verification that the pressure and temperature within the MCO does not exceed technical safety requirement (TSR) values prior to CSB receipt~~
- ~~— Hot conditioning to decompose any residual free water and decompose hydrates and hydrides prior to long term interim storage.~~

~~[The following has been moved to Section 2.5.1] Hydrogen generated in the SNF contained in the MCOs is assumed to pressurize the MCO (and periodically release from the MCOs) and cause a rise in the storage tube pressure. The H₂ generation is caused by corrosion, radiolysis of water, and by decomposition of hydrides and hydrates in the SNF within the MCOs. According to Table 3.2.2.1.2.2.2, "MCO General Attributes," in WHC S-0425 (Swenson 1996), the quantity of water present in an MCO is 1.8 kg (4 lb). This is based on the conservative assumption that 1.8 kg (4 lb) is the maximum expected amount, with 0.45 kg (1 lb) being the average.~~

~~[The following has been moved to Section 2.4.3] To account for uncertainties in the final MCO design, the storage tube impact absorber has been designed assuming a maximum MCO weight of 9,120 kg (20,100 lb) as compared with the maximum value of 8,869 kg (19,512 lb) given in Table 3.2.2.1.2.2.2 of WHC S-0425 (Swenson 1996).~~

~~[The following has been moved to Section 2.4.3] In specifying the lower impact absorber, the results contained in Letter SCS W-96-576, Drop Analysis of Multi-Canister Overpack in Canister Storage Building (Hyde 1996a) were used. The report (Hyde 1996a) indicates that the impact absorbers should be designed to limit the MCO deceleration to 35 g. Further analysis shows that an intermediate impact absorber is required between MCOs to prevent local damage to the shield plug top and to protect the mechanical seal from damage. The design of the intermediate absorber bottom will need to accommodate the MCO venting and pressure relief functions. In the event of an overpressurization, the released gas would travel to the annulus between the~~

MCO and storage tube. The bottom impact absorber is specified to limit its sideward thrust on the storage tube during deformation to that of the tube's working pressure. The bottom and intermediate impact absorbers are shown on Figure 2-9.

~~[The following has been moved to Section 2.4.3] The tube plug leak rate will be tested each time the tube is refilled with inert gas, using the same criteria as for construction acceptance. The current tube plug acceptance specification includes a test procedure to verify that the leak rate through the double seal is less than 1×10^{-6} standard cm³/s (3.5×10^{-5} standard ft³/sec) at a test pressure of 27 kPa gauge (4 lb/in² gauge). This test pressure ensures retention of inerting gas in the tubes during normal operations. Since this test measures leakage from the middle (out through both seals at once), the in-service leakage rate through one seal at a time will be lower (one fourth on average). This leakage rate was chosen to minimize the release of contamination from the tube in the event of a burst MCO rupture disk. Relief valves in the plug are designed to lift at 62 kPa (9 lb/in²), thus providing a means for the inerted storage tubes to maintain a normal operating pressure of 7 kPa to 28 kPa gauge (1 to 4 lb/in² gauge). The storage tube plug must be fastened to the tube to prevent the plug from lifting at the tube system design pressure of 524 kPa (76 lb/in² gauge). The approximate weight of the standard size storage tube plug is 2,406 kg (5,300 lb). During an MCO overpressurization accident as described in Section 3.4.2.1, the MCO pressure will reach 1.0 MPa (150 lb/in² gauge) above the tube pressure before the MCO rupture disk bursts. Should the resultant rise in tube pressure exceed the HEPA filtered plug's venting capabilities, the lifting forces on the tube plug could result in the release of unfiltered storage tube gases past the seals and into the operating area. The design of the storage tube plug seals, relief valves, HEPA filters and lock down devices, as described in Section 4.3.5.2, mitigates against this release.~~

2.4.5 Facility Modifications to Hanford Waste Vitrification—Plant Canister Storage Building

~~[This section has been moved to Section 2.3.3] The conversion of the CSB from the HWVP mission to the current SNF mission resulted in two structural revisions made possible by the lower radiation source term and lower heat load associated with the SNF MCOs as compared with the HWVP canisters. One is the removal of the intake plenum louvers in all three vaults. The other is the deletion of insulating concrete on the interior walls and underside of the operating deck in vault 1.~~

~~The total activity for one MCO is given as 309,883 Ci versus 891,000 Ci (5.4×10^{-3} Ci/gal $\times$ 165 gal) for a vitrified waste canister. This information can be obtained from Table 3.2.2.1.2.2.1 of WMC S-0425 (Swenson 1996) and Table 8.2.2 of WMC SD HWV PSAR 001 (WHC 1994). Shielding analysis results indicate that the dose rate at the base of the intake stack is less than 5.0×10^{-6} mSv/h (0.05 mrem/h), and in the adjoining below grade vault, the dose rate is less than 4.0×10^{-5} mSv/h (0.4 mrem/h) (Sienko 1996).~~

~~On page 3-32 of the WMC SD HWV PSE 001 (WHC 1992), the heat loads for the HWVP canisters in the three vaults are given as 800 canisters at 0.4 kW and 1,200 canisters at 1 kW for a total CSB heat load of 1,520 kW (507 kW per~~

vault). In Section 3.2.2.1.2.2 of WHC S-0425 (Swenson 1996), the SNF MCO heat load for one vault is given as 80% at 401 W and 20% at 852 W for a total of 192 kW for 390 MCOs. Based on these conservative assumptions, results of the thermal analysis indicate that the maximum air temperature inside the vault is 56 °C (133 °F) coincident with a steady-state intake air temperature of 46 °C (115 °F). This result is below the ANSI/ACI 349-90 (ANSI/ACI 1990) limit of 65 °C (150 °F) for reduction of concrete strength. See Chapter 4.0 for further information. Under these conditions the wall temperature of the MCO is conservatively estimated to be 118 °C (244 °F), which is well below the performance specification (Swenson 1996) limit of 132 °C (270 °F) wall temperature required to ensure not exceeding 204 °C (400 °F) for fuel centerline temperature.

The CSB design for the HWVP mission had partial length, below-grade interior walls and common intake and exhaust plenums. The current CSB configuration, as shown in Figures 2-2 and 2-3, extends the below-grade walls to isolate the individual vaults and creates individual intake and exhaust plenums for each vault. This design change also aided in the deletion of the intake shielding louvers.

The below-grade portion of the HWVP CSB was designed to carry the loads associated with a large, wheeled, shielded canister transporter that was to be used for the HWVP mission. The current CSB configuration assumes a large heavy crane, the MHM, is used to transport the MCOs. The MHM is designed to ride on steel rails that run north to south and are located at the 216.1 m (709 ft, 0 in.) floor elevation. Anchor bolts will be installed in the deck at the east and west sides of the operating floor for the installation of runway rails. The MHM rails will be installed during construction of the operating area superstructure. The MHM rails will be installed in trenches that will run north to south and cut across the receiving crane rails. The receiving crane rails will be installed in trenches that run east to west in the northernmost portion of the operating floor. The reinforced-concrete construction of that northernmost portion of the operating floor known as the load in/load out area is included in this Phase 2 of the CSB SAR. The receiving crane rails will be installed during construction of the operating area superstructure. Special rail crossover components called "frogs" will be provided in the locations where the MHM runway rails cross the receiving crane runway rails. Details of the MHM and other MCO-related handling equipment will be provided in Phase 3 of the CSB SAR.

DOE Order 6430.1A, Section 1300.3.2, considers safety class items as those whose failure would result in exposures exceeding DOE 5400 series limits for the public at the Site boundary or nearest point of public access. For the Hanford Site's 200 Area, this distance is 15,000 m (9.3 mi). The Regulatory Requirements Team's application of NRC equivalency has resulted in the requirement to identify SSCs that should be designated as important to safety in accordance with 10 CFR 72, Section 72.3, as implemented through Section 72.106 (Garvin 1996a). Once SSCs "important to safety" have been identified, the requirements for safety class 1 SSCs are imposed on them as defined in Revision 1 of WHC CM 4-46, Section 9.0, "Safety Classification of Structures, Systems and Components."

The facility design has been evaluated for the natural phenomena loads listed on Table 1-23 of Section 1.5, "Natural Phenomena Threats." NPH wind

loads associated with a reactor design basis tornado were evaluated using the tornado wind load from Table 1-23, given as 322 km/h (200 mi/h) total, versus the SDC 4.1 wind load of 145 km/h (90 mi/h) (DOE RL 1993). This higher wind load on the operating area superstructure and support building was incorporated into the appropriate analysis and load combination for the operating deck and below grade vault (FDI 1996b, Calculations CSB-S-0023, CSB-S-0025, and CSB-S-0026).

The intake and exhaust bases of the operating deck structure were redesigned to withstand tornado wind loads to meet the NRC tornado criteria for reactors as discussed in Section 1.4.1.1.4. The analysis and design of the superstructure for tornado generated missiles is discussed further in Section 4.3.4.4.

The architect engineer has performed a review of the performance requirements and design criteria imposed by ANSI/ANS 57.9 1992 (ANSI/ANS 1992). Section 6.17.1.1 of ANSI/ANS 57.9 1992 requires that the most adverse dead load loading condition be increased by 5% from the estimated value. The effects of an increase in the dead load have been included in the CSB design. The substructure walls, piers, and basemat continue to provide the strength needed to meet the criteria. The major difference between the CSB and the generic requirements of ANSI/ANS 57.9 1992 (ANSI/ANS 1992) is that in ANSI/ANS 57.9 1992 transportation package washdown, decontamination facilities, and safety class electrical power for instrumentation, lighting, communications, and physical security systems are assumed to be necessary. The technical justifications for not implementing the requirements demonstrated that nuclear safety of the facility was not impaired and that the requirements could be met by other facilities (Jacobs 1996a). Radioactive waste treatment facilities are not included in the CSB design because the volume of radioactive waste expected to be generated from CSB operations is very small and does not require an onsite dedicated radioactive waste treatment facility. Liquid radioactive waste from the CSB can be shipped by truck to the Effluent Treatment Facility in the 200 East Area. Emergency communications equipment is not provided as part of the CSB design because no dedicated emergency communication center is required; such communications will be handled through systems that interface with the Central Alarm Station. Two independent emergency generators provide backup power to safety-significant electrical loads. The generators and electrical distribution system are designed to meet the requirements of WHC CM 4-46 including the requirement that the system have sufficient redundancy to power safety-significant loads if one of its components fails to operate.

2.4.6 Construction Restart Issues

[This section has been moved to Section 2.3.4.] A readiness for construction task force of key project participants identified open issues that needed to be addressed before the restart of construction. These issues are documented in Report No. 951108-001, *Canister Storage Building Construction Restart Readiness Assessment* (Ares 1996). One of the requirements was to document the acceptability of the existing basemat before the resumption of CSB construction. Detailed inspections and evaluations of the acceptability of the existing basemat foundation were performed and documented, including a review of the adequacy and completeness of the

construction quality assurance records. The review is further discussed in Section 14.6.5.1.4.

The architect engineer prepared a statement of work document for the construction management organization to use as guidance for the inspection walkdown and report. This ensured that the report would contain sufficient information for the architect engineer to adequately evaluate the acceptability of the existing basemat. Detailed instructions to prepare the existing concrete for the resumption of construction were provided on the architect engineer's construction drawings and specifications.

Following the submittal of the architect engineer's statement of work for the inspection walkdown, the construction management organization performed a detailed inspection of the below grade vault basemat and partially completed walls (Islam 1996). The results were categorized and submitted by the construction management organization for disposition by the architect engineer. Category 1, 2, and 3 deficiencies are from CSB construction errors. Environment affected deficiencies are in category 4. To date all category 1, 2, and 3 deficiencies have been dispositioned. Category 4 deficiencies dealing with rebar, rust stains, and basemat embed surface rust have been dispositioned (Mortimer 1996). Deficiencies dealing with couplers have been dispositioned. The information on disposition is contained in RFI:PM T3-001, *Engineering Assessment Inspection* (FDI 1996a).

2.5 PROCESS DESCRIPTION

2.5.1 Baseline Operations

The SNF loaded into MCOs at the K Basins will be shipped to the Cold Vacuum Drying Facility (CVDF) covered by water. The presence of water in an MCO will increase the rate of hydrogen generation and the rate at which MCO pressure increases. The hydrogen pressure control strategy includes the following steps:

- Cold vacuum drying to remove all of the free water, significantly reducing the reaction rate
- Independent Testing at the CVDF to confirm that the fuel is dry by measuring the rate at which the pressure increases while the fuel (MCO) is heated to 75 °C (167 °F)
- Selection of an appropriate normal-condition-of-transport time (currently estimated as 4 hours TBD) to ensure that an MCO will not overpressurize before being placed in staging (current minimum bounding safety design basis estimate of 36 to 45 hours after cold vacuum drying)
- Verification that the pressure and temperature within the MCO does not exceed expected technical safety requirement (TSR) values prior to CSB receipt
- Staging with rupture disk and HEPA-filtered relief valve operational

- Hot conditioning to decompose any residual free water and decompose hydrates and hydrides prior to long-term interim storage
- Long-term interim storage with filtered lower pressure rupture disk and unfiltered safety-class rupture disk.

The MCO is shipped from the CVDFS to the CSB inside the cask in a sealed configuration (with no active pressure protection (pressure relief valve and rupture disk relief mechanism), and administrative controls on transportation and receiving at the CSB reduce the potential for significant delays while the MCO is in transit. Normal receipt at the CSB is based on tests performed on the MCO before it is shipped from the CVDF will provide an administrative window that allows time for transport to the CSB, offloading of the cask at the CSB, and MHM accessing of the MCO without the MCO pressure reaching the MCO rupture disk burst pressure or pressure relief valve pressure. Upon arrival at the CSB, the cask containing the MCO is unloaded into the MCO service station pit by the receiving crane. The MCO cask receiving system is designed to offload the MCO shipping cask from the transport trailer into the MCO service station pit in preparation for handling by the MHM.

Once the cask is inside the pit, the gas inside the cask is checked for excessive pressure, which would indicate excessive temperature or gas leakage from the MCO. The gas is sampled and the cask purged if required. If the cask pressure is and transportation time are within the normal range, the cask is vented and the lid is removed to prepare the MCO for sealed staging. Preparation consists of removing the flange covers from the MCO rupture disk and relief valve ports. The MCO must be vented before removing these covers in order to prevent accidental damage to a pressurized rupture disk during manual operations. After the covers are removed, the vent connection is used to test for leakage from the rupture disk or relief valve. The final steps in preparation are repressurization of the MCO with inert gas to 21 kPa gauge (3 lb/in² gauge) and reinstallation of the process vent connection cover. A service station portable ventilation enclosure provides secondary confinement during cask lid removal and placement of the shield hatch assembly, which provides confinement when the enclosure is removed these operations. Once reinerting operations are completed, the MCO is removed from the service pit and placed in a storage tube by the MHM. Upon completion of the MCO transfer, the shipping cask, containing an unused (empty) MCO, is loaded onto the transport trailer and transported to the K Basins for fuel loading.

The CSB includes an array of storage tubes that are cooled using passive, natural circulation air to remove the decay heat from the nuclear fuel (FDI 1996, Calculation CSB-HV-001, Table 3). This system is designed to maintain the maximum fuel centerline temperature below 204 °C (400 °F) if there is no runaway reaction of the fuel (Phillips 1996). It has been shown that fuel and MCO will not exceed temperature design limits from reactions within the MCO for all storage vault conditions. The storage vault is passively cooled using the "stack effect" to promote ventilation flow. Air passes down through the air intake stack, where its temperature and flow rate are monitored, to an inlet plenum. From the inlet plenum, the air flows into the enclosed volume of the vault, where it removes heat from the MCO storage tubes.

Hydrogen generated in the SNF contained in the MCOs is assumed to pressurize the MCO (and periodically release from the MCOs) and cause a rise in the storage tube pressure. The H_2 generation is caused by corrosion, radiolysis of water, and by decomposition of hydrides and hydrates in the SNF within the MCOs. According to Table 3.2.2.1.2.2 2, "MCO General Attributes," in WHC S 0425 (Swenson 1996), the quantity of water present in an MCO is 1.8 kg (4 lb). This is based on the conservative assumption that 1.8 kg (4 lb) is the maximum expected amount, with 0.45 kg (1 lb) being the average.

The MCO storage tube and tube plugs are designed as an integral system to provide pressure management, fire protection, and confinement. Both the MCOs and storage tubes contain pressure relief devices designed to prevent a sudden release of hazardous quantities of hydrogen due to overpressurization. The tube is inerted (at about 28 kPa gauge [4 lb/in² gauge]) to protect against hydrogen deflagration in the tube or detonation of hydrogen in the MCO. The tube is monitored and periodically reinerted using a tube vent and purge cart. The design limits for CSB confinement and inerting systems are based on MCO relief design criteria.

During staging the MCO has an active filtered pressure relief valve set at less than 0.8 MPa gauge (120 lb/in² gauge), which will relieve hydrogen pressure and protect against particulate release. It also has a 1.0 MPa gauge (150 lb/in² gauge) safety-class rupture disk to prevent pressure exceeding the MCO design pressure. During interim storage, rupture disks will provide pressure relief. Activation of the rupture disk will release enough hydrogen into the tube to pressurize it and raise the hydrogen concentration above its lower limit of flammability in air. Rupture disk relief also will release significant quantities of particulate. Activation of the pressure relief valve will not release significant quantities of particulate because there is a filter on the pressure relief system but none on the rupture disk.

The tube plug pressure relief system provides a filtered release path for hydrogen to the deck area and has an orifice sized to minimize the fire hazards above the deck. The tube plugs are mechanically fastened to the tubes to prevent the MCO pressure release from lifting them and breaching confinement and the inerting seal if an MCO rupture disk were to burst. The tube plug pressure could rise to 524 kPa gauge (76 lb/in² gauge) if the MCO rupture disk were to burst at 1.0 MPa gauge (150 lb/in² gauge) above the tube pressure during staging.

The MCO storage tube purge system is designed to monitor and maintain an inert gas environment around the MCO during staging in the MCO storage tubes. The system analyzes gas from the MCO storage tube, purges gas (containing hydrogen) from the tube through a series of HEPA filters to the operating area atmosphere, and replaces the purged gas with an inert gas (e.g., helium). This system also is used to evacuate the storage tube before an MCO is removed from staging to ensure that the MCO can be accessed by the MHM without an unfiltered release.

The tube plugs have double seals to control inert gas outleakage rates and maintain confinement. Several months can pass without the storage tube containing the baseline MCO requiring purging (FDI 1996, Calculation CSB-PR-0003). The tube plug has a pressure gauge and connections for testing the seals. The storage tube is expected to be reinerted twice per year.

(FDI 1996, Calculation CSB-PR-0002). Reinserting is also required after activation of an MCO pressure relief device. Even if the tube pressure drops to atmospheric pressure, the inert gas inside the tube, plug, and seals will keep air out of the MCOs. As described in Chapter 3.0, Section 3.4.2.4, hydrogen combustion in the MCO is precluded by ensuring that the MCO is surrounded by an inert gas atmosphere. The only mechanism for air ingress into the tube is failure of the vacuum system while testing the MCO pressure relief systems prior to transport to the HCS Annex.

The MHM contains an on-board filtered ventilation system that provides confinement and thereby mitigates against the effects of an unfiltered release from a burst or failed MCO rupture disk accidental drop of an MCO during placement in a storage tube. Maintenance of an inerted gas atmosphere surrounding the MCO during transport from the service station to the storage tube or HCS process module will be ensured by the inert gas system on the MHM. During staging of the MCOs, the storage tube is pressurized with inerting gas by the tube vent and purge carts to a slightly positive pressure. ~~The MCO is not vented during staging and has an active pressure relief valve set at something less than 1.0 MPa gauge (150 lb/in² gauge) and a 1.0 MPa gauge (150 lb/in² gauge) rupture disk to prevent pressure exceeding the MCO design pressure. During interim storage the MCO will have only the rupture disk for pressure relief.~~

At the end of staging, the MHM is used to transport the MCO to the HCS Annex for hot conditioning. Before the MHM can remove the tube plug and pick up the MCO, the tube plug, which is locked down, must be manually unlocked by loosening and removing the tube plug clamps from the tube bolts. Before the clamps are removed, the pressure gauge in the tube plug is examined to ensure that an MCO rupture disk has not failed and pressurized the tube. ~~The process cart flexible hose is attached to the tube plug purge connection, and the pressure on the tube is evacuated to approximately 14 kPa absolute (83 kPa vacuum) (2 lb/in² absolute [12 lb/in² vacuum]). This evacuation will cause any MCO with a pressure near 1.0 MPa gauge (150 lb/in² gauge [pressure greater than 138 lb/in² gauge]) to relieve, either through the pressure control valve or rupture disk. This safety feature is relied upon to ensure that if an MCO's HEPA-filtered relief valve line is plugged, the MCO's rupture disk does not fail after tube plug clamp removal and before MHM movement of the plug and actuation of the MHM floor seal. This feature also provides for worker safety and allows time for MHM transport of MCOs into the HCS process pits with reduced likelihood of MCO rupture disk failure in the MHM. Tube overpressurization caused by relief valve opening will be confined to the tube and to the tube vent and purge cart evacuation system. The MCO's relief valve port will be sealed at the HCS Annex before being placed in interim storage. The rupture disk will remain operational. The hot conditioning process, to be described in a future addendum to this SAR, is expected to result in having relied upon to have insufficient residual water, hydrates, and hydrides in the fuel and particulate to pressurize the MCO beyond its design pressure over a 40-year period. However, periodic monitoring of the CSB tubes will be performed to confirm the tubes remain inert and no premature failure of rupture disks has occurred.~~

~~All standard storage tubes contain bottom and intermediate impact absorbers to mitigate the effects of an accidental drop of an MCO and thereby~~

~~maintain the integrity of the MCO (including the rupture disk) and the storage tube.~~

~~2.5.1.12.4.2-6 Receiving Crane. The receiving crane is a 60-ton-capacity gantry crane with one 60-ton main and one 10-ton auxiliary wire rope hoist supported on a top-running trolley (Figure 2-122-13). The crane operates in a chemically clean indoor environment in the load-in/load-out area of the CSB. The crane is equipped with a shielded operator station together with remote accessories such as a powered rotating hook, local control panels, and a radio-controlled operator station. The various tasks performed with the receiving crane are mainly associated with off-loading MCO shipping casks in preparation for the MCO's transfer to the storage vault.~~

The receiving crane gantry has a span of 8.4 m (27 ft, 6 in.) and can travel 50 m (164 ft) in an east-west direction. The crane runs on runway rails that are recessed and flush with the operating floor. The runway travel of the receiving crane intersects with that of the MHM, which is also a gantry crane system. The intersecting runway rails are coplanar and therefore have been provided with movable rail sections (frogs) that match the bridge wheels on both cranes. The limits of gantry travel are established by bridge stops that have been accommodated in the east and west building walls. These stops are designed to be contacted by bumpers mounted on the gantry trucks to absorb the energy of a kinetic impact.

~~[The following has been moved to Section 4.4.5.4.] The receiving crane is considered decoupled from the runway rails (e.g., no mechanical rail clamps). Lateral displacement is restrained by the wheel flanges and longitudinal displacement is restrained by the crane wheel brakes during a seismic occurrence. The receiving crane is stable against overturning during a seismic occurrence with a safety factor of 1.1, in accordance with ASME NOG 1 (ASME 1995b).~~

The receiving crane is provided with a hook coverage capability that extends beyond the CSB load-in/load-out area. The maximum hook elevation of 8.2 m (27 ft, 0 in.) for the main hoist hook is based on the needed to lift a transportation cask containing FFTF fuel from the road truck. This hook elevation is approximately 1.5 m (5 ft) higher than the SNF cask transportation requirements.

~~[This paragraph has been moved to Section 4.4.5.2.] The receiving crane system is designed, fabricated, manufactured, inspected and tested in accordance with the requirements of NUREG 0554, Single Failure Proof Cranes for Nuclear Power Plants (NRC 1979); CMAA Specification No. 70, Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes (CMAA 1994); ASME B30.20, Below the Hook Lifting Devices (ASME 1993a); and ASME NOG 1 1995 (ASME 1995b), Type I with the exception of NOG 5420(a) (reeving is in accordance with CMAA Specification No. 70 [CMAA 1994]), and NOG 5428.1 (a single hook is used rather than a double hook). As described in Section 2.8.1.1, the receiving crane is provided with backup power as a defense in depth feature.~~

The receiving crane is expected to receive some radiation exposure when the shipping cask is being moved. Based on an analysis of the side exposure to the receiving crane, a maximum rate of about 11 mrem/h is obtained, or

about 4×10^3 Rad for a 40-year lifetime total integrated dose. This is a conservative value because it is unlikely that the receiving crane will experience a 40-year continuous work schedule.

The receiving crane has a shielded operator station mounted on the north bridge truck. The shielding is 9-cm- (3.5-in.-) thick carbon steel with viewing windows that have a shielding equivalency of 9 cm (3.5 in.) of iron or 1 MeV photons reduced by a factor of 50. The receiving crane specifications do not require that the supplier provide actual dose measurements because this is a secondary shield to the MCO cask. Actual measurements will be part of actual startup and routine operations.

The receiving crane, including its load blocks, will not be exposed to temperatures, pressures, or chemicals that would require special design considerations. The receiving crane design provides for fail-safe features, such as load blocking and brakes, to be applied upon loss of power.

~~2.5.1 22-4.2-4 Mobile Containment-Service Station Enclosure Tent and Gantry Crane.~~ The mobile containment-service station enclosure tent is wheeled and travels on rails in the load-in/load-out area of the CSB. Positive restraints are provided between the base of the enclosure tent and the support rail to prevent the enclosure tent from lifting up or moving off the rail during a seismic event and resulting in a potential loss of function.

~~The mobile containment-service station enclosure tent will be staged in the load-in/load-out area, an area adjacent to and to the east of the MCO service station. The enclosure tent will be placed staged over the MCO service station pit after receiving a transport cask loaded with an MCO is placed in the pit. The enclosure tent will be pushed manually moved away from the MCO service station pit after the servicing of the MCO has been prepared for staging completed and the shielding hatch assembly has been placed over the pit. The shield hatch assembly replaces the cask lid function after preparation for MHM transport to the storage tube. This hatch has double seals that mate to the MHM for confinement integrity. The shield hatch assembly is shown in Figure 2-13.~~

~~The mobile containment-service station enclosure tent is equipped with a HEPA-filtered exhaust unit with a built-in standby exhaust fan. One fan is in standby while the other is in operation. The exhaust system will maintain a negative 12.5 Pa to 24.9 Pa (0.05 to 0.10 in. water gauge) pressure between the inside and the outside of within the tent enclosure at a 0.5 m/s (1,000 ft³/min) flow rate during the servicing operations. The exhaust unit discharges to the operating area exhaust stack. On a loss of normal power, the emergency generator system will provide power to the mobile containment service station enclosure tent exhaust system.~~

~~The enclosure tent and the filtered exhaust system form the confinement envelope for the zone-2-ventilation area around the MCO service station. The confinement atmosphere is supported by maintaining a 12.5-Pa to 24.9 Pa (0.05-in. to 0.10-in. water gauge) negative pressure inside the enclosure tent. To achieve and maintain this negative pressure, the enclosure tent is sealed to the floor, and the openings and joints in the material of the enclosure tent are designed to efficiently maintain the seal.~~

The enclosure tent material is a fire-resistant nuclear grade fabric with a specific weight of 425 g/m² (18 oz/yd²) minimum. The tent material meets or exceeds all the requirements of MIL C 4306G, Cloth and Strip, Laminated or Coated, Vinyl Nylon or Polyester High Strength, Flexible (MIL 1989), Type I specifications. The enclosure tent material is also in accordance with NFPA 701, Standard Methods of Fire Tests for Flame-Resistant Textiles and Films (NFPA 1996d), Chapter 12, and has a maximum tearing strength that is in accordance with ASTM D 2261, Standard Test Method for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant-Rate-of-Extension Tensile Testing Machine) (ASTM 1983a), and ASTM D 2262, Standard Test Method for Tearing Strength of Woven Fabrics by the Tongue (Single Rip) Method (Constant-Rate-of-Traverse Tensile Testing Machine) (ASTM 1983b).

The enclosure tent is equipped with a lighting system to provide an illumination level of not less than 753 lx (70 footcandle) for a distance of 2.7 m (9 ft) from the top of the MCO. The enclosure is large enough tent has enough capacity to house the cask lid, the shield ring, the shield hatch assembly, the 5-ton gantry crane and hoist, and the storage rack. The enclosure tent is equipped with service sleeves, 7.6-cm- (3-in.-) diameter minimum, to bring services into the enclosure tent as needed to support ventilation, to supply power, and to introduce tools.

The 5-ton motorized gantry crane is used to remove and replace the cask lid in the service station pit. The crane has an underhung electrical wire rope hoist. The crane does not exceed 2.4 m (8 ft) in total height and has sufficient hoist capacity to effect a maximum lift of 4.6 m (15 ft). The underhung electrical wire rope hoist is equipped with brakes, end stops, and a free rotating hook. The wheels of the gantry crane are designed to withstand a minimum loading of 2,270 kg (5,000 lb) each and are provided with locking devices to prevent movement while in use. The gantry crane has an acceleration control, and its travelling speed does not exceed 10.7 m/min (35 ft/min). The wire rope hoist has a lift speed of 3.0 m/min (10 ft/min) maximum, and the motorized trolley has a 7.6 m/min (25 ft/min) maximum speed.

The MCO service station gantry crane and hoist are designed in accordance with ANSI/ASME B30.10, Safety Standard for Hooks (ANSI/ASME 1995d), ANSI/ASME B30.16, Overhead Hoist (Underhung) (ANSI/ASME 1995b), ANSI/ASME 30.17, Overhead and Gantry Cranes (Top Running Bridge, Single Girder, Underhung Hoist) (ANSI/ASME 1995a), and ANSI/ASME HST-1M, Performance Standard for Overhead Electric Wire Chain Hoists (ANSI/ASME 1995c).

2.5.1.3 Multicanister Overpack Servicing (Expected Operational Occurrences). The MCO servicing system is designed to address expected operational occurrences and off-normal MCO conditions. This system has been designated safety-significant (safety class 2) because of its function in preventing or mitigating radiological releases at the 100-m (328-ft) onsite boundary. It is important to prevent a hydrogen-containing atmosphere in the MCO from becoming a flammable or explosive gas mixture either inside or outside the MCO. This would occur if the MCO pressure reached the MCO rupture disk burst pressure. The MCO servicing system is designed to relieve MCO pressure, analyze gas from the MCO, purge generated gas (primarily hydrogen) from the MCO, and replace the purged gas with an inert gas (e.g., helium) to prepare the MCO for staging in a storage tube. The MCO servicing system could be used in the event an MCO is received in a pressurized cask or if the elapsed time for transportation

and handling exceeds the administrative limit for transport, offloading, and confinement inside the MHM cask, which is inerted. The MCO servicing system restores the normal margin of safety by monitoring the hydrogen concentration within the MCO, excluding air from the fuel, and providing confinement if the MCO pressure relief valve were to activate during servicing.

2.5.1.4 Inert Gas Supply. The inert gas supply system provides the inerting gas used at the service station pit for purging and reinerting MCOs, as shown on Drawing H-2-123393 (Appendix 4E). Inert gas is received at the CSB via 3,400-m³ (120,000-ft³) bottled gas trailers that will be parked outside and to the north of the truck vestibule. The inert gas bottle supply is designed in accordance with WHC-S-0425 (Swenson 1996) and CGA P-1-1991, *Safe Handling of Compressed Gases in Containers* (CGA 1991). Delivery to the CSB inert gas system will be through a 5-cm (2-in.) supply line and pressure control manifold that provides 552 kPa gauge (80 lb/in² gauge) inert gas to the MHM festoon cable connection and to the service station pit, as shown on Drawing H-2-125160, sheets 2 and 3 (Appendix 4E). A 5-cm (2-in.) high-pressure inert gas line enters the southwest corner of the support building and is routed to a bottle filling station on the west wall of the operating area shelter at column line 3, as shown on H-2-125162, sheet 2 (Appendix 4E).

2.5.1.5 2.4-2.5 Multicanister Overpack Handling Machine. *The material in this section is no longer current. A revised discussion of the MHM will be provided at a later date (Mahaffey 1997). The MHM as provided by Foster Wheeler Environmental Corporation is a fully shielded machine whose purpose is to remove MCOs from the service station pit in the receiving area of the CSB, place the MCOs in the vault storage tubes (having first removed and subsequently replaced the storage tube plug), and transfer and retrieve MCOs to and from the hot conditioning ovens. The MHM can be used to reverse the operation and remove the MCOs from the vault and, in addition, can handle the storage tube impact absorbers.*

The MHM consists of two main units that operate simultaneously as a single machine: the gantry crane system and the shielded turret system. The gantry crane system is a 125-ton capacity, equal leg gantry with a top running trolley. The crane system includes the trolley and control panel, girders, end ties, wheel trucks, and seismic clamps. The shielded turret system includes the cask body, MCO hoist, ventilation system, shield plug hoist, television navigation cameras, shield skirt, and turntable.

*The MHM gantry crane system is mounted on rails that run north-south in recessed troughs in the operating deck. The span between rails is 38.6 m (126 ft, 6 in.). The shielded turret system is mounted on the trolley, which runs in the east-west direction. The cask trolley can travel 31.6 m (103 ft, 10 in.) east-west and 58.06 m (190 ft, 6 in.) north-south (see Figures 2-14 and 2-15 2.11 and 2.12). Specifications for the gantry and main trolley systems require that they be designed and fabricated to meet the requirements of ASME NCG-1 1995, *Rules for Construction of Overhead and Gantry Cranes (Top Running Bridge, Multiple Girder)* (ASME 1995b), Type 1, and NUREG-0554, *Single Failure Proof Cranes for Nuclear Power Plants* (NRC 1979).*

~~The MHM gantry and trolley and the GSB support structures are designed with seismic restraints that will prevent damage to an MCO if a seismic event were to occur during handling.~~

~~The MHM controls are provided with east west and north south motion interlocks with the cask motion. The interlocks are designed to prevent damage to the MCOs during handling if a seismic event or MHM trolley control system failure were to occur. The MHM main girders are located at a height of 2.75 m (9 ft) above the operating deck to clear the MCO service station, the tube vent and purge carts, and the HCS process enclosures.~~

~~The turret consists of a rotating upper assembly and a stationary bottom nose assembly. A retractable shield skirt mounted to and concentric with the nose assembly is lowered to complete the shielding when the MHM is engaged with a storage tube or when the shield hatch is positioned over the MCO service station pit. The skirt is connected to a nose tube and is sealed with elastomeric O-rings to the operating station where it is positioned (storage tube or service station).~~

~~When the MHM is located over the MCO service station and the shield skirt is lowered and sealed, the turret is rotated into position to remove the center shield plate. The center shield plate is removed with the MHM's shield plug grapple and hoist. The turret is then rotated to position the cavity over the operating station, and the MCO is removed using the MCO hoist and grapple. After the MCO has been raised to the transporting position, the turret is again rotated, and the center shield plate is replaced in the shield hatch. The shield skirt is raised and locked into position, and the MHM then transports the MCO to the designated storage tube.~~

~~Upon arrival at the storage tube station, the shield skirt is lowered into place and sealed to insure proper confinement and shielding. The turret is rotated to position the shield plug cavity over the storage tube, and the shield plug is removed using the shield plug grapple and hoist. When the shield is in its stored position, the turret is rotated to align the cavity over the storage tube and the MCO is lowered into position using the MCO grapple and hoist. After the MCO is in place, the turret is again rotated to position the tube plug and it is re inserted into the tube opening. The shield skirt is then raised and the MHM taken to a designated staging or storage position. MCO retrieval and replacement operations are carried out in a similar manner for transfer of MCOs to and from the HCS ovens.~~

~~The dose criterion "shielding goal" for the MHM is 2.0×10^{-3} mSv/h (0.2 mrem/h) at contact (1 cm (0.4 in.)) with the MHM. The 10 CFR 835 design objective for controlling personnel exposure from external sources of radiation in areas of continuous occupational occupancy (2,000 h/yr) is to maintain exposure levels below an average of 0.5 mrem (5 microsieverts) per hour and as far below this average as is reasonably achievable. The 2.0×10^{-3} mSv/h (0.2 mrem/h) at contact goal considers the possibility of multiple other sources associated with the GSB.~~

~~The slant angle concrete path and the gap between the MHM and deck surface needs to be taken into account when estimating the dose rate at the floor surface of the operating deck. The dose rate including streaming should be less than the shielding goal of 2.0×10^{-3} mSv/h (0.2 mrem/h). The dose~~

rate was reduced by adding an extended shield gate skirt that extends at least 91 cm (36 in.) beyond the edge of the floor embed. Based on the preliminary specification scoping shielding analysis (Kidd 1996b), this distance is judged to be adequate. In addition, the MMH deck gap radiation streaming was mitigated by the use of a steel below deck insert into the embed on the bottom of the shield gate that blocks the direct line of sight radiation as the MCO is withdrawn into, or out of, the MMH (there is approximately 13 cm [5 in.] of steel blocking the path in addition to the very narrow and extended gap based on the extended skirt described above).

The air from the MMH cavity is monitored by a tritium monitor, which also monitors for ^{85}Kr activity, and by an alpha-beta continuous air monitor (CAM) that monitors for breakthrough of the MMH ventilation system's HEPA filters. The probes are located adjacent to the exhaust of the MMH ventilation system.

2.5.1.62-4.2-7 Tube Vent and Purge Carts. The tube vent and purge cart (Figure 2-162-14) is designed to monitor storage tube gas pressure and composition, evacuate tube atmosphere air, pressurize and dilute tube gas with inert gas, and provide for controlled venting of storage tube gases emitted from the MCOs. The gases are monitored and vented to the operating area through HEPA filters on the cart. The cart also can maintain and replenish the inert gas atmosphere in the storage tubes. An inert pressurized atmosphere is maintained in the tubes, which contain staged MCOs, to prevent an accumulation of explosive mixtures of hydrogen and oxygen. Periodic tube venting also keeps the pressure from rising high enough to activate the relief valves in the plug. Some portions of this system have been designated safety-class (safety class 1) because of their function in preventing or mitigating radiological releases at the Site boundary; other portions have been designated safety-significant (safety class 2) because of their function in preventing or mitigating radiological releases at the 100-m (328-ft) onsite boundary.

The tube vent and purge carts are battery-powered, rechargeable, utility vehicles designed to ASME B56.8, *Safety Standard for Personnel and Burden Carriers* (ASME 1993c, including the 1994 addenda), and Title 29, *Code of Federal Regulations*, Part 1910, "Occupational Safety and Health Standards," Section 1910.178 requirements (29 CFR 1910). The carts are designed with a rear bed and tow hitch. The rear bed, or cargo deck, is sized for a platform 1.4 m by 2.9 m (55 in. by 115.5 in.). The bed is fitted with all of the equipment and systems required to perform the tube venting and purging operations. The systems to be provided include vacuum, sampling, radiation monitoring, combustible gas detection, ambient oxygen level, and inert gas delivery. A flexible steel hose is provided to connect a piping header with the tube plug quick disconnect. The cart's rated load capacity is specified to be not less than 1,361 kg (3,000 lb). The carts will tow a portable floor crane designed to ASME PALD, *Portable Automotive Lifting Devices*, requirements (ASME 1993b). The floor crane is normally used for lifting the 193-kg (425-lb) center hatch of the standard or overpack tube plug cover. The portable floor crane can be used to remove the standard or overpack tube plug covers in preparation for tube plug removal by the MMH. The standard and overpack tube plug covers weigh 669 kg (1,475 lb) and 819 kg (1,805 lb), respectively. The portable crane's rated capacity is specified to be 907 kg (2,000 lb). The cart receives electrical power for recharging its batteries and operating equipment by means of an on-board retractable cable reel (480 V,

3-phase, four-wire cord with ground). The cord is plugged into the electrical distribution system outlets recessed into the operating deck.

The cart is connected to process-piping on each tube plug. The process piping allows monitoring and purging of the tube atmosphere without removing the plug. Before any MCOs are placed in a tube, the air initially in the accessed tube is evacuated using the vacuum pump, and the inert atmosphere is supplied from high-pressure inert gas bottles on the cart. Pressurization with inert gas is controlled through a pressure regulator, and overpressurization of the tube is prevented by a relief valve. A restrictive flow path from cart to tube also makes rapid overpressurization unlikely. The inert gas pressure in the tube is left slightly positive after inerting, and hydrogen, periodically, that may be relieved from the an MCO, gradually can increase the pressure within the tube.

The schedule for venting, purging, and inerting the tubes is determined from CVD drying curves initial operating experience. The interval between scheduled visits is set so the hydrogen concentration will be below 4% (the lower flammability limit for pure hydrogen in air). Temperature variations in the vault will affect the tube pressures; therefore pressure is not a sensitive indication of hydrogen concentration. Instead, the hydrogen concentration is measured each time the cart makes a scheduled visit to a tube. The measurement result is used to adjust the schedule as necessary. Should the hydrogen concentration exceed 4%, the tube gas will be diluted to below 4% before using the vacuum pump. The cart includes a function to manually automatically dilute pressurized gas that is higher than 4% hydrogen with inert gas as the pressure is vented from the tubes through the cart and into the operating area. Several carts will be required in order to meet the contemplated schedule when vault 1 staging capacity is reached. One cart will be reserved as a spare during normal operations.

The currently conceived operations scenario assumes that when gas generation from the first MCO in a tube has declined to very low rates, a second MCO is added to the tube; the purging and inerting process is repeated at that time. Periodically (up to 18 times per day), the tubes will be vented through the cart system and reinerted at the original slightly positive tube pressure. Tubes that contain only sealed MCOs, or no MCOs, do not require servicing by the tube vent and purge cart. The operating philosophy will be developed to accommodate actual conditions expected after the MCO design and hydrogen generation modelling are complete.

During the time the cart is being used to perform venting, purging, and inerting, the portion of the connected system that is between the cart-mounted HEPA filters and the tube atmosphere fills the same secondary confinement role as the storage tubes. Under accident conditions this confinement provides mitigation of radionuclide releases from the MCOs.

2.5.2 Sealed-Staging Operations

The SNF contained in the MCO generates hydrogen gas from the exothermic reaction of free water with uranium metal and from radiolysis of bound and free water. Hydrogen can accumulate in a storage tube if a pressure relief device on an sealed MCO actuates or leaks. Although the storage tube is

inerted, it is assumed that the tube plug seals permit very slight loss of storage tube atmosphere to the operating area. To limit the concentration of hydrogen, and to exclude air, the storage tubes will be sampled. They will be purged, if required, and reinserted then reinserted, or purged, to a slightly positive pressure as required specified in procedures. These operations will be performed as needed depending on observed vault temperature and tube pressure measurements during staging. Tube vent and purge carts are provided to facilitate these hydrogen-related storage tube operations. If the tube pressure is too low, inert gas will be added to reach 28 kPa gauge (4 lb/in² gauge). If the tube pressure is too high, the tubes will be purged of hydrogen, and reinserted if required or merely pressure reduced to the 28 kPa (4 lb/in²) value. Equipment on the carts will have the capability to detect airborne radioactivity and dangerous concentrations of hydrogen in a gas sample from the tube. Upon determining that the tube atmosphere is acceptable for purging, the carts will evacuate the storage tube and exhaust filtered storage tube atmosphere into the operating area through HEPA filters. If the tube vent and purge cart's H₂ hydrogen monitor determines that the H₂ hydrogen concentration exceeds 4% by volume, the vacuum pump is tripped by the hydrogen monitors, and the tube vent and purge procedure requires that the tube be purged by repeated pressurization with an inert gas (helium). The diluted gas will be vented to the operating area. The storage tube then will be reinserted to 28 kPa gauge (4 lb/in² gauge) pressure.

The amount of sludge and water in an MCO not only affects the potential consequences of an accident but also affects the frequency of tube purging. The CSB was designed for a maximum hydrogen generation rate of 0.4 g/s and a maximum generated quantity of 1.1 kg (2.4 lb) of hydrogen per MCO. Recent preliminary studies of gas generation in MCOs (Bergsman 1996) have estimated the amount of radiolytic hydrogen and oxygen produced in vented staging after cold vacuum drying. The MCO pressurization model predicts 1.0 MPa gauge (150 lb/in² gauge) after 5 hours and a maximum gas generation rate of 0.4 g/s of hydrogen based on a maximum fuel corrosion inventory of 160 kg (353 lb), a water inventory of 6%, and 800,000 cm² (124,000 in²) surface area. The pressurization model predicts 379 kPa absolute (55 lb/in² absolute) after 90 hours using a high nominal case (155 kg [342 lb], 6% water, 80,000 cm² [12,400 in²]). The expected gas generation will be less. The maximum quantity of water is 1.1 kg (2.4 lb) corresponding to the bound water with 160 kg (353 lb) of corrosion products with 6% water by mass.

The hydrogen generation calculations included a calculation of the hydrogen generated by radiolysis of water and decomposition of hydrides or hydrates. The rate of hydrogen generation by this means is less than 3.7×10^{-3} m³/yr (0.13 ft³/yr) based on 1.8 kg (4 lb) of water available for radiolysis. If the cold vacuum drying process works as intended (negligible free water in the MCO after processing), the rate of radiolysis and chemical decomposition of hydrides or hydrates will determine the frequency of tube purging in the CSB.

Calculations show that the water in the MCO and the reaction rates are insufficient to exceed the fuel and MCO design temperature limits (Thurgood 1997). Preliminary calculations, which need to be finalized, have confirmed that hydrogen gas generation rates will not exceed 0.4 g/s and that oxygen gettering by uranium will preclude detonable mixtures of hydrogen and oxygen from forming. During transfer from the CVDF to the CSB, the worst-case

MCO is estimated to reach a pressure of only 138 kPa gauge (20 lb/in² gauge) during the 14-hour estimated transfer time from cask closure at CVDF to staging in the CSB. The worst-case MCO is predicted to reach 310 kPa gauge (45 lb/in² gauge) after 24 hours inside the shipping cask. Tests performed on the MCO prior to shipment from the CVDF will provide an administrative window that allows for transport to the CSB, offloading of the cask at the CSB, and MCO accessing of the MCO without the MCO pressure reaching the MCO rupture disk burst pressure.

The temperature of the vault is not controlled, and therefore depends on the outdoor temperature, which has a specified range of ~~can vary from~~ -32 °C to 46 °C (-27 °F to 115 °F) (Swenson 1996). ~~No brittle fracture of tubes can occur, even at 32 °C (- 27 °F), because the carbon steel material is very low in carbon (API 5L is < 0.008% carbon; A 36 is < 0.2% carbon).~~ The temperatures in a tube and in the MCOs contained in it depend on the temperature of the vault at that location and on the heat produced by the MCOs. The vault air temperature varies between 57 °C and 62 °C (135 °F and 144 °F) for a fully loaded vault with a maximum ambient inlet air temperature of 46 °C (115 °F). This results in a calculated maximum equivalent MCO surface temperature of 122 °C (252 °F) for an MCO located in the hottest spot in the fully loaded vault (based on a "heat wave" outside air temperature of 46 °C [115 °F]) (FDI 1996, Calculation CSB-HV-0001). The use of thermocouples to identify hot spots in the vault is not practical because the small 5.6 °C (10 °F) variability would not have a significant impact in predicting the MCO surface temperature. Temperature and flow sensors installed at the air inlet (intake structure) and a temperature sensor at the exhaust stack provide sufficient information for predicting MCO surface temperatures.

Seasonal temperature changes in a tube can alter the tube pressure up to 28 kPa gauge (4 lb/in² gauge) (FDI 1996, Calculation CSB-PR-0003). The hydrogen generation reaction rate increases exponentially with fuel temperature below 250 °C (482 °F) (Cooper 1997). The hydrogen generation reaction rate increases exponentially by a factor of about 10 for every 30 °C (50 °F) increase in fuel temperature.

This creates a concern that several MCOs will become active if the vault suddenly warms up after a period of cold weather. Based on best currently available hydrogen generation information (Lorenz 1997), the four three tube vent and purge carts (three two operating and one spare) ~~may not be sufficient to can purge the tubes fast enough to prevent releases of tube gases through flammable gas from the tube plug relief valves (FDI 1996, Calculation CSB-PR-0009). A calculation will confirm this basis.~~ To avoid this occupational hazard to the operators, it may be necessary to limit the number of potentially active MCOs that are loaded in cold weather. ~~[The following has been moved to Section 4.3.2.4] The exact limiting number of MCOs should be determined from historical weather records, fuel characterization data, and hydrogen generation readings taken from initial CSB operating experience. Additional carts could also be procured if required at a later date.~~

2.5.3 Interim Storage Operations

After hot conditioning, the MCOs will be placed by the MHM into storage tubes containing bottom and intermediate impact absorbers. The storage tubes, containing up to two MCOs, will be required to maintain an inert gas atmosphere around the MCOs. The hot conditioned MCOs will contain one or more rupture disks to provide safety-class overpressure protection. Periodic replenishment or repressurization of the storage tubes, as well as monitoring of the interstitial plug seal and tube pressure, will be required. These operations can continue to be performed by the tube vent and purge carts.

2.6 CONFINEMENT SYSTEMS

2.6.1 Confinement During Staging Operations

Because some of the fuel cladding is not intact, the primary confinement feature for the SNF at the CSB consists of the stainless-steel MCOs. Initially, the MCOs to be stored in the CSB will have undergone processing cold vacuum drying at the CVDFS. Following cold vacuum drying at CVDF, the MCOs processed by the CVDS are assumed to contain a slight amount of moisture that will contribute to some radiolytic, but mostly corrosion-induced hydrogen gas generation. The MCOs will be sealed but pressure-managed and can relieve through a HEPA-filtered relief valve located atop the MCO closure head shield plug if the pressure increases above the setpoint (0.8 MPa gauge [120 lb/in² gauge]) during the staging period in the storage tubes. Safety-class overpressure protection of the MCO is provided by an unfiltered rupture disk set at 1.0 MPa gauge (150 lb/in² gauge).

2.6.1.1 Multicanister Overpack Servicing. MCO servicing includes normal operations such as checking the cask pressure before removing the cask lid as described in Section 2.5.1. Venting and reinerting the MCO are considered recovery from abnormal operations. These operations may be required as a result of receiving an MCO that has vented hydrogen to the cask or that was received after expiration of its administrative window for transport. During MCO venting and reinerting servicing operations in the MCO service station, air will flow from the operating area through the service station enclosure's HEPA filtration system. Confinement is provided by the enclosure's ventilation system from the time the MCO cask is opened placed in the service station pit until the shield hatch assembly is in place. During the brief time that the service station enclosure is moved out of the way of the MHM (FDI 1996, Calculation CSB-PR-0011), the reinerted MCO will be covered by a shield hatch assembly. A burst MCO rupture disk event is not credible during this short period of time. After the MCO has been evacuated and reinerted or purged, the rate of gas generation necessary to quickly burst the disk is considered incredible (Pajunen et al. 19XX).

During MCO handling by the MHM, air flowing from the operating area or from the storage tube will flow into the MHM cask space where it will be diluted by an inert gas. Inert gas is manifolded into the bottom of the cask and exhausted through the on-board HEPA filtration system. Confinement in the storage tube is maintained by the MHM's on-board, HEPA-filtered, exhaust ventilation system during MCO handling.

2.6.1.2 Staging. The secondary confinement system during MCO staging consists of the storage tube and tube plug. The MCOs have a pressure relief valve (setpoint less than 0.8 MPa gauge [120 lb/in² gauge]) and rupture disk (1.0 MPa gauge [150 lb/in² gauge]) to control pressure. The storage tubes are initially inerted and evacuated to the operating area through testable HEPA filters located on the tube vent and purge carts. The tube vent and purge carts are used to check, evacuate, and recharge the inerting gas in the storage tubes as needed. If the pressure inside of a tube rises above 62 kPa gauge (9 lb/in² gauge), the tubes will begin to vent to the operating area through a relief valve and HEPA filter in the tube plugs (FDI 1996, see Calculation CSB-PR-0003). The tube plug design includes a tube seal leak test tap and a direct reading tube pressure gauge. Excess hydrogen generation in the MCO and pressure relief is the primary cause for a rise in pressure inside the tube. Other effects, such as gas volume expansion or water vapor expansion, are considered minor. The storage tube and the tube plug are safety class (safety class 1) and have been designed to remain intact and functional when subjected to a DBE.

2.6.2 Confinement During Hot Conditioning and Interim Storage Operations

~~The Hot conditioning process is designed to react all-bound water, hydrides, and hydrates in the SNF and remove the hydrogen, oxygen, and any unbound water from the MCO. The process also is designed to passivate the dehydrated fuel by oxidizing it with the metallic fuel surfaces using a premixed oxygen inert gas mixture to preclude fuel ignition and hydrogen detonation.~~ Hot conditioning will take place in ovens that are located in six process pits below the HCS Annex operating deck. Confinement is provided by the ovens, which are essentially ~~thermos bottles vacuum flasks with a cover rings that allows hot air to be blown through the annular space between the MCO and the oven's interior wall.~~ The process pit covers serve as part of the secondary confinement boundary and as radiation shields. The covers are designed as two parts (plug within a cover) to allow the MHM to move the MCO, while maintaining the double confinement of the SNF, using the same procedure as is used in the rest of the CSB. Other systems in the HCS that are similar to those in the CSB are the impact absorber at the bottom of each pit, which would prevent catastrophic failure of an MCO if it were dropped to the bottom of the pit, and the MHM guidance system and interlocks, which prevent the MHM from colliding with or damaging the process enclosure or MCO. ~~Process~~ The lines that connect the oven with the ~~process~~ hot conditioning equipment (air cleaning, inert gas purge system, heaters and fans) run below floor level in a trench. A thick steel plate covers the trench to provide shielding from any potential particulate or condensed volatile radioactive materials in the lines. The exhausts will pass through air-cleaning equipment before being discharged from the facility through a stack. A portable ~~process~~ enclosure will be provided for shielding, for making and breaking MCO connections remotely and for changing air-cleaning traps and filters. The enclosure will be ventilated so that it ~~provides~~ maintains secondary confinement while the MCO's top is exposed and while the MCO's ports are manipulated. ~~The final closure of the MCO will be made by welding a cover piece on the MCO while the MCO is in the oven after hot conditioning has been completed. Welding the cover piece on the MCO after hot conditioning seals off the pressure device so that only the rupture disk is available for pressure relief.~~

During interim storage, one rupture disk will provide safety-class protection, and a second rupture disk set at a lower pressure, will provide filtered relief. Operations similar to those described earlier in Section 2.5.3 will be performed to ensure tube seal integrity and to maintain an inert gas atmosphere in the storage tube. The confinement provided by the tube plug HEPA filters will continue to be required.

2.7 SAFETY SUPPORT SYSTEMS

2.7.1 Backup Electrical Power

As described in Section 2.8.12.4-2.8, the design of the CSB electrical supply system includes backup safety-class 2 power to maintain controlled air flow to the MCO service station and MCM and to in-deck 480 V power outlets used for operating the MCO vent and purge cart equipment, as well as to auxiliary loads associated with the backup power emergency generators and radiation monitoring systems. This system has been designated safety-significant (safety class 2) because of its function in preventing or mitigating radiological releases at the 100-m (328-ft) onsite boundary. Figure 2-17 (3 sheets) shows one-line diagrams of the system.

The backup safety-class 2 emergency power system has two independent redundant backup emergency generators and two 480 V motor control centers (MCCs) located inside the CSB that comply with the single-failure and redundancy requirements of WMC CM 4-46, Revision 1, Chapter 9.0 for safety-significant (safety class 2) SSCs. The CSB support building is designed to protect the emergency backup power system against damage from NPHs, as described in Section 4.3.4.4, or from fire, as depicted by the fire protection features shown on Figure 2-18. The two motor control centers MCCs are equipped with transfer switches that connect the backed-up safety-class 2 loads as well as several safety-class 3 loads to provide defense-in-depth. The most important safety-class 2 loads have redundant hard-wired connections to either both motor control centers MCC. Portable equipment can be powered by either motor control center MCC via the 480 V floor outlets. Each backup power system is protected by independent fire barriers, detectors, and suppression systems. The system is designed to prevent failure of one system, structure, or component from causing cascading failure of important safety-class 2 loads. The system is designed to power all important safety-class 2 loads from either generator as described in the architect-engineer's File 106.151, *Failure Modes and Effects Analysis: Emergency Power System* (Zimmerman 1996). Table 2-1 lists the diesel generator loads.

2.7.2 Fire Protection

The safety support functions of the CSB are provided by backup electrical power and fire protection and monitoring systems. The design of the CSB anticipates that the CSB will be. The CSB was granted an exemption from the DOE Order 5480.7A, *Fire Protection*, requirement for a fully sprinkled building (Sellers 1996). WMC-SD-SNF-FHA-002, *Fire Hazard Analysis for the Canister Storage Building Storage Vaults* (WMC-Sadanaga 1996), indicates determined that a wet pipe sprinkler system is not warranted for the operating area.

Table 2-1. Backup Power Load List.

Safety-significant loads	Diesel generator EG-1A 100 KVA	Diesel generator EG-1B 100 KVA
Safety class 2		
Diesel fuel oil pump	0.88	0.88
Tube vent and purge cart	12.00	12.00
Tube vent and purge cart	12.00	12.00
Portable HEPA filter	2.07	2.07
Service station crane hoist	6.06	6.06
Subtotal	33.01	33.01
Safety class 3		
15 KVA output UPS	18.75	N/A
Security power panel	15.00	N/A
Panel G	N/A	30.00
Subtotal	66.76	63.01
HCS Annex loads (safety class 2)	30.00	30.00
Total	96.76	93.01

HCS = Hot Conditioning System.

HEPA = high-efficiency particulate air (filter).

N/A = not applicable.

UPS = uninterruptible power supply.

The exemption would be determination was based on the absence of significant existing combustible loading, the control of transient combustible loading, the minimal benefit of a sprinkler system, and the reduced potential for moisture entering the storage tubes and possibly overpressurizing the storage tube.

The various rooms of the CSB Support Building are protected against fire damage through incorporation of fire walls and provision of a sprinkler system. A 6-in. fire water supply system begins at the north side of the CSB Support Building at a connection to a 10-in. fire water main (Figure 2-2). A post-indicating valve provides isolation of the 6-in. CSB fire water line from the fire water main if required. Other water mains include the 10-in. and 12-in. fire and raw water lines to the north and east of the facility and smaller underground lines in the immediate area around the facility. This system has been designated non-safety class because of its limited function in protecting the facility worker from industrial and radiological hazards.

2.7.3 Heating, Ventilating, and Air Conditioning System

The HVAC system is designed to act, along with physical barriers, as a part of the CSB contamination confinement system to ensure contamination control within the building. This system has been designated non-safety class because of its limited function in protecting the facility worker from industrial and radiological hazards. The HVAC system provides pressure gradient flow of air from outside the building inward through noncontaminated areas to potentially contaminated areas of the building, and out through HEPA filters and a monitored exhaust. The HVAC system also provides climate control to ensure that environmental conditions within the building are maintained in the required ranges for personnel and equipment. The HVAC composite flow diagram can be seen on Figure 2-19. The HVAC system has its own programmable controller. The HVAC system operates by adjusting dampers to maintain the operating area negative pressure. The setpoint for starting the second exhaust air handling unit is 50% of 2.1 m³/s (4,500 ft³/min). This is the maximum that the HCS Annex ventilation can exhaust.

The HVAC system consists of two subsystems. The operating area HVAC subsystem provides ventilation and air conditioning for the operating area of the building and the HVAC equipment room. The operating area HVAC system is designed to maintain a negative pressure of 25 Pa (0.10 in.) with regards to the outside environment. The operating area HVAC system provides 20.8 m³/s (44,000 ft³/min) of supply air, recirculates 16.7 m³/s (35,500 ft³/min) of air through the operating area and HVAC equipment rooms, with continuous outside air makeup of 3.2 m³/s (6,750 ft³/min) and HEPA-filtered exhaust of 2.1 m³/s (4,500 ft³/min) to 4.2 m³/s (9,000 ft³/min) that is continuously monitored for contamination. Outside air is drawn through an electric duct heater to air handling units, where it is mixed with air recirculated from within the building. After passing through the operating area or the HVAC equipment room, air is exhausted through HEPA filters and an exhaust fan and out the main exhaust stack, where continuous radiation monitoring checks for contamination in the air. The operating area HVAC maintains the normal temperature range at 16 °C to 29 °C (60 °F to 85 °F) coincident with an outdoor temperature range of -16 °C to 38 °C (4 °F to 101 °F) (dry bulb).

The support area HVAC subsystem uses forced-air ventilation to maintain required support area temperatures and contamination confinement for potentially contaminated rooms (also known as "entry-related rooms," i.e., those rooms located between airlocks) in the support area. The support building exhausts 0.5 m³/s (950 ft³/min) to the HVAC equipment room while circulating 1.5 m³/s (3,100 ft³/min). The support building exhaust is added to the operating area recirculation flow. The support area subsystem provides ventilation, air conditioning, and contamination confinement for the support areas of the building, including the control room, corridor, telephone and equipment room, effluent monitor room, generator rooms, electrical equipment room, change room, health physics office, step-off pad and bag room, and the monitoring and decontamination room. Air is drawn from outside the building through an electric duct heater to an air handling unit and passes through the support area rooms. Air from entry-related rooms is exhausted through a HEPA filter at 0.5 m³/s (950 ft³/min) and discharged to the HVAC equipment room through another air handling unit; air supplied to the generator rooms is vented directly to atmosphere; the rest of the air is recirculated. The support area subsystem maintains the normal temperature at 22 °C to 26 °C

(72 °F to 78 °F) coincident with an outdoor temperature range of -11 °C to 37 °C (12 °F to 98 °F) (dry bulb).

The HCS process modules require up to 2.1 standard m³/s (4,500 standard ft³/min) to be provided from the operating area HVAC system. This air flow is exhausted through the HCS Annex exhaust stacks after being HEPA-filtered and monitored.

2.7.4 Health Protection System

The health protection system is designed to warn plant personnel of hazardous radioactive conditions that may occur as a result of malfunctions or accidents. This system has been designated non-safety class because of its limited function in protecting the facility worker from industrial and radiological hazards. The health protection system employs radiation monitoring equipment and personnel contamination monitors. No situations analyzed, even double contingency accidents, exceed the criticality protection limit (Schwinkendorf 1997). Therefore no need is seen for installation of criticality instrumentation in the CSB, and none is provided in the design of the CSB. This exclusion is permitted by ANSI/ANS-8.3-1979, *Criticality Alarm System* (ANSI/ANS 1979), and DOE Order 5480.24, *Nuclear Criticality Safety*, paragraph 7.b(3), and will be verified when the design is complete.

The airborne activity monitors for the CSB consist of the alpha- and beta-sensitive CAM, radioactive gas monitor, and radioactive particulate sampling. The components of the monitoring system include flow measurement (2% sampling rate); a shrouded sampling probe (80% to 150% aspiration ratios for 10 µm aerodynamic equivalent diameter particles); two vacuum pumps (single redundancy), which draw air through filters at a constant flow rate of 62 L/min (2.2 ft³/min) up to a maximum pressure drop of 20 kPa (6 in. of mercury); radioactive particulate sampling (both a CAEM record sampler and a remote stack sampler); alpha monitoring (alpha CAMs, which operate in series with the radioactive gas monitor); and a radioactive gas monitor. The sensitivity of the system will meet the following requirements:

- Category 1 (40 CFR 61, Subpart H, and DOE Order 5400.1) continuous stack monitoring for radionuclides that contribute more than 10% of the anticipated offsite effective dose (²³⁸Pu, ²³⁹Pu, ²⁴⁰Pu, ²⁴¹Pu, ²⁴¹Am, ¹³⁷Cs, and ¹⁴C)
- Constant air monitoring of alpha and noble gases
- CAM downtime for scheduled maintenance not more than 8 hours in each 24-hour period; unscheduled not greater than 72 hours (WHC-CM-7-5).

Figure 2-20 shows the approximate location of the monitoring equipment. Personnel exposure data are recorded and processed using a facility radiological database. Figure 2-21 shows the stack monitoring equipment. Each channel of the health protection system is controlled by an independent microprocessor with a self-contained ratemeter that will continue to operate even if the distributed control system (DCS) or its communication lines fail. Local indications such as count rate data and radiation field intensities will be available from each channel. If alarm conditions exist, there will be

local visual and audible annunciation at the microprocessor independent of the DCS. Each radiation monitoring channel is capable of self-testing using an independent check source. Testing can be initiated locally or from the DCS. The complete system provides monitoring, database management, and status reporting.

The remote stack sampler uses shrouded probes. The first set of shrouded probes is located at an elevation of 9.6 m (31 ft, 7.5 in.) and the other is located half way between the first probe and the wall of the exhaust stack. The flow from these probes is combined outside the exhaust stack and piped to the inline sample head and the noble gas monitor located in the CAEM cabinet. The alpha CAM and radioactive gas monitor collects a sample of particulate and gas exiting the stack for subsequent radionuclide analysis. The line loss and filter efficiency are such that the collected particle sample contains >50% of the 10 μm and larger (aerodynamic equivalent diameter) particles that are present in the free system. This performance will be tested and documented by (in order of preference) a field acceptance test, laboratory wind tunnel testing, or a verified model. The alpha portion of the alpha CAM includes a completely separate alpha sampler that contains a parallel 51-mm (2-in.) diameter, 0.3 μm efficient filter that is monitored by a lead-shielded, silicon surface barrier detector with an active area of 500 mm^2 (0.8 in^2). The alpha CAMs also include circuitry for background subtraction of radon-thoron activity. The alpha CAM has the same type ratemeter and alarms as the beta-gamma sensitive CAMs. The CAEM will include a noble gas monitor that is connected to the second set of shrouded probes located at 11.7 m (38 ft, 5.5 in.). The radioactive gas analyzer is located to monitor gases potentially released during MCO handling: ^{85}Kr , ^{129}I , ^3H , primarily in the form of tritiated water vapor $^3\text{H}_2\text{O}$, and ^{14}C , in the form of carbon monoxide (^{14}CO). The unit includes adjustable high and low set-point alarms, a microprocessor-based ratemeter, and dual counting units (one detects background subtraction, the other detects the soft beta [18.6 keV] emitted by ^3H).

2.8 UTILITY DISTRIBUTION SYSTEMS

The CSB design relies on offsite power and road transport of bulk gases and supplies for normal operation. The CSB's basic utility distribution systems, including backup power, ensure continued operation of safety systems during NPH or offsite emergencies.

2.8.1 Backup Electrical Power and Generators

2.8.1.1 Backup Electrical Power. Under normal circumstances, the CSB receives electrical power from the Hanford Site power grid through a dedicated 480-V transformer connected to an existing 13.8-kV power pole near the north end of the building. Power is fed from the transformer to four 480-V MCCs located inside the CSB support building. Figure 2-22 shows the one-line connections between the Hanford Site power, the CSB transformers, and switchgear for voltage and load control during normal operation of the CSB. Figure 2-22 also shows the relative locations of both the normal and backup powered MCCs. Loads supplied with backup power are listed in Table 2-1. The two MCCs handling backup power loads are equipped with transfer switches that

connect these loads and the defense-in-depth systems to the diesel generators in the event of loss of normal power. The design has both backup power MCCs energized at all times, whether under normal power or fed by the diesel generators.

Redundant electrical switchgear protection is provided to prevent failure of one load from causing cascading failure of other loads. The two backup power MCCs are separated by a fire barrier and other design features as necessary to prevent any single failure of one MCC from being a common mode failure of the other MCC.

2.8.1.24.2-8 Emergency Diesel Generators. The emergency generator system is designated safety-significant (safety class 2) because of its function in preventing or mitigating radiological releases at the 100-m (328-ft) onsite boundary. It is housed in the support building at the north end of the CSB. The system is composed of two identical and redundant units, each rated at 100-KVAkW output (3-phase, 480 V) and powered by a V-6 turbocharged diesel engine with air starter. The engine generator sets are positioned on vibration isolators to minimize transmission of vibration. The system has been designed in accordance with Engine Driven Generator Sets Guideline Specifications for Emergency or Standby (EGSA 1992); IEEE 446, Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (IEEE 1987); NFPA 70, National Electrical Code (NFPA 1993); and NFPA 110, Standard for Emergency and Standby Power Systems (NFPA 1996).

The two units are located in different rooms separated by a 2-hour firewall in accordance with ANSI/NFPA 30, Flammable and Combustible Liquids Code (ANSI/NFPA 1996a3). Each room houses the diesel generator set; a 190-L (50-gal), double-walled, diesel fuel day tank; and a 1.5 m³ (55 ft³) starting air receiver, operating at 758 kPa gauge (110 lb/in² gauge), that is capable of providing six-eight consecutive starts of the diesel generator. Each room also houses an automatic transfer switch that will initiate the startup of the diesel unit on sensing a loss of offsite power.

When a loss of offsite power occurs, each of the two automatic transfer switches will send a start signal to its dedicated generator. The generator will come up to speed within 6 seconds of receiving the signal to start, power the associated emergency-busses will be powered, and thus transfer the safety class 2 loads transferred to the to its generator within 15 seconds of the occurrence. The automatic transfer switch is programmed in such a manner that after two unsuccessful starting attempts, it will activate the second emergency generator to start and carry the backup safety class 2 loads. The generator will come up to speed within 6 seconds of receiving the signal to start. The two automatic transfer switches also are programmed in such a way that one is a lead and will receive the starting signal first, and if for some reason it fails to operate, the second transfer switch will take over and initiate the starting procedure.

Each generator will have a load bank permanently installed on the exhaust side of the engine radiator, on the generator skid extension on the north side of the diesel engine. This 100-kW load bank will allow generator load testing as needed required to ensure availability of reliable backup power.

Rotating equipment exposed to operator the outside contact is protected by metallic guards to prevent contact. The protection provided is in accordance with OSHA Instruction Standard 1-12-14, Guards for Rotating Equipment (OSHA 1978). Hot surfaces of 49 °C (120 °F) or more that are accessible exposed to human reach are insulated to prevent burns. This is in accordance with ASTM C1055, Standard Guide for Heated System Surface Conditions that Produce Contact Burn Injuries (ASTM 1992a).

Two 1,900-L (500-gal) diesel fuel storage tanks are located outside the north wall of the support building at a distance of 3 m (10 ft). Each tank is a double-walled, insulated, above-ground tank with a leak detection system. The primary steel tank is specified to be constructed of carbon steel not less than 0.3-cm (1/8-in.) thick in accordance with ASTM A36/A36M, Standard Specification for Carbon Structural Steel (ASTM 1994a). The diesel fuel storage tanks are specified to be furnished in accordance with UL 142, Standard for Steel Above Ground Tanks for Flammable and Combustible Liquids (UL 1993); UL 752, Bullet Resistant Equipment (UL 1995); NFPA 30 (NFPA 1996a); and NFPA 77, Recommended Practice on Static Electricity (NFPA 1996b). The secondary containment enclosure is specified to be constructed of reinforced gypsum concrete in accordance with ASTM C956, Standard Specification for Installation of Cast-in-Place Reinforced Gypsum Concrete (ASTM 1994b), and to provide a 2-hour fire resistance. The tanks are specified to be equipped with an emergency vent designed to vent when tank pressure reaches 17 kPa (2.5 lb/in²) in accordance with UL 142 (UL 1993) and NFPA 30 (NFPA 1996a). Overfill protection compartments can contain up to 9557-L (215 gal) of overflow as a minimum. When full each tank contains enough fuel to run one diesel generator unit for 48 hours at full power. Each tank has a positive displacement pump mounted on the top of the tank. This pump is activated by ~~to react to~~ the level control on the 190-L (50-gal) day tank and keeps the day tank filled with diesel fuel. The top of the storage tank is equipped with a walkway and ladders for access and maintenance. The two diesel fuel storage tanks are to be filled by a standard fuel hose and dispenser nozzle from a diesel fuel truck. The diesel fuel tanks are protected from lightning in accordance with NFPA 780, Lightning Protection Systems (NFPA 1995a). The diesel fuel tanks are specified to be properly designed and anchored to resist the effects of a seismic event acting through the center of gravity of a full tank at 0.75 g in any horizontal direction and 0.5 g in any vertical direction simultaneously.

2.8.2 Distributed Control System

The DCS is designed to serve as the central monitoring system for CSB facility conditions. This system has been designated non-safety class because of its limited function in protecting the facility worker from industrial and radiological hazards. There are two central processing units that provide redundant data collection from instrumentation and monitoring systems located throughout the facility. The DCS collects data from a separate HVAC programmable computer, which is used to monitor air temperatures in the storage vault and to perform calculations on heat removal in the vault. Components in the field (e.g., instruments, actuators, sensors) are connected to the DCS at remote termination unit cabinets and data multiplexers that are located throughout the facility. Dedicated Distributed processing units will be added later as the primary controllers for hot conditioning and to provide

signal conditioning and communications with operator workstations in the HCS Annex. These dedicated distributed processing units may share a cabinet with the remote termination units. The multiplexers concentrate serial data from the health physics instruments and transmit the data to the operator workstations. A data highway links all components of the DCS together. Printers in the control room allow for the printing of hardcopy listings of alarms, control actions, and other reports by operator request. The DCS also provides access to the Hanford Local Area Network (HLAN) through a separate HLAN server. The DCS is shown on Figure 2-23.

2.8.3 Instrument and Plant Air System

The CSB instrument and plant air system consists of two two-stage oil-free rotary screw compressors operating in lead-lag fashion to deliver a minimum of 5.7 standard m³/min (200 standard ft³/min) of compressed air at 862 kPa gauge (125 lb/in² gauge). The air passes through a coalescing prefilter, a heatless desiccant air dryer, and a particulate afterfilter before it resides in a 9,690-L (2,560-gal) air receiver to provide air on demand to the diesel air-start tanks, the MHM festoon supply, and the instrument and plant air utility stations, as shown on Drawings H-2-123392, H-2-125160, and H-2-125162 (Appendix 4E). This system has been designated non-safety class because of its limited function in protecting the facility worker from industrial and radiological hazards.

2.8.4 Liquid Waste Collection

The liquid waste collection system is designed to collect water condensate from the HVAC air handling unit's cooling coils and from the instrument air compressors, and some water effluent from other plant sources, and to provide for transfer of the waste condensate to drums that can be transported to the Treated Effluent Disposal Facility. This system has been designated non-safety class because of its limited function in protecting the facility worker from industrial and radiological hazards. Sump SU-1 is a 1.2 m by 0.6 m by 0.6 m deep (4 ft by 2 ft by 2 ft deep) recessed area in the support building floor between the air handling units, as shown on Drawings H-2-123395 and H-2-129416 (Appendix 4E). A second sump 0.6 m square by 0.6 m deep (2 ft square 2 ft deep) is located between the instrument and plant air compressors, as shown on Drawing H-2-125160 (Appendix 4E). The liquid waste collection system is not a floor drain or fire suppression water catchment. HVAC condensate drains to the liquid collection sump from drip pans located in the HVAC equipment room. The system is designed to collect condensate at approximately 3.8 L/h (1 gal/h) for 8 hours per day. An alarm is activated on the DCS when the level sensor in the sump indicates that the water level has reached 30.5 cm (12 in.), approximately 208 L (55 gal).— An operator empties the sump into a 208 L (55 gal) drum using a portable air-operated pump by first placing the pump's suction hose into the sump and then connecting an air hose between the pump motor and the nearby utility station. This process continues until the pump is unable to lower the level any farther and the alarm has cleared, or until the drum is full. The contents of the full barrels are then tested for radiological and chemical contamination.— When the contents are released for disposal, the barrels are shipped to a facility from which the contents can be transferred to the Treated Effluent

Disposal Facility. SNF Operations will be responsible for determining disposition of barrel contents that test over limits for radiological or chemical contamination and cannot be released for disposal.

2.8.5 Potable Water

The potable water system is designed and limited to supplying a clean water source to the CSB HVAC humidifier. This system has been designated non-safety class because of its limited function in protecting the facility worker from industrial and radiological hazards. The HVAC system humidifier is the only identified potable water user; in the future, sanitary water uses may be identified. The HVAC system humidifier will use approximately 1.1 L/h (0.3 gal/h) when in use. The potable water system begins at the north side of the CSB at a connection to an existing 3-in. underground sanitary water main. The 2-in. service line to the CSB enters the instrument air equipment room and is capped off at that point. The system is sized for small, periodic water uses. The system supplies water to the support area HVAC humidifier through a deionizer. Water flows from the supply pipe through a 1/4 in. copper pipe to the deionizing unit, then through a 3/8 in. stainless steel pipe to the HVAC humidifier located in the support area HVAC ducting just outside the control room. The potable water system could be expanded to provide service for future sanitary uses (e.g., toilets, sinks, showers, drinking fountains) if required.

2.9 AUXILIARY SYSTEMS

The plant communications system has been designated non-safety class because of its limited function in protecting the facility worker from industrial and radiological hazards. The design of the plant communications system will provide the cabling and/or raceway system equipment for the telephone, public address, intercom, and radio communications systems within the CSB to the interface point within the communications equipment room. All communications systems physical interfaces will be located in the communications equipment area of the electrical equipment room. Space will be provided in the equipment room for telephone exchange equipment, paging equipment, wire terminating frames, radio equipment, coaxial and fiber optic transmission equipment. Inside cable design will provide 50% spare cable and will provide spare raceway for inaccessible and/or embedded areas.

Telephone requirements will be based on providing internal and external communications service to all office and operating areas within the CSB. The telephone system will provide raceway only tie-ins to the Hanford Site crash alarm and the Hanford Site 911 emergency telephone system. The intercom system will be incorporated into the telephone system.

Public address system coverage is required for all areas accessible to personnel, both interior and exterior. Public address systems within the CSB will be accessed by the telephone system with master overrides from the central control room and the emergency response center. The public address system will also be accessible from specified telephone sets.

Area and plant-wide alarms are incorporated into the communications system. Ringdown phones will be installed for security use. Fire alarm and detection system signals will be transmitted offsite by means of the radio system. Radiation and hazardous condition alarms will be annunciated by means of the health protection computer system. The evacuation alarm or take-cover alarm will be annunciated through the public address system speakers. It will be possible to activate the evacuation alarm from the central control room and from the emergency control station. The Hanford Site crash alarm will be annunciated through the general plant telephone system ringer. The crash alarm will be directed to selected plant telephones.

All areas of the building have locking Medeco¹ doors and an alarm system. The operating area also has video cameras. Limited area entrances have special access hardware. The large exterior openings have telescoping doors and heavy rolling gates to prevent vehicle penetration at those locations. The concrete curb around the perimeter of the operations area shelter prevents vehicle penetration for the balance of the building. All vents, shafts, and ducts have intrusion barriers appropriate to their configuration.

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¹Medeco is a trademark of Medeco, Incorporated.

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Figure 2-1. Canister Storage Building.
(Sheet 1 of 3)

G A FLOOR PLAN

Figure 2-1. Canister Storage Building.
(Sheet 2 of 3)

Figure 2-1. Canister Storage Building.
(sheet 3 of 3)

GENERAL NOTES

Table with 2 columns: Item, Description. Contains 12 numbered items detailing site plan requirements and standards.

ABBREVIATIONS

Table with 2 columns: Symbol, Description. Lists various symbols used on the site plan, such as 'Proposed Security Fence', 'Proposed Entry/Access Road', etc.

LEGEND

Table with 2 columns: Symbol, Description. Defines symbols for proposed security fence, entry/access road, grading & drainage, and other site features.

QUALITY LEVEL II SAFETY CLASS 4

Table with 2 columns: Item, Description. Contains 12 numbered items detailing site plan requirements and standards.

Figure 2-2: Site Plan (Water Lines, Grading and Drainage) (Sheet 1 of 2)

N 42370.00 MATCHLINE SEE DWG. NO. H-2-117074

TABLE

NO.	DESCRIPTION	DATE
1	REVISION	11/1/72
2	REVISION	11/1/72
3	REVISION	11/1/72
4	REVISION	11/1/72
5	REVISION	11/1/72
6	REVISION	11/1/72
7	REVISION	11/1/72
8	REVISION	11/1/72
9	REVISION	11/1/72
10	REVISION	11/1/72

NOTES:
1. SEE DRAWING POWER IN-CHARGE FOR ADDITIONAL DETAILS AND
REVISIONS.

EXPLANATION:
1. AREA OF EXISTING SURFACE INDICATED WITHIN
2. EXISTING SURFACE INDICATED WITHIN
3. EXISTING SURFACE INDICATED WITHIN
4. EXISTING SURFACE INDICATED WITHIN
5. EXISTING SURFACE INDICATED WITHIN
6. EXISTING SURFACE INDICATED WITHIN
7. EXISTING SURFACE INDICATED WITHIN
8. EXISTING SURFACE INDICATED WITHIN
9. EXISTING SURFACE INDICATED WITHIN
10. EXISTING SURFACE INDICATED WITHIN

QUALITY LEVEL II
SAFETY CLASS 4

DETAIL 2

DETAIL 3

DETAIL 4

DETAIL 5

DETAIL 6

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DETAIL 9

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DETAIL 14

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DETAIL

NOTE:

1. FOR CONCRETE GENERAL NOTES AND TYPICAL DETAILS SEE DRAWING H-2-1119215.
2. STRUCTURAL CONCRETE AND CURBS SHALL BE AS SPECIFICATED IN SPECIFICATION SECTION 0115.

A. BELOW FL 70'-0", THE STRUCTURAL CONCRETE SHALL BE MAX CLASS 40MP (5800 PSI).

B. ABOVE FL 70'-0", THE STRUCTURAL CONCRETE SHALL BE MAX CLASS 40MP (5800 PSI).

Technical drawing of a mechanical part, likely a bracket or support, showing dimensions and material specifications.

Dimensions:

- Overall width: 2×6
- Overall height: 10 ± 0.1
- Top flange width: 1 ± 0.1
- Top flange thickness: $1/8$
- Bottom flange width: 1 ± 0.1
- Bottom flange thickness: $1/8$
- Central vertical slot width: 1 ± 0.1
- Central vertical slot depth: 1 ± 0.1

Material and Finish:

- MATERIAL: 6061 ALUMINUM
- FINISH: ANODIZED

DETAIL 95

SCALE: 1/2" = 1" - 0

NOTES:

1. POLYMERIZATION OF STYRENE, BUTADIENE AND VINYL ACETATE
SEE DOWNEY, 1962-1973
2. FLORENCE IS NOT CONSIDERED A "PERSON" AS STATED
IN 45-1575-10 TO REASON CONSIDERED
3. FLORENCE PACE CARRIES NAME RE CONCEPT FROM
WALL F. 2108 FLORENCE CARRIES NAME RE CONCEPT
CONSIDERED, SEE DOWNEY, 1962-1973
4. STRUCTURAL CONCEPT HAS CONCEPT REPEATED
FROM 1910-1973 THROUGH 1962-1973. SHALL BE AS
REPEATED CONCEPT
5. REASON RE CONCEPT REPEATED FROM CONCEPT
SHALL BE 1962-1973 THROUGH 1962-1973. SHALL BE AS
REPEATED CONCEPT
6. ABOUT RE, 204-1 OF THE STRUCTURAL CONCEPT
SHALL BE 1962-1973 THROUGH 1962-1973
7. FOR REASON/CONCEPT RE CONCEPT REPEATED FROM
CONCEPT SHALL BE 1962-1973 THROUGH 1962-1973

Figure 2-85. Canister Storage Building
Standard and Overpack Tube Plug
Assembly 18.

FLUOR DANIEL		WESTINGHOUSE HANFORD COMPANY	
DESCRIPTION CHANGE:		DESIGN CHANGE NOTICE	
ADD SERVICE PITS FOR FUTURE TRANSLADING OF FTIF FUELS AND FOR MAINTENANCE ON THE MCO AND MHW		BASE DOC. NO. H-2-120902	
PREPARED BY: G. HOLT		SMT/PG. 2	
DATE: 9/16/98		REV. 1	
DISCIPLINE ENGINEER: J. MCCLELLAN		CAD/CODE: 281BMACD212.C1/SS	
DATE:		PAGE	
DISCIPLINE: MECHANICAL		REV.	
CADFILE: 2N0P172		DCN -	
		2	

Figure 2-87. Tube Base Assemblies
for Standard and Overpack
Storage Tubes.

Figure 2-98. Bellows Assemblies for Standard and Overpack Storage Tubes.

1 STANDARD LOWER IMPACT ABSORBER ASSEMBLY
SCALE: 1/4"

3 STANDARD INTERMEDIATE IMPACT ABSORBER ASSEMBLY
SCALE: 1/4"

TBD/HOLD
CSB--TBD-032

② OVERPACK LOWER IMPACT ABSORBER ASSEMBLY
SCALE: 1/4

V. 7.2.2. PART/ORDER NUMBER		PARTS/MATERIAL LIST		UNIT/PCS/AVAILABILITY	
001	001	STATION LOCK IMPLCT ASSEMBLY ASS'Y	1	1	1
002	002	BRACKET LOCKER IMPLCT ASSEMBLY ASS'Y	2	2	2
003	003	STATION IMPLCT IMPLCT ASSEMBLY ASS'Y	3	3	3
004	004	STATION IMPLCT IMPLCT ASSEMBLY ASS'Y	4	4	4
1	1	ASSEMBLY	5	5	5
46	46	ASSEMBLY	6	6	6
46	46	ASSEMBLY	7	7	7
46	46	ASSEMBLY	8	8	8
46	46	ASSEMBLY	9	9	9
46	46	ASSEMBLY	10	10	10

NOTES: . UNLESS OTHERWISE SPECIFIED

1. FOR GUTTER, NOTES AND LEGEND SEE DWG NO.2-125131.
2. FABRICATION AND ASSEMBLY OF THIS EQUIPMENT IS ACCORDANCE WITH SPECIFICATION SECTION M-519-C-CSI-12596.
3. MARK PER SPECIFICATION SECTION 13048.
4. IMPACT ASSURANCE, WEIGHTS "A" AND "B" ARE TO BE DETERMINED BY STILES CALCULATIONS. THE REQUIRED LENGTH OF BOTH IMPACT ASSURERS SHALL NOT EXCEED 48".

Figure 2-109. Impact Absorbers for Standard and Overpack Storage Tubes.

3 RUBIN DANIEL RESERVATION CHANGES MOORE MARINE ASSOCIATES		WESTINGHOUSE POWERFORD COMPANY 341 CHARLES STREET BALTIMORE, MARYLAND	
PREPARED BY: C. HOBT DISCOUNT FURNITURE & SHEDS 155 10000 WILSON AVE. WILSONVILLE, INDIANA	DATE: 11/23/74 CREDIT: 5040340 10/24/74	DESIGN CHANGE NOTICE BOLD DOC. NO. W-1-120142 SM/PG. 1 REV. 1	CATALOG: 28 BOLD 112-1-158 PAGE: 7 REV. 0 DCN - 043

Figure 2.110. Tube Plugs and
Embed Covers for Standard and
Overpack Storage Tubes.

Figure 2-1213. Canister Storage Building
Receiving Crane.

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NOTES:
1. SEE SHEET 1 FOR GENERAL NOTES AND PARTS LIST.

QUALITY LEVEL 1
SAFETY CLASS 3 (EXCEPT AS NOTED)

REVISIONS											
NO.	DATE	DESCRIPTION	BY	CHKD	APP'D	DESIGNED	DRAWN	INSTRUMENTED	TESTED	REVIEWED	APPROVED
1	10/20/92	ISSUED FOR CONSTRUCTION	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB
2	10/20/92	ISSUED FOR CONSTRUCTION	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB
3	10/20/92	ISSUED FOR CONSTRUCTION	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB
4	10/20/92	ISSUED FOR CONSTRUCTION	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB
5	10/20/92	ISSUED FOR CONSTRUCTION	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB
6	10/20/92	ISSUED FOR CONSTRUCTION	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB
7	10/20/92	ISSUED FOR CONSTRUCTION	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB
8	10/20/92	ISSUED FOR CONSTRUCTION	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB
9	10/20/92	ISSUED FOR CONSTRUCTION	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB
10	10/20/92	ISSUED FOR CONSTRUCTION	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB
11	10/20/92	ISSUED FOR CONSTRUCTION	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB	W. J. JACOB

Figure 2-13. Shield Hatch Assembly (Sheet 1 of 3)

Figure 2-13. Shield Hatch Assembly.
(Sheet 2 of 3)

ITEM	DESCRIPTION
4	SHIELD HATCH RING
8	SHIELD HATCH PLATE
10	SEAL RING
11	O-RING SEAL
12	O-RING SEAL
15	O-RING SEAL
16	O-RING SEAL
27	NEOPRENE GASKET
29	SWIVEL HOIST RING
35	3/8-16 UNC SOC HD CAP SCREW

3 SHIELD HATCH ASSEMBLY

SCALE: 1"=1'-0"

Figure 2-141. Canister Storage Building Multicanister Overpack Handling Machine Operations Area Plan View.

Figure 2-152. Canister Storage Building Multicanister Overpack Handling Machine Operations Area Elevation View.

ELEVATION LOOKING NORTH
MHM CASK TRAVEL

(Backup Power)
(sheet 1 of 3)

NOTES:

- EG.

Figure 2-17. Electrical
One-Line Diagram
(Backup Power).
(sheet 2 of 3)

- [illegible]

Figure 2-17. Electrical
One-Line Diagram
(Backup Power)
(Sheet 3 of 3)

NOTES:

1. FOR STANDARD DRAWING SYMBOLS, ABBREVIATIONS, AND OTHER NOTES SEE DWG H-2-122731 SH 1 AND SH 2.
2. SET RELAYERS INDICATES AUTOMATIC CONTROLS.
3. CABLE NUMBERS REFLECT THE ASSIGNED NUMBER ALONG WITH A, B, C SUPPLIES FOR EACH PHASE AND N SUPPLY FOR NEUTRAL, AND O SUPPLY FOR GROUND IF APPLICABLE. SEE DWG H-2-122731 SH 1-181117 FOR CONDUIT AND CONDUCTOR INFORMATION.
4. ALL CABLE NUMBERS ARE PREFIXED WITH "03" UNLESS NOTED OTHERWISE, WHICH REFLECTS THE BUILDING NUMBER ASSIGNED TO THE CLUSTER STORAGE BUILDING.
Eg. 030001A-2
5. UNLESS OTHERWISE NOTED, BOTH TRANSFER SWITCHES SHALL BE IN THE OPEN POSITION. UNLESS OTHERWISE NOTED, EACH TRANSFER SWITCH WILL RECEIVE A START DIRECT FROM THE DIESEL GENERATOR.
6. ALL CIRCUIT BREAKERS ARE IN THE CLOSED POSITION.

GRAPHIC SCALE
3/32" = 1'-0"

1. AUTOMATIC WET PIPE SPRINKLER HEADS SUGGESTED LOCATION: CONTRACTOR TO VERIFY SUPPORT AND STRUCTURAL DETAILS. ROUTING SHALL BE IN ACCORDANCE WITH NFPA 13.
2. 2 HOUR FIREWALL (ALL DOOR AND OPENINGS SHALL BE PROTECTED WITH 2 HOUR RATED DOORS, DAMPERS OR STOPS.
2. AREA NORTH OF FIREWALL IS FULLY SPRINKLERED. AREA SOUTH OF FIREWALL (STORAGE AREA) IS NOT SPRINKLERED, BUT PROVIDED WITH RATE OF RISE/RYED TEMPERATURE HEAT DETECTIONS.

☐ MANUAL ALARM - PULL STATION

F2-51/F2-52

Figure 2-18. Support Building Emergency Power Fire Protection. (sheet 2 of 2)

FLUOR DANIEL		WESTINGHOUSE HANFORD COMPANY SNF-CANISTER STORAGE BUILDING		DESIGN CHANGE NOTICE	
DESCRIPTION CHANGE: MCC RELIABILITY CHANGES				BASE DOC. NO. H-2-117795	
ADD FIRE RATED ENCLOSURE				SMT/Pg. 1	
ADD FIRE RATED DOOR ASSEMBLIES				REV. 1	
PREPARED BY: C ASH		DATE: 12/09/96		CAO CODE: DOS-6-22-ACD2-12C4-S5	
DISCIPLINE ENGINEER: C ASH		DATE: 12/09/96		PAGE 10	
DISCIPLINE: ARCHITECTURAL		CAD FILE: DCN03407		REV	
		DCN - 034

1. FOR GENERAL DATING STUDIOS SEE M-2-133300 SM 1 & 2.
2. FOR STIMULANT ADMINISTRATION, SEE ADR 191.
3. FOR INSTRUMENT CALIBRATION ASSISTANCES, SEE INSTRUMENT NOTE.
4. THE AREA IS UNCLASSIFIED.
5. ALL INSTRUMENTS ARE 4-5' ABOVE FRESHED SURFACE OR PULMONARY DARTS HOLD CHINESE.

[illegible]

FLUOR DANIEL		WESTINGHOUSE HANFORD COMPANY SW-CANISTER STORAGE BUILDING	
DESCRIPTION CHANGE: DELETE ITEM 27. MOVE ITEM 33. CHANGE FE-227 TO FE-533.		DESIGN CHANGE NOTICE	
PREPARED BY: SG IRBY		DATE: 11/01/95	
DISCIPLINE ENGINEER: DA PADUA		DATE: 11/01/95	
DISCIPLINE: CONTROL SYSTEMS		CAD/PLOT: DCN03201	
CAD/CODE: D056822AC0212CLASS		BASE DOC NO. H-2-121101	
SH1/PG. 2		REV. 1	
DCN - 032		PAGE 59 REV. 0	

Figure 2-21. Stack Monitoring Equipment. (Sheet 1 of 3)

31 FRONT VIEW
ST-989

CABINET DOORS REMOVED FOR CLARITY.

FLUOR DANIEL WESTINGHOUSE HANFORD COMPANY
SNF-CANISTER STORAGE BUILDING

DESCRIPTION CHANGE: STACK MONITORING MODIFICATIONS - EDN-014

DESIGN CHANGE NOTICE

BASE DOC. NO. H-2-131101

SHT/PG. 2 REV. 1

PREPARED BY: SC MBY DATE: 11/01/96

DISCIPLINE ENGINEER: DA PAOLA DATE: 11/01/96

DISCIPLINE: HEALTH PHYSICS CADFILE: DCH03203

CADCODE: 0056122AC0212CA55

DCN - 032

PG# 6/ REV. 0

Figure 2-21. Stack Monitoring Equipment.
(Sheet 2 of 3)

Figure 2-22 Overall Canister Storage Building One-Line Diagram

- NOTES:
1. FOR STANDARD DRAWING SYMBOLS, ABBREVIATIONS AND GENERAL NOTES SEE DWG H-2-122733 SH 1 AND SH 2.
 2. SEE ATTACHED SPECIFICATIONS, ABBREVIATIONS, AND GENERAL NOTES.
 3. CABLE RANGES REFLECT THE ASSIGNED NUMBER ALONG WITH A, B, C RANGES FOR EACH PHASE AND N, GROUND, SEE CONDUIT/CABLE SCHEDULE W-273-C-001-111111 FOR CONDUIT AND CABLE INFORMATION.
 4. ALL CABLE RANGES ARE LISTED WITH 90° UNLESS OTHERWISE SPECIFIED. SEE THE NUMBER ASSIGNED TO THE CABLE RANGES FOR THE NUMBER ASSIGNED TO THE CABLE RANGES.

QUALITY LEVEL II (EXCEPT AS NOTED) SAFETY CLASS 3 (EXCEPT AS NOTED)

1		10		PERSON FOR H-2-122733		20		10		20		30		40		50		60		70		80		90		100	
2		20		APPROVED FOR CONSTRUCTION		30		30		40		50		60		70		80		90		100		110		120	
3		30		APPROVED FOR CONSTRUCTION		40		40		50		60		70		80		90		100		110		120		130	
4		40		APPROVED FOR CONSTRUCTION		50		50		60		70		80		90		100		110		120		130		140	
5		50		APPROVED FOR CONSTRUCTION		60		60		70		80		90		100		110		120		130		140		150	
6		60		APPROVED FOR CONSTRUCTION		70		70		80		90		100		110		120		130		140		150		160	
7		70		APPROVED FOR CONSTRUCTION		80		80		90		100		110		120		130		140		150		160		170	
8		80		APPROVED FOR CONSTRUCTION		90		90		100		110		120		130		140		150		160		170		180	
9		90		APPROVED FOR CONSTRUCTION		100		100		110		120		130		140		150		160		170		180		190	
10		100		APPROVED FOR CONSTRUCTION		110		110		120		130		140		150		160		170		180		190		200	
11		110		APPROVED FOR CONSTRUCTION		120		120		130		140		150		160		170		180		190		200		210	
12		120		APPROVED FOR CONSTRUCTION		130		130		140		150		160		170		180		190		200		210		220	
13		130		APPROVED FOR CONSTRUCTION		140		140		150		160		170		180		190		200		210		220		230	
14		140		APPROVED FOR CONSTRUCTION		150		150		160		170		180		190		200		210		220		230		240	
15		150		APPROVED FOR CONSTRUCTION		160		160		170		180		190		200		210		220		230		240		250	
16		160		APPROVED FOR CONSTRUCTION		170		170		180		190		200		210		220		230		240		250		260	
17		170		APPROVED FOR CONSTRUCTION		180		180		190		200		210		220		230		240		250		260		270	
18		180		APPROVED FOR CONSTRUCTION		190		190		200		210		220		230		240		250		260		270		280	
19		190		APPROVED FOR CONSTRUCTION		200		200		210		220		230		240		250		260		270		280		290	
20		200		APPROVED FOR CONSTRUCTION		210		210		220		230		240		250		260		270		280		290		300	
21		210		APPROVED FOR CONSTRUCTION		220		220		230		240		250		260		270		280		290		300		310	
22		220		APPROVED FOR CONSTRUCTION		230		230		240		250		260		270		280		290		300		310		320	
23		230		APPROVED FOR CONSTRUCTION		240		240		250		260		270		280		290		300		310		320		330	
24		240		APPROVED FOR CONSTRUCTION		250		250		260		270		280		290		300		310		320		330		340	
25		250		APPROVED FOR CONSTRUCTION		260		260		270		280		290		300		310		320		330		340		350	
26		260		APPROVED FOR CONSTRUCTION		270		270		280		290		300		310		320		330		340		350		360	
27		270		APPROVED FOR CONSTRUCTION		280		280		290		300		310		320		330		340		350		360		370	
28		280		APPROVED FOR CONSTRUCTION		290		290		300		310		320		330		340		350		360		370		380	
29		290		APPROVED FOR CONSTRUCTION		300		300		310		320		330		340		350		360		370		380		390	
30		300		APPROVED FOR CONSTRUCTION		310		310		320		330		340		350		360		370		380		390		400	
31		310		APPROVED FOR CONSTRUCTION		320		320		330		340		350		360		370		380		390		400		410	
32		320		APPROVED FOR CONSTRUCTION		330		330		340		350		360		370		380		390		400		410		420	
33		330		APPROVED FOR CONSTRUCTION		340		340		350		360		370		380		390		400		410		420		430	
34		340		APPROVED FOR CONSTRUCTION		350		350		360		370		380		390		400		410		420		430		440	
35		350		APPROVED FOR CONSTRUCTION		360		360		370		380		390		400		410		420		430		440		450	
36		360		APPROVED FOR CONSTRUCTION		370		370		380		390		400		410		420		430		440		450		460	
37		370		APPROVED FOR CONSTRUCTION		380		380		390		400		410		420		430		440		450		460		470	
38		380		APPROVED FOR CONSTRUCTION		390		390		400		410		420		430		440		450		460		470		480	
39		390		APPROVED FOR CONSTRUCTION		400		400		410		420		430		440		450		460		470		480		490	
40		400		APPROVED FOR CONSTRUCTION		410		410		420		430		440		450		460		470		480		490		500	
41		410		APPROVED FOR CONSTRUCTION		420		420		430		440		450		460		470		480		490		500		510	
42		420		APPROVED FOR CONSTRUCTION		430		430		440		450		460		470		480		490		500		510		520	
43		430		APPROVED FOR CONSTRUCTION		440		440		450		460		470		480		490		500		510		520		530	
44		440		APPROVED FOR CONSTRUCTION		450		450		460		470		480		490		500		510		520		530		540	
45		450		APPROVED FOR CONSTRUCTION		460		460		470		480		490		500		510		520		530		540		550	
46		460		APPROVED FOR CONSTRUCTION		470		470		480		490		500		510		520		530		540		550		560	
47		470		APPROVED FOR CONSTRUCTION		480		480		490		500		510		520		530		540		550		560		570	
48		480		APPROVED FOR CONSTRUCTION		490		490		500		510		520		530		540		550		560		570		580	
49		490		APPROVED FOR CONSTRUCTION		500		500		510		520		530		540		550		560		570		580		590	
50		500		APPROVED FOR CONSTRUCTION		510		510		520		530		540		550		560		570		580		590		600	
51		510		APPROVED FOR CONSTRUCTION		520		520		530		540		550		560		570		580		590		600		610	
52		520		APPROVED FOR CONSTRUCTION		530		530		540		550		560		570		580		590		600		610		620	
53		530		APPROVED FOR CONSTRUCTION		540		540		550		560		570		580		590		600		610		620		630	
54		540		APPROVED FOR CONSTRUCTION		550		550		560		570		580		590		600		610		620		630		640	
55		550		APPROVED FOR CONSTRUCTION		560		560		570		580		590		600		610		620		630		640		650	
56		560		APPROVED FOR CONSTRUCTION		570		570		580		590		600		610		620		630		640		650		660	
57		570		APPROVED FOR CONSTRUCTION		580		580		590		600		610		620		630		640		650		660		670	
58		580		APPROVED FOR CONSTRUCTION		590		590		600		610		620		630		640		650		660		670		680	
59		590		APPROVED FOR CONSTRUCTION		600		600		610		620		630		640		650		660		670		680		690	
60		600		APPROVED FOR CONSTRUCTION		610		610		620		630		640		650		660		670		680		690		700	
61		610		APPROVED FOR CONSTRUCTION		620		620		630		640		650		660		670		680		690		700		710	
62		620		APPROVED FOR CONSTRUCTION		630		630		640		650		660		670		680		690		700		710		720	
63		630		APPROVED FOR CONSTRUCTION		640		640		650		660		670		680		690		700		710		720		730	
64		640		APPROVED FOR CONSTRUCTION		650		650		660		670		680		690		700		710		720		730		740	
65		650		APPROVED FOR CONSTRUCTION		660		660		670		680		690		700		710		720		730		740		750	
66		660		APPROVED FOR CONSTRUCTION		670		670		680		690		700		710		720		730		740		750		760	
67		670		APPROVED FOR CONSTRUCTION		680		680		690		700		710		720		730		740		750		760		770	
68		680		APPROVED FOR CONSTRUCTION		690		690		700		710		720		730		740		750		760		770		780	
69		690		APPROVED FOR CONSTRUCTION		700		700		710		720		730		740		750		760		770		780		790	
70		700		APPROVED FOR CONSTRUCTION		710		710		720		730		740		750		760		770		780		790		800	
71		710		APPROVED FOR CONSTRUCTION		720		720		730		740		750		760		770		780		790		800		810	
72		720		APPROVED FOR CONSTRUCTION		730		730		740		750		760		770		780		790		800		810		820	
73		730		APPROVED FOR CONSTRUCTION		740		740		750		760		770		780		790		800		810		820		830	
74		740		APPROVED FOR CONSTRUCTION		750		750		760		770		780		790		800		810		820		830		840	
75		750		APPROVED FOR CONSTRUCTION		760		760		770		780		790		800		810		820		830		840		850	
76		760		APPROVED FOR CONSTRUCTION		770		770		780		790		800		810		820		830		840		850		860	
77		770		APPROVED FOR CONSTRUCTION		780		780		790		800		810		820		830		840		850		860		870	
78		780		APPROVED FOR CONSTRUCTION		790		790		800		810		820		830		840									

HEALTH PROTECTION
INSTRUMENTS

Figure 2-23 Distributed
Control System

GENERAL NOTES

1. FOR GENERAL DRAWING SYMBOLS SEE H-2-12380 SH 1.2.
2. FOR STANDARD ABBREVIATIONS, SEE ASME Y11.1.
3. FOR INSTRUMENT INSTALLATION ASSEMBLES, SEE INSTRUMENT INDEX.
4. THE AREA IS UNCLASSIFIED.
5. ALL INSTRUMENTS ARE 4"-6" ABOVE FINISHED SURFACE OR PLUMBING UNLESS NOTED OTHERWISE.

3.0 HAZARD AND ACCIDENT ANALYSES

3.1 INTRODUCTION

This chapter summarizes the hazard and accident analyses performed to support the CSB design and initial construction activities. The methods used to identify CSB hazards and select accident scenarios for analysis are described in Section 3.3. The analyses of the selected accidents are presented in Section 3.4, with emphasis on the identification of SSCs required for accident prevention and mitigation. The potential impacts of these SSCs on the design of the CSB structure and systems, including the HCS Annex structure are discussed. The hazard category classification of the facility is presented in Section 3.3.2.2 with the conclusion presented that the CSB is a hazard category 2 facility. Dose assessments to operating personnel and the public during normal operations and anticipated operational occurrences will be provided in Chapter 7.0 of the final SAR.

An assessment team conducted a preliminary hazard analysis (PHA) to identify potential hazards to the facility worker, collocated worker, the public, and the environment. Potential events considered ranged from normal operation through beyond design basis accidents. Accidents for consideration of consequence analyses were grouped as follows:

- Release of MCO gases under pressure during handling, staging, or interim storage
- Single MCO damage failure during handling
- • Multiple MCO failures during handling
- Hydrogen gas combustion
- Multiple MCO-tube failures during temporary staging or interim storage
- Beyond design basis events accidents.

The PHA also identified off-normal conditions for consideration of defense-in-depth features for the protection of the workers, environment, and the public.

The results of the subsequent accident consequence analyses identify the need for both safety-class and safety-significant accident prevention and mitigation features as required by DOE Order 5480.23, *Nuclear Safety Analysis Reports*. In general, the safety-class features are required to protect the environment or the offsite receptor and the safety-significant features are required for protection of the collocated worker, for protection of the facility worker, or to provide defense in depth. As a general rule, according to DOE-STD-3009-94, *Preparation Guide For U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*, safety-significant SSC designations for worker safety are limited to those SSCs whose failure is estimated to result in an acute worker fatality or serious injury to the worker. In many cases, the choice of safety-class or safety-significant features to mitigate exposure to the public or to the collocated worker will result in protection

of the facility workers as well. For example, confinement of potential releases near the source of the release, rather than at the facility boundary, prevents exposure of the facility worker as well as protecting personnel outside the facility.

The location of the offsite receptor and the bases for this location are discussed in Section 1.3. The collocated worker is assumed to be located at 100 m (328 ft) from the CSB release point.

The accident analysis is augmented by a formal design review process and independent safety review to ensure that the safety-related design requirements have been correctly identified, interpreted, and applied to the design. This process is described in Section 17.4.1 as suggested by DOE-STD-3009-94. The appropriate design requirements, with identified options, have been established through the safety classifications process based on the analyses presented in this chapter. A configuration management plan that follows the design process has been implemented (WHC 1995). The plan ensures that the safety-class SSCs are maintained and that any open items are tracked and closed. Additional detail on this configuration management plan and other aspects of its implementation are discussed in Section 17.4.2.

The final SAR will define the safety basis of the facility, document the logic of its derivation, demonstrate adherence to the safety basis, and justify its adequacy in accordance with appropriate regulatory requirements. Chapter 3.0 of the final SAR will include the results of the safety analyses that identify the dominant contributors to the risk of the facility so that these vulnerabilities can be managed.

3.2 REQUIREMENTS

This section lists the design codes, standards, regulations, and DOE orders that are required for establishing the safety basis for the CSB. Only the requirements that are specific for Chapter 3.0 and that pertain to the hazard and accident analysis are provided.

3.2.1 U.S. Department of Energy Orders and Standards

The following DOE orders and standards are applicable to the safety analysis.

- DOE Order 5400.5, 1990, *Radiation Protection of the Public and the Environment*. This order establishes standards and requirements for operations of DOE and its contractors with respect to protection of members of the public and the environment against undue risk from radiation.
- DOE Order 5480.22, 1992, *Technical Safety Requirements*. This order states the requirements to have technical safety requirements (TSRs) prepared for DOE nuclear facilities and to delineate the criteria, content, scope, format, approval process, and reporting requirements of these documents and revisions thereof.

- DOE Order 5480.23, 1992, *Nuclear Safety Analysis Reports*. In DOE Order 5480.23, Section 8.B.(3).(k) sets the requirement for analysis, and Attachment 1 to the order includes guidance to meet this requirement.
- DOE Order 6430.1A, 1989, *General Design Criteria*. This Order provides requirements for the identification of safety-class items.
- DOE-STD-1027-92, 1992, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*. This standard establishes guidance for the preparation and review of hazard categorization and hazards and accident analyses techniques as required by DOE Order 5480.23. Of particular importance to Chapter 3.0 is the guidance relative to the hazard categorization methodology and the hazards and accident analyses techniques appropriate to the graded approach required by the DOE Order 5480.23.
- DOE-STD-3009-94, 1994, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*. This standard supplements DOE Order 5480.23 by providing guidance specific to nonreactor nuclear facilities. In this regard, the standard provides more detailed information on the performance of hazards and accident analyses for hazard category 2 and 3 facilities. The standard also establishes additional requirements for the establishment of defense in depth and the identification of safety-significant SSCs.

• 10 CFR 835, Title 10, Part 835, "Occupational Radiation Protection," Code of Federal Regulations. This rule provides primary standards for occupational radiation protection of workers at DOE facilities.

3.2.2 U.S. Nuclear Regulatory Commission Rules and Guidance

In Memorandum EM-36-3.1.6.7, *Concurrence with K-Basins Spent Nuclear Fuel Project Policy on Nuclear Safety Requirements* (Grumbly 1995), DOE established the requirement for new SNF Project facilities to achieve "nuclear safety equivalency" to comparable NRC-licensed facilities. The SNF Project identified the NRC requirements that were needed in addition to existing and applicable DOE requirements to establish nuclear safety equivalency. These NRC requirements and the process method used to identify them are documented in WHC-SD-SNF-DB-003, *Spent Nuclear Fuel Project Path Forward, Additional NRC Requirements* (Garvin 1996) and in WHC-SD-SNF-DB-009, *Canister Storage Building Natural Phenomena Hazards* (Tallman 1996). These documents establish the design requirements to be met for the CSB to achieve this equivalency.

The following NRC rules and guidance were considered in the development of WHC-SD-SNF-DB-003 (Garvin 1996) and WHC-SD-SNF-DB-009 (Tallman 1996) and have particular significance to Chapter 3.0.

- 10 CFR 72, Title 10, Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," Code of Federal Regulations (10 CFR 72). This rule is used

for the licensing of ISFSIs. Section 72.3, "Definitions," provides the definition of SSCs that should be considered as "important to safety." For the CSB, SSCs determined as "important to safety" by the definition of Section 72.3 are designated safety class and are subject to the requirements of DOE Order 6430.1A. Section 72.106, "Controlled Area of an ISFSI or MRS," establishes a limit of 50 mSv (5 rem) at the controlled area boundary for any design basis accident (DBA). A more restrictive limit of 5 mSv (0.5 rem) to the worst-case public receptor is used to determine safety-class functions for SSCs for this facility. Section 72.122, "Overall Requirements," requires that the design bases for SSCs important to safety must reflect appropriate combinations of the effects of normal and accident conditions, and the effects of natural phenomena. Section 72.24, "Content of Application: Technical Information," provides requirements in 72.24(m) for the analyses of accidents and natural phenomena events that may result in a dose at the controlled area boundary.

- NRC Regulatory Guide 3.48, *Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage)* (NRC 1989). This guide establishes the format and content for materials license applications for ISFSIs, including the requirements for a chapter on accident analyses. For such a chapter, Regulatory Guide 3.48 states that ANSI/ANS-57.9-1984, *Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)*, defines four categories of design events that provide a means of establishing design requirements to satisfy operational and safety criteria. This standard was reissued in 1992 as ANSI/ANS-57.9-1992 and retitled *Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)* (ANSI/ANS 1992a).
- NRC Regulatory Guide 3.60, *Design of an Independent Spent Fuel Storage Installation (Dry Storage)* (NRC 1987), adopts, with qualification, ANSI/ANS-57.9-1984 as acceptable for use in the design of an ISFSI that uses a dry environment as the mode of storage for SNF. Of the nine qualifications made by the NRC staff on the use of the standard, one relates to the content of Chapter 3.0 of this SAR. The staff points out that Section 2.8 of the standard defines a new term, "important to confinement features," to classify SSCs with regard to the degree of their importance to safety. The staff requires that the definition of the term "important to safety" provided in 10 CFR 72.3 should be used instead of "important to confinement features."

As mentioned above, ANSI/ANS-57.9-1984 was reissued and retitled in 1992. Section 2, "Definitions," defines design event categories that are to be used to evaluate the radiological protection provided by the facility. Design events I and II cover normal and off-normal events. These events are usually addressed by summarizing analyses that confirm the SSCs are appropriately designed to accommodate the events without challenge to the design. Design events III and IV cover a range of postulated accident events for which radiological

calculations are performed to confirm that onsite and offsite doses are within acceptable limits as defined in 10 CFR 72.

- NUREG-0612, 1980, Control of Heavy Loads at Nuclear Power Plants: Resolution of Generic Technical Activity A-36.
- NUREG/CR-2651, 1982, Accident Generated Particulate Materials and Their Characteristics -- A Review of Background Information.

3.2.3 Industry Consensus Standards and Other Documentation

The following rule and industry standards are applicable to the safety basis for the facility.

- 29 CFR 1910, Title 29, Part 1910, "Occupational Safety and Health Standards," Code of Federal Regulations.
- ANSI/ANS-57.9-1992, 1992, Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type).
- ANSI/ANS-57.1-1992, 1992, Design Requirements for Light Water Reactor Fuel Handling System.

3.2.4 Hanford Site Requirements

The following Hanford Site standards and specifications are applicable to the safety analysis.

- WHC-SD-SNF-DB-003, 1996, Spent Nuclear Fuel Project Path Forward, Additional NRC Requirements.
- WHC-SD-SNF-DB-009, 1996, Canister Storage Building Natural Phenomena Hazards.
- WHC-S-0425, 1996, Performance Specification for the Spent Nuclear Fuel Canister Storage Building.

3.3 HAZARD ANALYSIS

This section describes the hazard identification and evaluation performed for the CSB.

3.3.1 Methodology

This subsection presents the methodology used to identify and characterize CSB hazards. It also presents the methodology used to evaluate the identified accidents. The results of the application of this methodology to the CSB are presented in Section 3.3.2.

3.3.1.1 Hazards Identification. Hazard identification is the process of highlighting material, system, process, and facility characteristics with the potential to initiate accidents having undesirable consequences. For the CSB, this would be undesirable consequences to the workers, public or environment. The hazard identification methodology considers the following characteristics of hazards:

- Inherent physical, radiological, or chemical characteristics that have the potential to cause harm to people, property, or the environment
- Combinations of hazardous material, an operating environment, and planned and unplanned events that can result in an accident.

To identify hazards associated with the CSB, a PHA, based on conceptual design, was performed by an assessment team that included individuals knowledgeable of accident analyses, chemical systems processes, CSB design, and facility operations. As the CSB design evolved, the assessment PHA team was reconvened, as necessary, to examine the effect of design and process changes, and to revise the PHA as appropriate. The main contributors to the PHA team, and their qualifications, are listed alphabetically in Table 3A-2, Appendix 3A. The PHA is an initial effort directed at the requirements of DOE Order 5480.23 and its implementing standard, DOE-STD-3009-94, for a systematic, rigorous technique for identifying the range of potential hazards posed by the operation of the facility. The PHA supports current CSB safety analysis and design activities. Modification of the PHA process and/or use of other hazard evaluation techniques will be applied to support the hazards analysis for the final SAR will examine the actual facility design and planned operations. The final hazards analysis is the basis for selection of accident scenarios that demonstrate the adequacy of safety SSCs.

The PHA process consisted of identifying the various operational steps to be conducted within the CSB. The main operational steps are

- Cask receiving
- MCO servicing
- MCO handling
- MCO staging (residence time in the CSB storage tube before removal for hot conditioning)
- MCO interim storage (residence time in the storage tube after return from hot conditioning until removal from the CSB for final disposal).

Each step was subdivided into specific activities, as provided in Appendix 3A. For each activity, the potential hazards were identified along with the potential causes and consequences of the hazard. The hazards were further evaluated by establishing accident initiators and sequences, potential targets or consequences, and potential mitigating features (engineered and administrative), and by qualitatively estimating the severity of each accident

and its likelihood. The completed PHA and a discussion of its development are provided in Appendix 3A.

The effects of natural phenomena and external hazards on the CSB can include ~~process~~-upsets and/or challenges to the integrity of the MCO and CSB confinement systems. These are reflected in the PHA (Appendix 3A, Table 3A-1) in the following manner.

- ~~Process~~-Parameter changes initiated by natural phenomena and external events are often the same type as changes that may be initiated by equipment failures or operator error.
- In some cases, external events can add hazardous material to the system (e.g., a radionuclide release from a nearby facility) possibly initiating accidents.
- The common-cause failure of several non-safety-class structural features of the CSB that have not been designed for a particular severe natural phenomenon may be more challenging than the failures considered individually.

For the first two cases, the natural and external phenomena are included in the "Causes" column of the PHA form (Appendix 3A, Table 3A-1). The third case is included in Appendix 3A, Table 3A-1, as "Accident/system, ~~item number~~ 60.f."

3.3.1.2 Hazard Evaluation. The PHA team used the following "S" rankings to assign qualitative levels of severity to the hazard consequences. Unless noted otherwise in Appendix 3A, Table 3A-1, the severity assignments were made with the assumption that the accident was unmitigated. As such, these assignments are not true indications of the potential consequences of the accident to the worker, the public, or the environment.

- S0 No effect outside the CSB confinement systems and no safety concerns for the facility worker, the collocated worker, or members of the general public
- S1 Potential industrial injury, radiological dose consequences, or chemical exposure to the facility worker; limited environmental discharge of hazardous material outside the facility
- S2 Potential significant radiological dose consequences or chemical exposure to the collocated worker; significant environmental discharge of hazardous material within the Hanford Site boundary
- S3 Potential significant radiological dose consequences or chemical exposure to the offsite receptor; environmental discharge of hazardous material outside the Hanford Site boundary or to the groundwater.

In assigning these severity levels the PHA team had the benefit of preliminary safety evaluations that had been completed for the CSB (Brehm 1995a and 1995b). These preliminary safety evaluations included

quantitative estimates of the exposures to the collocated worker and the offsite receptor.

The assignment of the likelihoods were qualitative, consensus estimates of the frequency of the initiating event. An alphanumeric system was used to designate the frequency (events/year) by the following "F" rankings:

- F1 Anticipated event (the event can be expected to occur regularly during the course of the activity: $> 10^{-2}$ to $\leq 10^0$)
- F2 Unlikely event (the event is not expected to occur regularly during the course of the activity but may occur sometime during the operating life of the CSB: $> 10^{-4}$ to $\leq 10^{-2}$)
- F3 Extremely unlikely event (the event is credible but not expected to occur during the operating life of the CSB: $> 10^{-6}$ to $\leq 10^{-4}$)
- F4 Beyond extremely unlikely event (the event is not considered "credible": $\leq 10^{-6}$).

The upper bound for the F1 classification is 1.0. This differs from ~~is more comprehensive than the classification given in DOE-STD-3009-94, which defines the upper bound as 0.1 and thereby does not account for events from 1.0/yr to 0.1/yr.~~

The initiating events can be internal or external events. External events include severe natural phenomena, range fires, and hazards from nearby facilities. In most cases, the internal events dominate the frequency assignment.

The selection of accidents for quantitative analysis was performed by a binning ~~process methodology~~ based on phenomenon and the potential quantity of material for release.

DOE-STD-3009-94 suggests a matrix approach in which only "unacceptable accidents" (moderate to high consequences, unlikely to extremely unlikely frequency) should be identified. For the binning of the CSB hazards, only those hazards ranked as categories S2 and S3 were considered to be sufficiently significant to require consideration for additional analysis. The selection of the S2 and S3 events was made independent of the frequency assignment, that is, independent of the "F" ranking.

The worst-case accident in each major grouping served as a representative and bounding scenario for that set of accident types. The worst-case accidents are evaluated in detail in Section 3.4. The major groupings are as follows.

- Release of MCO gases under pressure during handling, staging, or interim storage
- Single-MCO ~~damage failure~~ during handling
- • ~~Multiple MCO failures during handling~~

- Hydrogen gas combustion
- Multiple MCO-tube failures during temporary-staging or interim storage
- Beyond design basis ~~events-accidents~~.

The specific accidents included in each group are provided in Section 3.3.2.3.5.

~~As stated in DOE-STD-3009-94, analysis of beyond design basis accidents is not required to provide assurance of public health and safety. Therefore, the presentation of these analyses will be postponed until the final SAR are not analyzed in detail in this issue of Chapter 3.0. They will be addressed in the final SAR as suggested by Section 3.4.3 of DOE STD 3009-94.~~

Section 3.2.2 discusses implementation of NRC nuclear safety equivalency for the CSB. An element of that equivalency is ANSI/ANS-57.9-1992 (ANSI/ANS 1992a). This standard presents the following set of events for consideration in the design and accident analyses for an ISFSI:

Design event I	Expected to occur regularly or frequently in the coarse course of normal operation
Design event II	Can be expected to occur with moderate frequency or on the order of once during a calendar year of operation
Design event III	Infrequent events that could reasonably be expected to occur during the lifetime of the installation
Design event IV	Postulated because their consequences may result in the maximum potential impact on the immediate environs.

This chapter is limited to consideration of off-normal and accident conditions. As design event I occurrences are associated with normal operation, they are not addressed in this chapter except for identifying hazards to the facility worker. Hazards to the facility worker during normal, off-normal, and accident conditions are addressed in Section 3.3.2.3.3. Protection of the facility worker for normal and off-normal events will be addressed in Chapters 7.0 and 8.0 of the SAR as required by DOE-STD-3009-94. ~~The loadings the CSB will experience during design event I conditions (i.e., normal operation), such as dead and live weight, pressure, and thermal loading, will be discussed in Chapters 2.0 and 4.0 of the final SAR as suggested by DOE STD 3009-94. Similar loadings for the MCOs will be discussed in the MCO Topical Report.~~

Design event II, III, and IV occurrences are identified by the hazard identification process methodology discussed in Section 3.3.1.1. Consequence analyses for design event II, III, and IV hazards are performed as discussed in Section 3.3.1.2.

3.3.2 Hazard Analysis Results

3.3.2.1 Hazard Identification. The results of the PHA activity are provided in Appendix 3A, Table 3A-1. Table 3A-1 presents, for each hazard, its form (e.g., fuel particulate within an MCO), type (i.e., type of energy source or hazardous material e.g., radiological inventory or missile), location (e.g., pressure relief in the service station), and total quantity (e.g., the contents of one MCO). The form, type, and total quantity are presented in the "Inventory at risk" column. The location of the hazard is presented in the "Accident/system" column. Quantitative information on the hazard is presented in Section 3.4 for those hazards for which consequence analyses were performed. The "Potential Hazard" and "Causes" columns of Table 3A-1, Appendix 3A, provides information on the type of energy source or material used by present in the CSB facility that may generate constitute the hazard. The "Comment" "Remarks" column provides information on sources of energy that may exacerbate an accident resulting from the hazard.

The CSB has one main inventory of hazardous material: the radionuclide contents of the MCOs. The CSB does not include any chemical process systems, as discussed in Section 3.3.2.3.4.

As the CSB does not have an operating history, major hazards that have resulted from the facility operation cannot be summarized as suggested by DOE-STD-3009-94. However, the CSB is similar to facilities issued materials licenses under 10 CFR 72, so the 10 CFR 72 dockets including notices of violations issued and reported under 10 CFR 72.75, "Reporting Requirements for Specific Events and Conditions," were reviewed. The results of this review are presented in Table 3-1. This table also addresses events at DOE facilities similar to the CSB.

3.3.2.2 Hazard Classification. The CSB has been assigned a hazard category of 2 in accordance with DOE-STD-1027-92. The hazards category for the CSB was derived in WHC-SD-SNF-HC-007, *Hazard Category Analysis for the Canister Storage Building* (Kummerer 1995). That document was prepared in accordance with the requirements of DOE Order 5480.23 and DOE-STD-1027-92. This hazard classification assignment for the CSB has been approved by DOE (Sellers 1996b). In accordance with DOE-STD-1027-92, the final hazard category of the CSB will be based on the hazard analysis presented in the final SAR.

The initial hazard category was determined by identifying the facility radioactive materials inventory at risk for release, unmitigated by any safety features. The bounding scenario for release of material from the CSB was taken to be a beyond design basis seismic event that collapsed the operating floor. All the MCOs broke open during the event. The release from these MCOs was a resuspension over a 24-hour period of the fine particulate material within an MCO. It was also assumed that 1% of the MCOs (four) had not been adequately dried, or adequately vented, and contained hydrogen gas buildup from radiolysis and corrosion. These MCOs experienced a sudden venting, releasing the fine particulate material with the MCO gases.

Table 3-1. Off-Normal Events at Independent Spent Fuel Storage Installations and Similar Facilities.

Event	Facility	Where addressed in this chapter
Partial blockage of air inlet by frosting of bird and rodent protection screens	Fort St. Vrain	Table 3-2 relative to loss of natural convection cooling of the vault
External contamination of cask above technical specification limit ^a	Fort St. Vrain H. B. Robinson	Appendix 3A, Table 3A-1, entry 60.a.4
Defect in cask design or materials that could call for questioning the cask integrity, for example: Palisades indications in main longitudinal weld (leading to unloading of casks) Vectra casks - weld material ground down beyond parent metal	Pacific Sierra Nuclear, Vectra-Pacific Nuclear Fuel, Oconee, Prairie Island Calvert Cliffs Surry	Appendix 3A, Table 3A-1, entries 60.d.1 and 60.e.1
Potential brittle fracture of cask components ^b (lifting attachments)	Palisades	Appendix 3A, Table 3A-1, entry 60.a.3 for cask drop; event is not likely for MCO, which is not made of ferritic material
Failure to satisfy technical specification limit of drying process ^c	Calvert Cliffs	Appendix 3A, Table 3A-1, entry 60.b.5
Potential failure of Swagelok ^c tube fittings (used for seal pressure monitoring)	Several 10 CFR 72 ^d	Appendix 3A, Table 3A-1, entries 60.b.7, 60.b.9, and 60.b.10 for events related to MCO purging, which could use similar fittings
Ignition of hydrogen during preparation for welding of final closure	Point Beach	Burn during welding is applicable to CSB Annex Preliminary Hazards Analysis. For the CSB, hydrogen burn during MCO servicing, handling, staging, and interim storage is addressed in several entries in Appendix 3A, Table 3A-1
Drop of fuel container	Savannah River	Appendix 3A, Table 3A-1, entry 60.a.3 for cask and MCO drop

^aApplicable to path forward shipping cask and MCO.^bApplicable to the cask only for the reason stated.^cSwagelok is a trademark of Crawford Fitting Company.^d10 CFR 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste" Code of Federal Regulations, as amended.

MCO = multicanister overpack.

SNR = safety analysis report.

The inventory at risk for release in this event was the total assumed quantity of particulate material in the MCOs. For the 386 MCOs from which resuspension of particulates was the only release mechanism, 6.5 kg (14 lb) particulates per MCO was assumed. This value is based on total expected fuel particulate, not individual bounding values per MCO, because all MCOs are assumed to be damaged. For the four MCOs that also experienced sudden venting, an upper value of 13.0 kg (29 lb) particulates per MCO was assumed. This value was chosen to account for additional particulate that could form in MCOs that were not properly treated before shipping.

The total inventory at risk for release was

$$(386 \text{ MCOs} \times 6.5 \text{ kg} + 4 \text{ MCOs} \times 13.0 \text{ kg}) \times \frac{1,000 \text{ g}}{\text{kg}} = 2.56 \times 10^6 \text{ g}$$

(Kummerer 1995). It was assumed that the particulate material at risk for release had the same radionuclide content as the fuel. Using these assumptions, the sum of ratios to the hazard category 2 threshold quantities of DOE-STD-1027-92 was 19.0. If the sum of the ratios exceeds 1.0, the facility is designated hazard category 2.

During the time since the hazard category analysis was performed, estimates of the total expected particulate inventory of an MCO have been reassessed (Pajunen and Cowan 1996). The expected process value for particulate quantity in a typical MCO remains near 6.5 kg (14 lb) is 40 kg (88 lb) and. However, the bounding value for the four inadequately processed pressurized MCOs is now 300 kg (660 lb). If the four MCOs that experienced sudden venting are assumed to contain 300 kg (660 lb) particulate, the inventory at risk for release is increased to 3.7×10^6 ~~1.7×10^6~~ g and the ratio to hazard category 2 threshold values increases to ~~27~~ 120. The increase does not change the hazard category 2 designation.

The ~~process described~~ description above did not rely on segmentation of the radionuclide inventory.

3.3.2.3 Hazard Evaluation. The PHA ~~process~~ described in Sections 3.3.1.1, 3.3.1.2, and 3.3.2.1, in addition to identifying the potential hazards, also characterized the identified hazards in the context of the actual ~~processes~~ practices to be used in the CSB. For example, while the MCO is being serviced in the service station ("Accident/system, 60.b" in Appendix 3A, Table 3A-1), a number of hazards may put the MCO radionuclide inventory at risk. These hazards are listed in the table and include dropping the cask lid, inadvertent release of the MCO atmosphere, and errors in the purging operation. The "Safety features" columns include suggestions for prevention and mitigation features, both engineered and administrative.

The accident groupings provided in Section 3.3.1.1 provide systematic evaluation of the accidents based upon common phenomena. The qualitative severity of assignments of the hazard consequences described in Section 3.3.1.2 consider the potential impact of the hazard on the environment.

DOE-STD-3009-94 suggests discussion of specific topics of concern relative to the accident analyses. During the completion of the analyses

discussed in Section 3.4, key assumptions were made that will need to be confirmed before the CSB design and SAR safety analyses are finalized. These are presented in Table 3-2 as concerns requiring resolution.

Some of the items in Table 3-2 indicate plans for using data from fuel and particulate characterization efforts. The schedule for acquiring these data is given in WHC-SD-SNF-PLN-012, *Spent Nuclear Fuel Project Integrated Safety Management Plan* (Daschke 1996).

3.3.2.3.1 Planned Design and Operational Safety Improvements. According to DOE-STD-3009-94, this section is to discuss planned improvements for an existing facility. As the CSB is a new facility, this specific requirement is not meaningful for this SAR.

The CSB definitive design is currently evolving in parallel with the hazards evaluation. The accident analyses discussed in Section 3.4 have identified the need for safety-class and safety-significant prevention and mitigation features for several postulated accidents. As the definitive design progresses, the architect-engineer will evaluate these requirements and recommend the most cost-effective options. The acceptance of the recommendations will be closely coordinated with the CSB safety analysis group.

3.3.2.3.2 Defense in Depth. This section summarizes the plans to address the significant aspects of defense in depth. Defense in depth consists of multiple features (equipment and administrative) applied to accident prevention or mitigation to a degree proportional to the hazard risk (i.e., likelihood and consequence). This provides for an increased level of protection by providing additional barriers that, while not used specifically within the accident analyses to prevent or mitigate, serve to (1) reduce the number of challenges to the safety-class systems identified within the accident analysis, (2) mitigate releases upon barrier failure, or (3) ensure the safety of the facility is not unduly dependent upon the existence of a particular barrier. For example, where an MCO is designed to withstand all anticipated drops without confinement failure, the design of a crane system that reduces the likelihood of an MCO drop is an implementation of defense in depth. The crane function would not be taken credit for in the analysis (and therefore would not require designation as safety class) although it serves to reduce the likelihood of events that challenge the safety function of the MCO barrier.

Defense in depth also includes administrative programs that ensure features continue to be available for accident prevention or mitigation and that promulgate a particular set of safety practices.

CSB hazards that are not characteristic of industrial safety hazards are associated with the uncontrolled dispersion of radionuclides from an MCO. Because this hazard may result in effects at a distance from the CSB (either to the offsite receptor or the collocated worker) and can also cause exposure to the facility worker, the defense-in-depth items that protect the individuals at a distance also protect the facility worker. This section discusses the defense-in-depth items for the collocated worker and the offsite receptor with the implicit assumption that these also apply to the facility worker. Section 3.3.2.3.3 addresses defense-in-depth considerations for accidents that affect only the facility worker.

Table 3-2. Topics of Concern Requiring Further Resolution. (3 sheets)

Assumption	Confirmation required and data needs
Preparation of the fuel for transport at K Basins and vacuum drying in the 100 Area will include removal of sludge and free water. All accidents assumed a maximum particulate content of 300 kg (660 lb) remained in the MCO.	<p>The assumption that 300 kg is the bounding particulate value is based on the assumptions used to derive that value. One of these assumptions is that there will be only one scrap basket per MCO. If the baseline changes such that it is anticipated that there will be more than one scrap basket per MCO, the assumption that 300 kg is the bounding value must be reevaluated.</p> <p>The particulate bounding estimate relies on implementation assumptions given in HNF-SD-SNF-11-023. These assumptions must be validated and/or implemented to provide assurance that the quantity of particulates assumed bounds the MCO particulate inventory.</p> <p>The effectiveness of the fuel-cleaning solutions at the K Basins must be verified, and cleaning procedures must be followed for all fuel. The amount of free water left in the MCO after cold-vacuum drying must be confirmed to be acceptable by monitoring at the cold-vacuum drying facility. Particulate drying curves from characterization efforts will help confirm this.</p>
Loss of natural convection in the vault will not result in degradation or structural failure of the MCOs.	<p>For fuel staging and interim storage in a dry condition, it must be determined whether cooling of the MCOs is a critical function. This must consider maximum wet-dry cycles and concrete temperatures. The loss of vault cooling calculations (Calculations CSB-WP-0003) show that loss of degradation of airflow to the vault results in MCO and vault wall temperatures below the design limits. Additional calculations are required to determine that MCO integrity will not be affected on the basis of fuel temperature (runaway fuel reactions) and that radioactive/hydrogen releases to the tubes and operating deck from simultaneous pressurization of multiple MCOs is not a credible event.</p>
Fire is not an initiating event for MCO failure.	<p>A final fire hazard analysis must be completed for the CSB to confirm whether additional safety-class and safety-significant features are required to satisfy offsite and onsite radiological exposure limits. The preliminary fire hazard analysis is available.</p>
Releases of toxic chemicals will not result in requirements for safety-significant class items.	<p>No use of toxic chemicals will be associated with CSB design or plans for operation. Also confirm that the toxicological consequences of a release of uranium, plutonium, or heavy metals do not require additional mitigating features beyond those required to mitigate the radiological consequences of such a release. Characterization of basins and canister materials will identify and validate expected components of the particulate material.</p>
In implementing DOE Order 4130.1A, subsection 1320.5.2, features that ensure safe loading, removal, and handling of the fuel will not be arbitrarily classified as safety-class independent of their role in accident prevention or mitigation. They would be classified as safety-class if required to meet the dose limits for the offsite receptor.	<p>Confirm this application of DOE Order 4130.1A.</p>
Reactivity and ignition characteristics of damaged fuel are not yet available. Fuel reactivity assumptions are based on empirical relationships.	<p>Information obtained by the fuel characterization program will be incorporated into the analyses so that releases associated with MCOs containing damaged fuel can be evaluated.</p>

Table 3-2. Topics of Concern Requiring Further Resolution. (3 sheets)

Assumption	Confirmation required and data needs
Fuel ignition in the MCO is not credible if air ingress is limited.	Confirm with analysis based on best available reaction rate data.
The systems used to receive, handle, and store the MCOs do not have a critical need for offsite ac power.	When the active accident prevention and mitigation systems have been identified (if any) the CSP will need to be evaluated for a loss of offsite power.
The inventory at risk for the hazard category determination is dominated by the amount of material in a nominal MCO times 400 MCOs.	An increase in the bounding particulate loading does not invalidate this assumption. The assumed nominal value has not changed. A bounding average value could increase inventory at risk by about a factor of 2. This increase does not change the hazard classification of the facility as determined by DOE-STD-1027-92, d
The ability of the service cart to pull a partial vacuum on the storage tubes does not introduce new accidents.	Revise PMA to address the operation of the service cart.
Hydrogen detonation/combustion in an MCO or storage tube is not credible.	Detailed hydrogen and oxygen generation and detonation analysis and consideration of the potential for flammable hydrogen/air mixtures will be performed with consideration of the transient behavior of the system and the effect of storage geometry. Effectiveness of oxygen gettering will be verified by analysis.
Deviations from AMS/ANS-57.9 do not impact accident prevention or mitigation or worker safety.	PMA team will review Jacobs (1996) and revise PMA table if necessary.
Dropping of the tube plugs does not initiate any accidents with the potential to produce onsite or offsite dose consequences, or to challenge the function of safety-class SSCs.	Add tube plug drop to the PMA table and complete analyses have been completed showing that the operating desk and tube will not fail upon a tube plug drop and that the drop cannot lead to onsite or offsite dose consequences.
Immersion and ingestion pathways do not have a significant impact on the total dose.	Complete bounding analyses for all pathways.
Particulate physical characteristics and air entrainment assumptions used in accident analyses to estimate releases are consistent with the character of the material that will be stored.	Fuel and particulate characterization data will be used to validate the assumptions.
A truck stop is not required to prevent a truck from colliding with a sack MCO in the receiving area.	The safety analysis for packaging and/or cask must ensure that a release from the MCO is precluded.
The storage tube, as designed, will maintain its structural safety-class function and its confinement safety-significant function if an MCO is dropped into it.	Structural analysis is needed to show this.
Dropping the MCO into the cask at the receiving area will not breach the MCO.	Structural analysis is needed to show this.

Table 3-2. Topics of Concern Requiring Further Resolution. (3 sheets)

Assumption	Confirmation required and data needs
Fuel Unit 1 is precluded if air ingress into the WCD is limited to two openings less than 2.5 cm (1 in.) in diameter.	Analysis is in progress to verify this.

10 CFR 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste, "Code of Federal Regulations, Section 72.3, Definitions," and Section 72.106, Controlled Area of an ISFSI or MSF," as amended.
 Rajuram, A. L., and R. G. Cowan, 1996, "Boarding Particulate Contents of a Multi-Canister Overpack," WRC-SO-SNF-11-023, Rev. 1, Westinghouse Hanford Company, Richland, Washington.
 FDI, 1996, Design Calculations for the SNF Canister Storage Building Project, Elton Daniel, Incorporated, Richland, Washington.
 "Sadashige, C. I., 1996, Phase 2 Fire Hazard Analysis for the Canister Storage Building, WRC-SO-SNF-FHA-002, Richland, Washington.
 DOE Order 6430-1A, General Design Criteria, U.S. Department of Energy, Washington, D.C.
 DOE-STD-1027-92, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480-23, Nuclear Safety Analysis Reports, DOE Standard 1027-92, U.S. Department of Energy, Washington, D.C.
 ANSI/ANS, 1992, Design Criteria for an Independent Spent Fuel Storage Installation (Dry-Type), ANSI/ANS-57-P-1992, American Nuclear Society, La Grange Park, Illinois.
 "ANSI/ANS-57-P-2202 to M. K. Mahaffey, Westinghouse Hanford Company, May-15), Elton Daniel, Incorporated, Richland, Washington.

CSB = Canister Storage Building.
 WCD = multicanister overpack
 WHM = multicanister overpack handling machine.
 PHA = preliminary hazard analysis.
 SSC = structures, systems, and components.

During the performance of the PHA, options were identified for establishing defense in depth for each hazard. These options are noted in Appendix 3A, Table 3A-1, in the two columns included under "Safety features." Both engineered and administrative features are suggested. Table 3-3 shows the approach that will be used in the final SAR to address defense in depth for accidents that have the potential to affect the collocated worker and the offsite receptor.

The defense-in-depth administrative and engineered features listed in Table 3-3 provide a partial list ~~are examples only for the purpose of illustrating the approach, with the exception of reference to the MCOs as the primary barrier against a radionuclide release and the service area ventilation enclosure, MCO storage tubes and MHM as the secondary barriers.~~ These barriers are ~~All~~ engineered features listed as pertaining to the CSB that are within the construction request described in Section 2.4.1 and are part of the current design. Engineered features from fuel cleaning operations and cold vacuum drying, and certain MCO design details, are not yet finalized. Upon completion of the final hazards analysis for the CSB definitive design, Table 3-3 will be completed to provide a listing of revised to identify the location of additional information on the important engineered defense-in-depth features discussed in the SAR. Before requesting DOE approval for operating authorization of the CSB, Table 3-3 will be revised again to describe the types of ~~provide reference to specific procedures and training that provide implement~~ the administrative defense-in-depth features.

Safety Classification. DOE-STD-3009-94 requires that this section address the identification of safety-significant SSCs that relate to the prevention of uncontrolled release of hazardous material. To present a complete description of the safety classification process used for the CSB, all of its elements are described here. Safety classification for CSB SSCs is developed by considering the requirements found in DOE Order 6430.1A and DOE-STD-3009-94.

In addition, the application of NRC nuclear safety equivalency discussed in Section 3.2.2 has resulted in requirements that impact safety classification, as documented in WHC-SD-SNF-DB-003 (Garvin 1996). These safety classification requirements were derived from 10 CFR 72.

DOE Order 6430.1A defines safety-class items in Section 1300-3.2, "Safety Class Items":

Safety class items are systems, components, and structures, including portions of process systems, whose failure could adversely affect the environment or the safety and health of the public. Specifically, safety class items are those systems, components, and structures with the following characteristics:

- Those whose failure would produce exposure consequences that would exceed the guidelines in Section 1300-1.4, Guidance on Limiting Exposure of the Public, at the site boundary or nearest point of public access
- Those required to maintain operating parameters within the safety limits specified in the operating safety requirements during normal operations and anticipated operational occurrences

Table 3-3. Potential Examples of Defense-in-Depth Features for Accidents with Potential Effects to a Collocated Worker or Offsite Receptor (S2 and S3 Consequence Items). (2 sheets)

No.	Accident	Target	Administrative safety features	Engineered safety features
1	Runaway truck leading to MCO failure (failure of the cask-MCO being delivered or an MCO already in the CSB receiving area)	Collocated worker and/or offsite receptor	Driver training Speed limited by design of approach No other MCOs in vulnerable location during cask-MCO delivery No critical operations in service station during cask-MCO delivery	Roadway approach designed to force speed limit MCO is always protected by cask or MHM Cask-MCO designed to preclude failure of MCO being delivered
2	MCO cask drop by receiving crane or MCO drop by MHM into shipping cask or storage tube	Collocated worker and/or offsite receptor	Training and procedures for receiving crane and MHM use and maintenance Review of failures and near misses with similar equipment to apply lessons learned	Interlocks and controls to prevent challenges to the receiving crane and MHM structural integrity (e.g., controls to prevent two-blocking) Robust MCO design and use of impact absorbers to prevent MCO failure on a drop (primary barrier) Use of HEPA filters (non-safety related) for CSB exhaust to limit release Maintenance of MHM and MCO storage tubes to contain any radionuclide release from the MCO (for drop by MHM into tube only) (secondary barrier)
3	Release of radionuclides from cask when removing lid (This would occur because of MCO rupture disk relief from MCO overpressure or a faulty rupture disk. The MCO is shipped with the vent closed; therefore, MCO overpressurization can result from too much free space remaining in the MCO or a delay in shipment of the MCO.)	Collocated worker and/or offsite receptor	Inspection of all rupture disks and sample testing of selected disks to limit risk of spontaneous relief Monitoring of MCO for pressure increase before leaving the CWS Shipment schedules and backup capability to decrease risk of shipping delay Required sampling of cask atmosphere prior to unbolting of the lid	Well-designed canister sludge facilities at K Basins to limit amount of particulates shipped to CWSs and then on to the CSB Well-designed water removal capability at CWSs to facilitate removal of free water Small diameter release path through the MCO to limit release (primary barrier)

1. FOR GENERAL NOTES AND LEGEND SEE H-127156 SHEET 1.

OPERATING AREA FLOOR PLAN EL. 709'-0"

0	APPROVED FOR CONSTRUCTION					DATE	BY	DATE	BY
1	1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18	19
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30	31	32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47	48	49
50	51	52	53	54	55	56	57	58	59
60	61	62	63	64	65	66	67	68	69
70	71	72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87	88	89
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100	101	102	103	104	105	106	107	108	109
110	111	112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127	128	129
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140	141	142	143	144	145	146	147	148	149
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170	171	172	173	174	175	176	177	178	179
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220	221	222	223	224	225	226	227	228	229
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250	251	252	253	254	255	256	257	258	259
260	261	262	263	264	265	266	267	268	269
270	271	272	273	274	275	276	277	278	279
280	281	282	283	284	285	286	287	288	289
290	291	292	293	294	295	296	297	298	299
300	301	302	303	304	305	306	307	308	309
310	311	312	313	314	315	316	317	318	319
320	321	322	323	324	325	326	327	328	329
330	331	332	333	334	335	336	337	338	339
340	341	342	343	344	345	346	347	348	349
350	351	352	353	354	355	356	357	358	359
360	361	362	363	364	365	366	367	368	369
370	371	372	373	374	375	376	377	378	379
380	381	382	383	384	385	386	387	388	389
390	391	392	393	394	395	396	397	398	399
400	401	402	403	404	405	406	407	408	409
410	411	412	413	414	415	416	417	418	419
420	421	422	423	424	425	426	4		

Table 3-3. Potential Examples of Defense-in-Depth Features for Accidents with Potential Effects to a Collocated Worker or Offsite Receptor (S2 and S3 Consequence Items). (2 sheets)

No.	Accident	Target	Administrative safety features	Engineered safety features
4	Hydrogen burn in MCO or storage tube during staging	Collocated worker and/or offsite receptor	<p>Monitoring of MCO for pressure increase before leaving the CVI's</p> <p>Monitoring of storage tubes for presence of hydrogen alone or hydrogen and oxygen</p> <p>Storage tube monitoring of data to identify problem MCOs</p>	<p>Water removal capability at CVI's to ensure all free water is removed</p> <p>Hydrogen absorbers, recombiners, or oxygen getters installed in MCO</p> <p>Rupture disk sized to protect MCO integrity during a burn (may not be practical)</p> <p>MCO designed to limit oxygen ingress and radionuclide release to small diameter release path (primary barrier)</p> <p>Storage tube maintained as an inerted environment to limit burn and radionuclide release (secondary barrier)</p> <p>HEPA filters (non-safety related) used for CSB exhaust to limit release</p>
5	Loss of MCO confinement during interim storage	Collocated worker and/or offsite receptor	<p>Close monitoring of hot conditioning process to obtain maximum possible removal of chemically bound water</p>	<p>Hydrogen absorbers, recombiners, or oxygen getters installed in MCO</p> <p>Storage tube maintained as an inerted environment to prevent burn if hydrogen is released</p> <p>MCO material selected to limit risk of corrosion and subsequent MCO failure (primary barrier)</p> <p>MCO storage tube designed to withstand sudden MCO pressure relief to limit radionuclide release (secondary barrier)</p> <p>HVAC system tripped (if no HEPA filters used) and CSB maintained as a reasonably leak tight building to enhance radionuclide deposition</p>

CSB = Canister Storage Building.
 CVI's = Cold Vacuum Drying System facility.
 HEPA = high-efficiency particulate air (filter).
 HVAC = heating, ventilating, and air-conditioning.
 MCO = multicanister overpack.
 MMH = multicanister overpack handling machine.

- Those required for nuclear criticality safety
- Those required to monitor the release of radioactive materials to the environment during and after a DBA
- Those required to achieve and maintain the facility in a safe shutdown condition
- Those that control the safety class items described above.

Section 1300-1.4.2 of DOE Order 6430.1A states that "Facility design shall provide attenuation features for postulated accidents (up to and including DBAs) that preclude offsite releases that would cause doses in excess of the DOE 5400 series limits for public exposures." The DOE primary standard for public exposures as a result of normal operations is given in DOE Order 5400.5 as 100 mrem (1 mSv) effective dose equivalent in a year, but indicates that a higher limit of 500 mrem (5 mSv) may be authorized for a limited period if it is justified by unusual operating conditions.

For the purpose of assigning safety-class attenuation features for the postulated releases to the public from the accidents presented in Section 3.4, the 500 mrem (5 mSv) limit is chosen as a conservative criterion that would ensure compliance with the intent of DOE Order 6430.1A. For the final SAR, the DBAs will be reevaluated to include the functions of the safety-class features and to demonstrate that the criteria of DOE Order 6430.1A are met. For the CSB, the maximum dose public receptor was found to be at the near Columbia River bank 15 km (9.3 mi) east of the facility (see Section 3.4.1.2).

Section 1300-1.4 of DOE Order 6430.1A and the other orders referenced in this section do not contain quantitative guidelines for the identification of safety-class SSCs. These guidelines are provided in, WMC CM 4-46, *Safety Analysis Manual*, Section 7.0, "Risk," Revision 4, and are summarized in Table 3-4.

Because of uncertainties at this stage of the CSB design and operation, all dose assessments are performed to the "anticipated" criteria provided in Table 3-4. For the final SAR, the complete risk acceptance guidelines will be applied.

Table 3-4. Radiological Risk Guidelines.

Event frequency category	Event frequency (yr^{-1})	Effective dose equivalent (mSv)	
		Onsite	Offsite
Anticipated	$>10^{-2}$ to $\leq 10^0$	—50	—5
Unlikely	$>10^{-4}$ to $\leq 10^{-2}$	—250	—50
Extremely unlikely	$>10^{-6}$ to $\leq 10^{-4}$	1,000	50*

*The 250 mSv limit of WMC CM 4-46 is not available to the CSB because of the application of the NRC nuclear safety equivalency offsite dose limit of 50 mSv (5 rem) to the CSB.

In addition to the general criteria listed above for the identification of safety-class items, DOE Order 6430.1A contains the following specific requirement in Section 1320, "Irradiated Fissile Material Storage Facilities":

Special design features shall be considered to ensure safe loading, removal, and handling of IFM [irradiated fissile material]. These systems and equipment shall be designed as safety-class items and shall protect against the dropping of shipping casks, IFM assemblies, and other items on the stored IFM.

The requirement has been interpreted to require safety-class items for the movement of SNF assemblies and equipment over SNF in unprotected storage. This does not occur in the CSB where the fuel, that being moved and that in staging or interim storage, is always contained in an MCO.

DOE-STD-3009-94, Section 3.4.2.X.4, "Comparison to Guidelines," requires that receptor dose/exposure for the accident sequence be compared to the evaluation guidelines; however, quantitative guidelines are not provided. DOE-STD-3009-94 defines safety-significant SSCs as

Structures, systems, and components not designated as safety-class SSCs but whose preventive or mitigative function is a major contributor to defense in depth (i.e., prevention of uncontrolled material releases) and/or worker safety as determined from hazard analysis.

As a general rule of thumb, safety-significant SSC designations based on worker safety are limited to those systems, structures, or components whose failure is estimated to result in an acute worker fatality or serious injuries to workers. Serious injuries, as used in this definition, refers to medical treatment for immediately life-threatening or permanently disabling injuries (e.g., loss of eye, loss of limb) from other than standard industrial hazards. It specifically excludes potential latent effects (e.g., potential carcinogenic effects of radiological exposure or uptake).

The general rule of thumb cited above is not an Evaluation Guideline. It is a lower threshold of concern for which safety-significant SSC designation may be warranted, not a quantitative criteria. Estimates of worker consequences for the purpose of safety-significant SSC designation are not intended to require detailed analytical modeling. Considerations should be based on engineering judgement of possible effects and the potential added value of safety-significant SSC designation.

The criterion chosen to assign safety-significant designation to SSCs needed to mitigate or prevent accidental releases that would allow undue exposure to workers located at nearby facilities (collocated workers) is 50 mSv (5 rem) committed effective dose equivalent (CEDE). This limit is based on the yearly occupational dose limit for stochastic effects given in Title 10, *Code of Federal Regulations*, Part 835, "Occupational Radiation

Protection" (10 CFR 835). The maximum dose collocated worker was found to be 100 m (328 ft) east of the facility.

NRC nuclear safety equivalency requirements for ISFSIs define SSCs important to safety in broad terms (Garvin 1996). For ISFSI application, NRC requirements are established in 10 CFR 72.3, which defines SSCs important to safety as those that perform one or more of the following functions:

1. Maintain the conditions required to store spent fuel or high-level radioactive waste safely
2. Prevent damage to the spent fuel or the high-level radioactive waste container during handling and storage
3. Provide reasonable assurance that spent fuel or high-level radioactive waste can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

Relative to this aspect of NRC nuclear safety equivalency, the following SNF Project position has been established (Garvin 1996).

~~For the CSB only, identify structures, systems and components (SSCs) 'important to safety' in accordance with Section 72.3, as implemented through Section 72.106. Once SSCs 'important to safety' have been identified, impose the requirements for safety class 1 SSCs, as defined in WHC CM 4-46, Safety Analysis Manual, Section 9.0, Revision 1, Safety Classification of Structures, Systems and Components. This includes the loaded MCO once it is received at the CSB.~~

SSCs required to support or safeguard the safety-class function of a safety-class SSC are also safety class. Therefore, the storage tubes, operating deck, vault structure, and intake and exhaust stacks for vault cooling are all safety class.

Thus, identification of SSCs important to safety for the three functions contained in 10 CFR 72.3 is by application of the 50 mSv (5 rem) dose limit provided in 10 CFR 72.106. For example, if failure of a piece of equipment required to receive, handle, package, store, or retrieve SNF will result in a dose that exceeds 50 mSv (5 rem) at the controlled area boundary, then that equipment is classified as important to safety and, therefore, safety class.

The requirements for safety class 1 SSCs in the quote from WHC-SD-SNF-DB-003 (Garvin 1996) refer to such items as industry consensus standards and codes, redundancy, reliability, and environmental qualification.

Technical Safety Requirements. The determination of TSRs will be accomplished in accordance with the requirement of DOE Order 5480.22, *Technical Safety Requirements*.

3.3.2.3.3 Worker Safety. Worker safety for the CSB is assured by a combination of confinement and shielding features and institutional practices. The main radiological hazard of the CSB is the fuel particulate material contained in the MCOs. For MCO receiving and purging operations, an enclosure

is placed over and around the cask-MCO to protect the workers from exposure during normal and off-normal conditions. While the MCOs are in staging or interim storage, the storage tube and plug serve to provide this protection. The MHM and the MHM-deck floor seal provide protection during MCO handling operations. Chapter 7.0 of the SAR will provide more detail on radiation protection for the worker, as required by DOE-STD-3009-94.

Table 3-45 provides potential examples of defense-in-depth items that may provide protection for normal and off-normal operation and accident conditions that affect only facility workers. This table is provided as an example of how this issue will be addressed in this chapter of the final SAR and as such, the items listed may not be available or cost effective for the CSB as it is to be operated. The consequence column of the table is used to highlight features that may be provided to prevent or mitigate a significant worker exposure to hazardous materials with the potential to cause a serious injury.

The hazards listed in Table 3-45 are based on the completed PHA form in Appendix 3A. The PHA study specifically ranked various hazards according to the potential receptor that is impacted. For the final SAR, a final hazards analysis, based on final design and operating information, will be used to identify the defense-in-depth features for completion of this table. Use of the PHA study hazards analysis to identify worker safety concerns and potential accidents satisfies the process safety management guidelines in Title 29, Code of Federal Regulations, Part 1910, "Occupational Safety and Health Standards" (29 CFR 1910), Section 1910.119, "Process Safety Management of Highly Hazardous Chemicals," relative to evaluating hazards of a process. Process safety management is an integrated approach to hazard identification and risk management. This method of assessing facility worker hazards is also consistent with the guidance provided in DOE-STD-3009-94.

Table 3-45 identifies the CSB worker hazards according to various operations and proposed engineered and administrative barriers that could be in place to control possible exposure to the identified hazards. This identification follows the safety management process and the guidance of DOE-STD-3009-94. Engineered barriers are design features (e.g., cover blocks, ventilation system) that prevent or mitigate the exposure of the facility worker to hazards. Administrative barriers are procedures and programs designed to prevent and mitigate exposure of the facility worker to hazards. It should be noted that safety-class or safety-significant SSCs designed to protect the collocated worker and public will also provide protection for the facility worker. For the accidents addressed in Section 3.4.2, no credit is taken for operator action for accident mitigation and, as such, no operator dose assessment is made.

3.3.2.3.4 Environmental Protection. The external hazards associated with CSB operation all involve the potential release of radionuclides. The release pathway for these radionuclides is only via the air to the boundaries and receptors discussed in Section 1.3.1.3. None of the accidents identified by the PHA involve radiological releases to the ground or groundwater. The MCO will be drained and the fuel dried at the CVDFs to remove excess free water before shipping to the CSB. Therefore, the potential for liquid releases to the ground during receiving, handling, staging, or interim storage does not exist.

Table 3-45. Potential Examples of Defense in Depth for Facility Workers (S1 Consequence Items). (2 sheets)

No.	Hazard	Target	Administrative features	Engineered features	Consequence Rank
1	Release of radionuclides from cask when removing lid (This is the same event as described in Table 3-3.)	Workers inside enclosure	Inspection of all rupture disks and sample testing of selected disks to limit risk of spurious relief Monitoring of MCD for pressure increase before leaving the CVOIS Shift schedules and backup capability to decrease risk of shipping delay Required sampling of cask atmosphere prior to unbolting of the lid	Well-designed cask cleaning facilities at K Basins to limit amount of particulates shipped to CVOIS and then on to the CSB Well-designed water removal capability at CVOIS to ensure all free water is removed	A
2	Contaminated liquid forced out the purge supply line (This can result from cross-connecting purge lines or purge gas supply pressure that is too low.)	Workers near purge supply exhaust or supply	Procedures and training to prevent cross connection of purge lines and to monitor purge supply pressure before initiation of purge	Connector design precludes cross connection Interlock prevents purging with low gas supply pressure	A
3	Inert gas accumulation in confined space to the service station	Workers in confined space	Procedures and training on confined space entry Maintenance of ventilation systems to ensure air exchange	Ventilation and oxygen monitoring of confined spaces that require routine entry	I
4	Loss of confinement shielding provided by service station shield ring (This can result from premature removal of the shield ring without a documented accident condition, the release will be limited to the CSB.)	Workers near service station area	Preventive maintenance of food to decrease the risk of its failure Operator training and procedures to decrease likelihood of shield ring removal with floor valve open	Shield ring designed to withstand natural and human generated hazards	A
5	Direct radiation dose from MCD during lifting from the service station or lowering into the storage tube (This could result if MIM nose shielding is not in place.)	Workers in CSB; in particular those near the MIM	Training and procedures to ensure that the MIM shielding is in place before lifting the MCD	Human factors design of MIM controls limits likelihood of operator failing to move the MIM shielding to into place Interlock on MIM prevents raising or lowering on MCD with the MIM shielding not fully positioned Radiation monitors provide early warning of shielding cellar not in place	H

Table 3-45. Potential Examples of Defense in Depth for Facility Workers (SI Consequence Items). (2 sheets)

No.	Hazard	Target	Administrative features	Engineered features	Consequence rank*
6	MHM collision with other equipment	Workers near MHM	Procedures and training for MHM operation	Recessed floor covers to prevent collision Provide MHM with obstacle detection	A

CSB = Canister Storage Building.

MCO = multicanister overpack.

MHM = multicanister overpack handling machine.

*H = high potential exposure.

I = exposure potentially greater than an as-low-as-reasonably-achievable exposure.

E = industrial injury that could be prevented by standard industrial safety design and work practices.

These consequence ranks will be further defined in the final SAR.

Based on the CSB design and operating information currently available, no use of toxic chemicals has been identified. The risk of toxic chemical exposure will need to be considered as more detailed information on each phase of the process is developed. This is listed in Table 3-2 as an item to be tracked.

Potential consequences, including offsite releases, and required prevention and mitigation features are discussed in Section 3.4.2. Implementation of the prevention and mitigation features will prevent large releases that could have significant environmental impact.

The project features that protect the collocated worker and public against radiological exposure also serve to prevent and mitigate radiological release to the environment. In addition, there are Fluor-Daniel Hanford, Incorporated (FDH), site-wide programs for environmental monitoring that provide for assessment of the impact of facility releases. Normal CSB operational activities are expected to have a minor impact on the local and regional environment. Expected environmental impacts include the following:

- Increased noise levels from trucks in the 200 East Area during the cask-MCO receiving phase
- Increased levels of vehicle exhaust to the atmosphere, which will be very limited during the interim storage phase
- Air emissions of water vapor, hydrogen, and small amounts of radioactive pollutants such as ^{85}Kr (levels of ^{85}Kr above allowable emissions would be detected by the stack radiation monitors)

The CSB will be designed and operated to maintain CSB facility worker, collocated worker, and offsite public exposures to all known hazards to levels as low as reasonably achievable and well below regulated levels.

3.3.2.3.5 Accident Selection. Accident analysis criteria require that a set of accidents be quantitatively analyzed. The results of this analysis demonstrate compliance with the risk acceptance criteria identified in Section 3.3.2.3.2 and justify the choice of safety-class and safety-significant SSCs. The accident selection methodology is described in Section 3.3.1.2.

This section documents the results of the accident selection activity. The initial screening criterion used was that all S2 and S3 accidents be chosen as candidate accidents. The selection of the S2 and S3 events was made independently of the frequency assignment, that is, independently of the "F" ranking. From this list, the accidents were grouped by phenomenon based on the potential quantity of radioactive material available for release to the facility from the event (the numbers preceding each entry refer to corresponding entries in Appendix 3A, Table 3A-1).

- Releases of MCO gases under pressure during handling, staging, or interim storage

A pressurized release could potentially will involve the MCO atmosphere and the inventory of particulate material in the MCO.

- PHA 60.b.23 MCO pressurized release during shipping cask-sampling pressure testing in the service station
- PHA 60.b.34 Pressurized release during unbolting of shipping cask lid
- PHA 60.b.45 Pressurized release from MCO resulting from damage caused by dropped shipping cask lid, or shielding ring, or shield hatch assembly
- PHA 60.b.56 Pressurized release resulting from delay during unbolting of MCO flanges
- PHA 60.b.78 Pressurized release caused by MCO overpressurization by inert gas during purging
- PHA 60.b.11 Pressurized release from MCO resulting from damage caused by dropping the shielding ring or the shield plug
- PHA 60.c.10 Release of unfiltered MCO contents through pressure relief device or due to MCO failure during MCO handling
- PHA 60.d.1 Release of unfiltered MCO contents through pressure relief device during MCO staging
- PHA 60.e.1 Release of unfiltered MCO contents through pressure relief device or due to MCO failure during MCO interim storage

- Single-MCO Damage-Failure during Handling

These accidents involve the potential of spilling-releasing the contents of one or two MCOS into the building.

- PHA 60.a.1 Damage to MCO in service station caused by runaway transport vehicle
- PHA 60.a.2 Shipping cask-MCO tipover or drop from transport trailer
- PHA 60.a.3 Shipping cask-MCO drop onto transporter, floor, or into service station
- PHA 60.c.2 MCO drop onto into shipping cask-without impact absorber
- PHA 60.c.4 Shearing of an MCO during handling
- PHA 60.c.5 MCO drop onto operating area floor or storage tube plug
- PHA 60.c.6 MCO drop into empty storage tube

PHA 60.c.7 MCO drop into storage tube with second MCO present

PHA 60.c.8 Tube plug drop into storage tube with MCO in place

- ~~Multiple MCO Failures during Handling~~

~~This accident involves the potential to spill the contents of two MCOs into the building.~~

~~PHA 60.c.7 MCO drop into storage tube with second MCO present~~

- Hydrogen Gas Combustion

Chemical and radiolytic hydrogen production, and subsequent mixing with oxygen-containing atmospheres, could lead to combustion events that would release MCO gases and particulates and potentially entrain greater amounts of particulates than would be the case with a simple depressurization.

PHA 60.b.1011 Hydrogen combustion in purging evacuation equipment or in MCO during purging

PHA 60.c.9 Hydrogen combustion in MHM or tube caused by hydrogen release from MCO

PHA 60.d.2 Hydrogen combustion in MCO during staging

PHA 60.d.3 Hydrogen combustion in storage tube during staging

PHA 60.e.2 Hydrogen combustion in MCO during interim storage

PHA 60.e.3 Hydrogen combustion in storage tube during interim storage

- Multiple MCO-tube Failures during Temporary Staging or Interim Storage

This accident involves the potential for release of atmosphere and entrained particles from multiple MCOs.

PHA 60.e.1 Loss of MCO integrity during interim storage caused by loss of convective cooling

- Beyond Design Basis Events

Beyond design basis events are to be included in a future revision to this chapter.

PHA 60.e.1 MCO structural failure

PHA 60.d.1 MCO structural failure or rupture disk relief

PHA 60.f Structural failure of the CSB or SSCs within the CSB.

An accident scenario from each of the accident groups identified by the PHA was selected for analysis. This was done by choosing the scenario judged to bound the potential releases from the group to represent the group. In most cases, this selection was based on an assessment of the energy driving the release. For instance, for MCO overpressure accidents, pressure high enough to rupture the rupture disk would provide greater releases, both in quantity of particulate released and the fraction of the particulate that is respirable, than would releases occurring at lower pressures.

Following the analysis of the representative and bounding scenarios, safety-class design features to mitigate or prevent the release were identified. Then the list was reexamined to judge whether any of the remaining scenarios could challenge a different barrier or require different SSCs to mitigate or prevent the release. For the preliminary accident analyses presented in these phased SARs, no additional consequence analysis for the remaining scenarios was performed. Rather, it was assumed that the bounding consequence would apply to the whole group, and appropriate mitigative or preventive design features were identified.

3.4 ACCIDENT ANALYSIS

This section presents the ~~formal processes methodology~~ used to develop the potential accidents identified in Section 3.3.

3.4.1 Methodology

3.4.1.1 Source Term. The bounding source term used for the accident analysis was based on data for the fuel in the K East and K West Basins given in WHC-SD-SNF-TI-009, *105-K Basin Material Design Basis Feed Description for Spent Nuclear Fuel Project Facilities* (Willis 1995). That document defines an inventory for safety analysis considering inventories of MKIV, Mark IA (MKIA), and single-pass reactor (SPR) fuel in K Basins. High-burnup MKIV fuel, the fuel type that results in the highest estimated dose to people exposed to the material, was selected as the bounding inventory from the radiological dose perspective. Nuclear accountability records gave the basis for the quantity, exposure variation, and decay time variation of the stored fuel. The radionuclide inventory was estimated from these data. Spent fuel and sludge returned from the PUREX-Plutonium-Uranium Extraction Facility to K Basins is not included in the baseline for assessing bounding source term at this time.

The assumed radioactive inventory of the MCO is the inventory associated with 270 high-burnup MKIV fuel assemblies. The MCO will contain finely divided particulate material associated with the fuel. This includes particulates left on fuel surfaces and in crevices after fuel washing and racking into the MCO, with expected increases in oxidation products following cold vacuum drying, staging, and hot conditioning.

The particulate inventory of the MCO dominates the airborne release. It is expected to be similar in makeup, and radionuclide content, to the sludge found in the canisters in the K Basins. Because the canister sludge has not yet been characterized, the analyses assume that the available particulate material contains the same radionuclide content as the fuel.

The total amount of fuel oxide in an MCO is greater than the total amount of particulate available for release since some fraction of the oxide adheres to the metal surface. The fuel will go through a cleaning process intended to remove loose particulates before it is loaded into the MCO. However, some oxide may remain beneath cladding, on some fuel surfaces, and within fuel assembly flow channels. Subsequent to loading the SNF into the MCO, the quantity of particulate matter is expected to increase, because of additional fuel oxidation by residual water in the MCO, until all of the residual water in the MCO is consumed. ~~This oxidation will continue, possibly into the interim storage period.~~ Additional fuel oxide also will be generated during the passivation process (Pajunen and Cowan 1996).

A bounding value for the mass of particulate in the MCO after hot conditioning was estimated to be 300 kg (660 lb) (Pajunen and Cowan 1996). This bounding value is intended to provide a conservative estimate of the MCO's maximum particulate inventory in support of design and safety analyses. This bounding value for safety analysis was derived using combined worst-case assumptions on fuel condition, cleaning, and vacuum drying. It assumes one scrap basket and four full fuel baskets in the MCO. A probabilistic assessment of the parameters used to derive this bounding value indicates that the probability of exceeding 300 kg (660 lb) in an MCO is on the order of 10^{-6} (Pajunen et al. 1996). For the purpose of the accident analyses presented in Section 3.4.2, the bounding value of 300 kg (660 lb) is used throughout, without regard to the process stage the MCO is in when the accident is postulated to occur. ~~Sufficient conservatism is included in the bases that analyses using this estimate will define safety constraints that will not need to be supported by a direct measure of the particulate inventory in each MCO during system operation.~~

~~Efforts have been made to minimize any operating constraints associated with arguing the conservatism of the bound. To be consistent with the bounding particulate estimates, the analysis includes the following selected assumptions and constraints for operations.~~

- ~~• The analysis is limited to a consideration of N Reactor fuel; SPR fuel will need to be evaluated as a special case.~~
- ~~• The inventory of elements and scrap baskets must be controlled consistent with the assumptions.~~
- ~~• Cleaning by a qualified system must be performed on all fuel.~~
- ~~• Fuel and scrap basket queuing is limited to 30 days before recleaning will be required.~~
- ~~• Cold vacuum drying should be procedurally controlled to limit oxide generation.~~
- ~~• A transport time constraint must be observed.~~
- ~~• The water inventory of MCOs entering staging is assumed to completely react with fuel, generating particulate (the MCO water inventory entering staging at the CSB is based on achieving~~

~~particulate water content of less than 10 wt% at the conclusion of cold vacuum drying).~~

- ~~• The hot conditioning process must be procedurally controlled to restrict oxidation.~~
- ~~• No additional particulate generation is assumed to occur during interim storage, which is consistent with sealed storage.~~

The SNF is primarily uranium metal, which is known to have toxicological effects. Plutonium and other heavy metals are present in smaller quantities. It is not expected that the toxicological consequences of the release of these substances would require mitigating features beyond those required by the radiological doses.

No routine chemical processes will be conducted within the CSB. Purging and backfilling the MCOs will involve the use of an inert gas. Some chemicals, such as those used for equipment decontamination, may be used occasionally ~~(WHC 1995)~~. However, there are no chemical inventories of concern for safety analysis considerations.

3.4.1.2 Consequence Analysis. Radiological inhalation dose consequences for each accident analyzed are based on

- Mass of material available for release
- Airborne release fraction (ARF) and respirable fraction (RF)
- Dose conversion factors
- Atmospheric dispersion of airborne particles
- Duration of exposure
- Breathing rates.

The radiological dose to a maximum receptor of interest is typically determined by using the following equation:

$$D = M \times \frac{X}{Q} \times R \times C$$

where

- D = Dose (Sv)
- M = Mass of ~~respirable~~ material released (g)
- X/Q = Time-integrated atmospheric dispersion coefficient (s/m^3)
- R = Breathing rate (m^3/s)
- C = Dose per unit respirable radioactive material inhaled (Sv/g).

The quantity of respirable material released (M) is determined by the specific accident scenario.

The atmospheric dispersion coefficient (X/Q) is based on specific release conditions (e.g., ground level or elevated, long or short duration) and the receptor's distance from the release. The atmospheric dispersion coefficient is the time-integrated normalized air concentration at the receptor's

location. The coefficient represents the dilution of an airborne contaminant caused by atmospheric mixing and turbulence. All X/Q values for these analyses have been generated using the GXQ computer program (Hey 1993a and Hey 1993b).

Table 3-56 contains the X/Q values used to determine onsite and offsite consequences. Section 1.4.1.1.8 provides additional information on the calculation of the X/Q values. The basis for defining the location of the onsite and offsite receptors is provided in Section 1.3.1.3.

Table 3-56. Atmospheric Dispersion Coefficients Used in Accident Analyses for the Canister Storage Building.

Receptor location description	X/Q point source (s/m ³)		
	Without plume meander, without stack	With plume meander, without stack	Stack release (one fan at 5.66 m ³ /s)
Onsite (100 m E)	3.41 E-02	1.13 E-02	4.18 E-05 (230 m W)
Hanford Site boundary (18.3 km E)	1.32 E-05	1.11 E-05	7.14 E-06
Near riverbank (15.0 km E)	1.96 E-05	1.55 E-05	8.31 E-06

Values of X/Q were calculated for various distances from the release in the full range of compass directions. For these analyses, the worst-case meteorology (windspeed and direction) for the Hanford Site was used to determine the location at the Site boundary where the maximum doses would occur. The same approach was used to determine the direction of the maximum doses at 100 m (328 ft) for the collocated worker (onsite receptor).

For calculation of offsite releases, values of X/Q were calculated for a receptor in the highest dose direction at the Hanford Site boundary and for a maximum dose receptor at the Columbia River to the east and at Highway 240 to the west. The maximum offsite receptor for the Site boundary was found to be at a location 18.3 km (11.3 mi) east of the CSB. The maximum offsite receptor at the near river boundary 15 km (9.3 mi) east of the facility was found to be more limiting than one at Highway 240. This is the case even though Highway 240 is closer to the facility. The maximum onsite (100 m [328 ft]) receptor was east of the facility for the ground-level release.

Table 3-56 also reports X/Q values for an elevated release with operating deck ventilation airflow to enhance the elevation of the release point. The accidents analyzed in this document do not credit mitigation of the release through this building ventilation. The values are preserved here for potential use in analyzing mitigating features of the design.

Correction to the X/Q may be taken for building wake effects if the accident does not change the building configuration. To provide conservatism in the analysis, none of the accidents analyzed in this document use building wake effect corrections. Correction for plume meander is credited for ground releases assumed to occur during neutral or stable atmospheric conditions with windspeeds less than 6 m/s (19.7 ft/s) and with release times greater than 1 hour.

The breathing rate (R) depends on activity factors and exposure duration. All accidents analyzed assume 8-hour exposure (the duration of a typical working shift) to the onsite receptor and 24-hour exposure to the offsite receptor. It is assumed that within one day's time, emergency measures will have caused evacuation of offsite areas affected by the accident. Therefore, the breathing rate used is the acute, light activity rate given in *Reference Man: Anatomical, Physiological, and Metabolic Characteristics* (ICRP 1975). Its value is $3.3 \times 10^{-4} \text{ m}^3/\text{s}$.

The dose per unit material inhaled (C) is the value for the total committed effective dose equivalent (CEDE). The relative contribution of each nuclide to the total composite dose was calculated using the GENII computer code (Napier et al. 1988). The CEDE for a 50-year dose commitment period was calculated using the code's worst-case solubilities library (Huang 1996). This is the most conservative dose conversion factor library used by GENII.

The major radiation exposure pathway for the identified accidents is inhalation of radioactive material. Dose contributions from the submersion and groundshine pathways were calculated and found to be negligible with respect to the total dose (Huang 1996) for the radionuclides of interest (Hey 1995). Doses from groundshine are also expected to be negligible because most of the radionuclides of interest are alpha emitters. Therefore, the dose from groundshine and submersion are not included in the radiological dose calculations.

Potential doses from the ingestion pathway are not considered because DOE, state, and federal emergency preparedness plans limit ingestion of contaminated food in the event of an accident. DOE/RL-94-02, *Hanford Emergency Response Plan* (DOE-RL 1995), governs emergency response for all Hanford Site facilities. Specific emergency plans for the CSB will be covered in Chapter 15.0 of the final SAR. Ingestion doses were calculated only for assessment of economic impact because affected farmland would be taken out of production if contaminated by a release from the facility. The potential doses from the ingestion pathway were found to be 1.6 times the total inhalation dose. The primary determinant of exposure from the ingestion pathway, however, is the effectiveness of public health measures (i.e., interdiction) rather than the severity of the accident itself. Therefore, consequences from ingestion doses are not included in the estimated dose calculations for accidents analyzed in Section 3.4. The ingestion pathway, if it occurs, is a relatively slow to develop pathway and is not considered an immediate threat to an exposed population in the same sense as the inhalation pathway.

Table 3-67 shows the results of the radiological analysis of the high burnup MKIV fuel and the corresponding CEDE per gram of respirable release. CEDE values for some daughter product isotopes, ^{106}Rh , ^{110}Ag , and ^{137}Ba , are not listed because the GENII program includes them with their parent isotopes. The actinides, primarily the plutonium isotopes (^{241}Am and ^{244}Cm) and ^{90}Sr , contribute 99.5% of the total CEDE. The remaining 0.5% is contributed by fission and corrosion product isotopes, which include ^3H and ^{85}Kr . Only these isotopes contributing more than 0.1% to the inhalation dose are reported, except for the gases ^3H and ^{85}Kr . Those two isotopes are included because their release pathways and release fractions of the gaseous isotopes can be significantly different from the isotopes primarily bound in the that are transported with the solids matrix. Isotopes of plutonium, ^{241}Am , ^{244}Cm , and ^{90}Sr constitute 99.6% of the total inhalation dose. The relative contribution from the remaining nuclides is minor in comparison. The specific dose for the safety analysis inventory is $4.3 \times 10^5 \text{ Sv/g}$ ($4.3 \times 10^5 \text{ rem/g}$).

3.4.1.3 Frequency Estimates. Specific data for estimating accident frequencies are not available at this stage of the design. Therefore, the accident consequences are evaluated solely against the deterministic guidelines discussed in Section 3.3.2.3.2 for the identification of safety-class and safety-significant SSCs. This approach is more limiting than the risk-based approach that allows higher dose consequences for accident sequences judged to be of sufficiently low estimated frequency.

3.4.1.4 Risk Guidelines. The radiological consequences of the accidents, unmitigated by any safety features, were determined and compared to the criteria listed in Table 3-78. By the guidelines of DOE-STD-3009-94, analysis of unmitigated scenarios may take credit for reduction of releases by passive design features (e.g., buildings) that may be assumed to remain in place during and after the accident. In many of the accident scenarios presented in Section 3.4.2, no credit is taken for such passive features and therefore additional conservatism is incorporated in the results. For the final SAR analyses, holdup in the building and other passive structures will be considered where appropriate.

The criteria for identifying safety-class SSCs implement the guidance of DOE Order 6430.1A, Section 1300-1.4, "Guidance on Limiting Exposure of the Public," and are consistent with the graded approach to safety required by DOE Order 5480.23. They are more limiting than the 10 CFR 72.106 limit of 50 mSv (5 rem) at the controlled area boundary (see Section 1.3.1.3).

3.4.1.5 Safety-Class Structures, Systems, and Components. For each accident scenario, the airborne radiological dose calculated using the methods described was compared to the appropriate acceptance guideline limit. If the radiological dose for the unmitigated case exceeded the guideline, mitigating safety features, with appropriate safety-class designation, were suggested. The dose consequences will be recalculated for the final SAR, taking appropriate credit for the mitigating safety features, in addition to the reduction of releases by passive design features, to verify that the mitigated doses satisfy the guidelines.

Table 3-6. Radiological Analysis of High Burnup Mark IV Fuel (Decayed to January 1, 1995).^a

Isotope	Activity (Ci/MTU)	CEDE per unit intake (Sv/g) ^b	Isotope	Activity (Ci/MTU)	CEDE per unit intake (Sv/g) ^b
Fission and activation products					
H-3	5.57 E+01	3.33 E-05	Sn-123	3.25 E-11	1.09 E-14
C-14	5.52 E-01	1.12 E-03	Sn-126	1.23 E-01	1.18 E-04
Fe-55	2.86 E+00	7.88 E-05	Sb-124	0.00	0.00
Co-60	1.19 E+02	9.70 E-03	Sb-125	5.31 E+01	6.67 E-03
Ni-59	3.17 E+02	1.09 E-04	Sb-126	1.71 E-02	2.30 E-06
Ni-63	3.64 E+00	2.01 E-01	Sb-126m	1.23 E-01	1.27 E-06
Se-79	6.32 E+02	6.06 E-06	Te-123m	7.31 E-16	0.00
Kr-83	5.39 E+02	9.09 E-06	Te-125m	1.30 E+01	9.39 E-04
Br-89	0.00	0.00	Te-127	3.86 E-13	0.00
Sr-90	7.84 E+03	1.61 E+01	Te-127m	3.94 E-13	0.00
Y-90	7.84 E+03	6.97 E-01	Te-129	0.00	0.00
Y-91	0.00	0.00	Te-129m	0.00	0.00
Zr-93	2.88 E-01	9.09 E-04	I-129	4.04 E-03	7.23 E-06
Zr-95	0.00	0.00	Cs-134	5.16 E+01	2.24 E-02
Nb-93m	1.56 E-01	4.85 E-05	Cs-135	5.74 E-02	2.58 E-06
Nb-95	0.00	0.00	Cs-137	1.08 E+04	3.33 E+00
Nb-95m	0.00	0.00	Ba-137m	1.02 E+04	0.00
Te-99	2.12 E+00	1.88 E-04	Ce-141	0.00	0.00
Ru-103	0.00	0.00	Ce-144	1.97 E-01	7.58 E-04
Ru-106	1.77 E+00	8.48 E-03	Pr-143	0.00	0.00
Rh-103m	0.00	0.00	Pr-144	1.96 E-01	1.46 E-07
Rh-106	1.77 E+00	DP	Pr-144m	2.36 E-03	5.46 E-10
Pd-107	1.48 E-02	1.91 E-06	Pm-147	5.45 E+02	2.15 E-01
Ag-110	3.80 E-07	DP	Pm-148	0.00	0.00
Ag-110m	2.86 E-05	1.09 E-07	Pm-148m	0.00	0.00
Cd-113m	3.51 E+00	5.46 E-02	Sm-151	1.01 E+02	3.00 E-02
Cd-115m	0.00	0.00	Eu-152	1.07 E+00	2.30 E-03
In-113m	1.22 E-13	0.00	Eu-154	1.81 E+02	4.85 E-01
Sn-113	1.22 E-13	1.30 E-17	Eu-155	2.42 E+01	9.70 E-03
Sn-119m	3.82 E-05	2.55 E-09	Gd-153	3.33 E-07	7.88 E-11
Sn-121m	6.72 E-02	7.58 E-06	Tb-160	0.00	0.00
Fission and activation product totals				3.84 E+04	2.12 E+01
Actinides					
U-234	3.83 E-01	5.15 E-01	Pu-241	9.25 E+03	7.58 E+02
U-235	1.29 E-02	1.61 E-02	Pu-242	1.05 E-01	4.55 E-01
U-236	7.20 E-02	9.09 E-02	Am-241	3.58 E+02	1.61 E+03
U-238	3.29 E-01	3.94 E-01	Am-242	8.30 E-01	4.89 E-04
Np-237	5.67 E-02	3.64 E-01	Am-242m	8.35 E-01	3.64 E+00
Pu-238	1.71 E+02	6.67 E+02	Am-243	1.20 E-01	5.45 E-01
Pu-239	1.58 E+02	6.97 E+02	Cm-242	6.90 E-01	1.18 E-01
Pu-240	1.28 E+02	5.76 E+02	Cm-244	8.36 E-01	1.36 E+01
Actinide totals				1.01 E+04	4.33 E+03

^aResults decayed to 01/01/1995. Total mass of fuel is 6.90 metric tons of uranium (MTU). Total activity as of 01/01/1995 is 3.35 E+05 Ci.

^bTo convert Sv/g to rem/g multiply by 100.

CEDE = committed effective dose equivalent.

DP = daughter products (included with parents and not tracked individually).

MTU = metric tons of uranium.

Table 3-7. Radiological Analysis of High Burnup Mark IV Fuel
(Decayed to January 1, 1995).

Radionuclide	Activity (Ci/MTU)	CEDE per unit intake Sv/g (rem/g)
^3H	3.57 E+01	3.3 E-05 (3.3 E-03)
^{85}Kr	5.39 E+02	3.0 E-05 (3.0 E-03)
^{90}Sr	7.84 E+03	1.6 E+01 (1.6 E+03)
^{90}Y	7.84 E+03	7.0 E-01 (7.0 E+01)
^{137}Cs	1.08 E+04	3.3 E+00 (3.3 E+02)
^{238}Pu	1.71 E+02	6.7 E+02 (6.7 E+04)
^{239}Pu	1.58 E+02	7.0 E+02 (7.0 E+04)
^{240}Pu	1.28 E+02	5.8 E+02 (5.8 E+04)
^{241}Pu	9.25 E+03	7.6 E+02 (7.6 E+04)
^{241}Am	3.58 E+02	1.6 E+03 (1.6 E+05)
^{244}Cm	5.36 E+00	1.4 E+01 (1.4 E+03)
Total		4.3 E+03 (4.3 E+05)

$$\text{WTU Ci} = 3.7 \times 10^{10} \text{ eq.}$$

CEDE - committed effective dose equivalent.
MTU - metric tons of uranium.

Table 3-78. Safety Classification Criteria.

	50-year committed effective dose equivalent
Offsite guideline	0.005 Sv (0.5 rem)
Onsite guideline	0.05 Sv (5.0 rem)

3.4.2 Design Basis Accidents

This section discusses the representative accidents analyzed from each of the major groupings and the accidents initiated by human-caused external events or natural phenomena. The MCO has a provides a confinement function during staging or interim storage. During staging, the MCO is provided with a filtered relief valve and rupture disk, and during interim storage, the MCO is provided with a rupture disk when it is vented and a containment function when it is sealed. In the following discussion of accidents, when the MCO may exist in either mode, its function is referred to as "confinement/containment."

3.4.2.1 Release of Multicanister Overpack Gases Under Pressure during Handling, Staging, or Interim Storage. Pressurization of the MCO to the design limit of its rupture disk unfiltered pressure relief device is an operational accident caused by failure of the filtered relief device and conditions in the MCO leading to gas generation and pressurization to the point of rupture disk relief, to ensure sufficient water removal during the cold vacuum drying and hot conditioning processes. The scenario results in a pressurized release from the MCO.

3.4.2.1.1 Scenario Development. MCOs arrive at the CSB sealed and containing an inert gas atmosphere. Both the pressure relief valve and the rupture disk are available for relief of MCO overpressure during shipping. During for those MCOs that require servicing before staging, the MCO penetrations are opened. An inert gas purge is initiated to flush out unwanted gases that may have formed during shipping. There is a potential for accumulation of hydrogen as a result of radiolytic or chemical reactions of residual water with the fuel during shipping, staging, or interim storage, resulting in MCO overpressurization. Operator or equipment failure could also lead to uncontrolled pressurization with purge gas during the purging operation. Operator failure or equipment failure could result in MCO overpressurization.

The excessive pressure from either purging or hydrogen generation may cause the unfiltered pressure relief device rupture disk to actuate with potential releases of solids. The design pressure of the MCO is 1.0 MPa gauge (150 lb/in² gauge). For the purpose of this analysis, it is assumed that the MCO pressure is 1.01 MPa gauge absolute (150.165 lb/in² gauge absolute) when the pressure relief device rupture disk actuates. This would allow MCO gases with suspended particulate to vent. For the purpose of this analysis, no mitigation of the release is assumed. The release is vented to the environment.

The basis for choosing this scenario to bound the class of MCO overpressurization accidents in the CSB is that the release is a direct function of MCO internal pressure and the MCO internal pressure is limited by the pressure at which the rupture disk relieves, and 1.0 MPa gauge (150 lb/in² gauge) is the highest pressure the MCO will credibly reach under current design assumptions. The MCO could achieve this internal pressure during transport, handling in the MHM, staging, or interim storage. Following are the assumptions for this choice.

- The MCO will be shipped inside the cask with its pressure relief valve and rupture disk available to relieve excess pressure to the cask, in a sealed configuration and A test such as verification of the gas generation rate of the MCO for a 24-hour holding period would measure the rate of rise of the MCO pressure at the end of cold vacuum drying. This test, as well as administrative controls on transportation and receiving at the CSB will to reduce the potential for significant delays before the MCO is placed in the tube for staging, will ensure that significant pressure release from the MCO will not occur in the receiving area, while the MCO is in transit. The inert gas purge system will incorporate design features to preclude MCO pressurization beyond the MCO design pressure.

- The MCO is not vented during staging. It has and has an active pressure relief valve set at something less than 1.0 MPa gauge differential (150 lb/in² gauge differential) and a rupture disk set at 1.0 MPa gauge differential (150 lb/in² gauge differential) rupture disk to prevent pressure exceeding the MCO design pressure. During interim storage the MCO will have only the rupture disk for pressure relief.
- The inert gas purge system will incorporate design features to preclude MCO pressurization beyond 1.0 MPa gauge (150 lb/in² gauge).

3.4.2.1.2 Source Term Analysis. The inventory at risk is the 300 kg (660 lb) of particulate material in the MCO available for release. A particulate release fraction for an MCO blowdown from 1.0 MPa gauge absolute (150 lb/in² gauge absolute) to atmospheric pressure was estimated (Kummerer and Plys 1996). Resuspension rate parameters for fuel assembly baskets and a scrap basket in the MCO were estimated using calculated flow velocities through the fuel baskets and experimental data for particulate resuspension. Calculation of the mass flow from the MCO breach during the blowdown provided the basis for estimating flow velocities over the fuel surfaces and estimating the duration of the event.

An MCO will contain five or six baskets of SNF stacked one above the other. The baskets have perforated plate bottoms designed to allow drainage of water during cold vacuum drying and to facilitate gas flows during cold vacuum drying processing. Most of the baskets will contain whole fuel assemblies resting vertically on their ends, arranged in a hexagonal matrix. There will be up to 54 fuel assemblies in a fuel basket.

Some baskets will hold broken fuel pieces and scrap, ranging in size from sections of a fuel element down to 0.6-cm (0.25-in.) pieces. In these scrap baskets the fuel pieces will be randomly distributed and are modeled as a bed of rubble. The analysis assumes that there will be, at most, one scrap basket in an MCO.

The standard equations for compressible flow and choked flow were employed in a simple computer simulation to calculate the flow behavior during the blowdown. The following key MCO assumptions were used in the analysis.

- The area of the MCO rupture disk orifice was taken to be $3.2 \times 10^{-5} \text{ m}^2$, corresponding to a 0.25-in.-diameter hole. The flow loss coefficient for the opening was 1.27, to account for a sudden contraction, friction losses, abrupt turns, and a sudden expansion.
- The MCO gas was assumed to be hydrogen, and the MCO free volume was assumed to be 1.0 m^3 .
- The temperature of the MCO gas was taken to be 75 °C throughout the event.

An additional calculation was made to test the effect of the higher initial temperatures that would be expected after staging in the CSB. Increasing the temperature to 250 °C showed insignificant effects on the gas velocities and blowdown time. In addition, gas at higher temperature has

lower density and would entrain fewer particles as it flows past the fuel. Therefore, the conclusions and assumptions incorporated in the analysis remain valid and conservative.

The standard compressible flow equation (Daily and Harleman 1966) gives

$$W = \frac{A}{\sqrt{K}} \left[\gamma P \rho \left(\frac{2}{\gamma+1} \right)^{\frac{\gamma+1}{\gamma-1}} \right]^{0.5}$$

where

W = mass flow rate (kg/s)
 A = flow area ($3.2 \times 10^{-5} \text{ m}^2$)
 K = loss coefficient (1.27)
 ρ = density of the gas (kg/m^3)
 P = gas pressure (Pa)
 γ = ratio of specific heats for a gas (1.4 for diatomic gases, 1.667 for monatomic gases).

During the blowdown, pressure and gas density change with time.

The maximum free stream velocity past the fuel was calculated from the mass flow rate.

$$V_{\text{MAX}} = \frac{W}{\rho A_f}$$

where

A_f = the flow area through a cross section of a fuel basket (0.14 m^2 [224 in^2]).

A_f was taken as the difference between the cross-sectional area of the MCO and the total cross-sectional areas of 54 fuel assemblies. This equation applies to the upper portion of fuel loaded in the uppermost position. The free stream velocity is zero at the bottom of the MCO and increases linearly along the height of the MCO.

The gas velocity through the interstices in the scrap basket was estimated by observing that the free stream flow would be further restricted by passing through the smaller cross-sectional area available in the scrap basket. Using a void fraction, e , of 0.5 for the scrap, and assuming the maximum free stream velocity from the fuel basket for the gas as it enters the scrap basket, the interstitial velocity in the scrap basket, V_i , is given by

$$V_i = \frac{V_{MAX}}{e}.$$

The maximum possible interstitial velocity corresponds to a scrap basket in the uppermost position in the MCO. The maximum free stream velocity in a fuel basket was found to be 0.16 m/s. MCO blowdown for this case was estimated based on the calculated blowdown period for a 500-L gas volume provided in WHC-SD-WM-CN-079, *MCO Blowdown Release Fraction* (Kummerer and Plys 1996). Using a ratio of the new volume (1,000 L) to the original volume (500 L), the blowdown was estimated to be approximately 110 seconds. For this analysis, a 10% uncertainty factor was applied and the particulate release was determined on the basis of a 120-second MCO blowdown period. WHC-SD-WM-CN-079 (Kummerer and Plys 1996) also shows MCO pressure, gas temperature, and gas velocity transients during blowdown.

Data from measurements of particle resuspension rates in low air flow over surfaces were examined to provide a resuspension parameter for the fuel surfaces and the scrap basket. Report SR-0980-5, *Experimental Studies of Resuspension and Weathering of Deposited Aerosol Particles* (Reynolds and Slinn 1979), measured resuspension of ZnS particles from a surface in horizontal flows between 2 and 8 m/s. The particle mean diameter was 3 μm , and the particulate mass concentration on the surface was 10^{-3} g/cm².

The relationship derived from the data gives the following

$$\Lambda = 7.4 \times 10^{-10} U_\infty^{3.08}$$

where

Λ = resuspension rate parameter (1/s)
 U_∞ = free stream velocity (m/s).

The resuspension rate parameter, Λ , was calculated from measured experimental parameters and is defined as follows:

$$\Lambda = \frac{M}{\chi A_s t}$$

where

M = resuspended mass
 A_s = surface area
 χ = particulate mass concentration on the surface
 t = time the surface is exposed to the airflow.

The maximum air velocity of interest in the MCO is well below the flows used in the experiments. Extrapolating the experimentally derived relationship for Λ to the calculated MCO flow velocities gives

$$\Lambda = 7.4 \times 10^{-10} (0.16)^{3.08}$$

$$= 2.6 \times 10^{-12}/s$$

Using the experimentally derived resuspension rates, the ARF can be estimated by multiplying the resuspension parameter by the duration of blowdown. It is conservatively assumed that $\Lambda = 10^{-6}/s$.

$$\text{ARF} = \Lambda t$$

$$= \frac{10^{-6}}{s} \times 120 \text{ s}$$

$$= 1.2 \times 10^{-4}.$$

This approach represents a departure from the pressurized powder models presented in DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions/Rates for Nonreactor Nuclear Facilities* (Mishima 1994). It is an attempt to provide a model that more closely represents the physical configuration of the MCO system while still providing adequate conservatism. Key uncertainties involved in the approach, and conservative assumptions used to address them, include the following.

- Uniformly distributed flow across the MCO cross section is assumed. Flow splits would be likely to cause higher flows at the periphery with lower velocities through the fuel baskets so that entrained particulate would be lower than assumed by the analysis. ~~Additional conservatism is provided by increasing the assumed ARF to using a value of $\Lambda = 10^{-6}/s$, the lower limit of the experimental data taken at 2 m/s (6.5 ft/s) air velocity, rather than the value calculated from the estimated flow velocities, provides additional conservatism.~~
- The data are reasonable for a scrap basket with 6-cm-diameter particles that resemble gravel. The resuspension parameter is likely to be much higher for a smooth surface. However, surfaces in the MCO bearing corrosion products are expected to be rough. Data from "Initial Correlation of Particle Resuspension Rates as a Function of Surface Roughness Height" (Sehmel and Simpson 1975) show that an increase of about three orders of magnitude could be expected for smooth surfaces, but the low end of the data still corresponds to a velocity of 2 m/s or greater, so a value of $10^{-6}/s$ is taken to bound the case.
- At present, no quantitative assumption can be made about the expected particle mass concentration, χ , on the fuel surfaces. However, concentrations greater than the 10^{-3} g/cm^2 experimental condition are anticipated. ~~Greater values of χ would give lower values for Λ if surface area, suspended mass, and experimental time are held constant. Therefore, the experimental data are judged to bound the SNF from the standpoint of surface particle mass concentrations.~~

- The expected MCO particulate may display different suspension characteristics than the material used to generate the experimental data. As characterization data on fuel particulate become available, the conservatism of using these data will be ~~confirmed~~ reevaluated.

The RF is conservatively taken to be 1.0 because the experimental data are based on particles largely in the respirable range. Additional conservatism is introduced into the calculation by neglecting redeposit of particles by impaction caused by turns and bends in the gas-particle flow path, particularly as the flow passes through the scrap basket.

With the maximum particulate loading of 300 kg (660 lb) per MCO on arrival at the CSB, the estimated inventory released is

$$(1.2 \times 10^{-4})(300 \text{ kg}) = 3.6 \times 10^{-2} \text{ kg.}$$

3.4.2.1.3 Consequence Analysis. The released source term was used to determine the radiological doses to the onsite and offsite receptors. The following assumptions were used to determine radiological consequences to human receptors.

- The release is caused by pressure in the MCO.
- Only exposure effects resulting from inhalation are evaluated. As indicated in Section 3.4.1.2, submersion and direct radiation doses provide an insignificant contribution to the total dose, and interdiction limits the exposure from the ingestion pathway.
- The values of X/Q for the selected receptor location are those given in Table 3-~~56~~ for ground-level releases without plume meander.
- The dose per unit of respirable radioactive material inhaled is the total given in Table 3-~~67~~ ($4.3 \times 10^3 \text{ Sv/g}$ [$4.3 \times 10^5 \text{ rem/g}$]).

The unmitigated effective dose equivalent for the onsite receptor that results from the depressurization of an MCO during handling can be calculated using the equation in Section 3.4.1.2.

$$D = M \times \frac{X}{Q} \times R \times C$$

$$= (3.6 \times 10^{-2} \text{ kg})(1,000 \text{ g/kg}) \left(3.41 \times 10^{-2} \frac{\text{S}}{\text{m}^3} \right) (3.3 \times 10^{-4} \frac{\text{m}^3}{\text{s}}) (4.3 \times 10^3 \frac{\text{Sv}}{\text{g}}) \\ = 1.8 \text{ Sv (180 rem).}$$

Dose consequences calculated in the same manner for other selected receptors are given in the Table 3-~~89~~.

Table 3-89. Unmitigated Dose Consequences for Multicanister Overpack Overpressurization during Handling.

Receptor location	Point source, without stack or plume meander		Guidelines Sv (rem)
	X/Q (s/m ³)	CEDE Sv (rem)	
Onsite (100 m E)	3.41 E-02	1.8 (180)	5.0 E-02 (5.0)
Hanford Site boundary (18.3 km E)	1.32 E-05	7.0 E-04 (0.07)	5.0 E-03 (0.5)
Near riverbank (15.0 km E)	1.96 E-05	1.0 E-03 (0.1)	5.0 E-03 (0.5)

CEDE = committed effective dose equivalent.

3.4.2.1.4 Comparison to Guidelines. If this accident is not mitigated or prevented by designed safety features, the radiological dose consequence to the onsite receptor 100 m (328 ft) east of the facility is 1.8 Sv (180 rem). The dose to the offsite receptor at the Hanford Site boundary is 7.0×10^{-4} Sv (0.07 rem); and at the near river bank it is 1.0×10^{-3} Sv (0.1 rem). The dose to the onsite receptor exceeds the guidelines discussed in Section 3.3.2.3.2. This mandates mitigative or preventive design features designated safety significant.

Either the filtered ventilation enclosure in the service area will be shown to be capable of confining the pressurized releases when the cask lid is removed and when the flanges are removed from the MCO pressure relief devices or administrative controls will be imposed to preclude reduce to acceptably low levels the likelihood of receiving and opening an MCO with sufficient internal pressure to challenge the enclosure confinement function. These controls would include verification of the gas generation rate of the MCO from the 24-hour holding period at the CVDFS facility, combined with control of shipping time and conditions covered in the safety analysis report for packaging. The confinement features of the MHM, the storage tube, and the vent and purge cart are designated safety-significant. The dose reduction factors for these mitigation options depend on the final design.

3.4.2.1.5 Summary of Safety-Class Structures, Systems, and Components and Technical Safety Requirement Controls. Reduction of the risk from a pressurized release from the MCO requires safety-significant confinement around the MCO at all times during receiving operations, handling, staging, and interim storage. Alternately, For the receiving area, an alternate approach is to provide administrative controls that would may be necessary to ensure MCOs opened in the receiving pit are not pressurized beyond the capability of the enclosure to contain the release.

A key assumption in estimating the dose consequences of the pressurized release is that the particulate inventory of the MCO when it enters the CSB is no greater than 300 kg (660 lb). Validation and/or implementation of the

assumptions outlined in WHC-SD-SNF-TI-023 (Pajunen and Cowen 1996) are necessary to provide assurance that the quantity of particulate assumed bounds the MCO particulate inventory, of the basis for this assumption will require administrative controls for the fuel washing operation at K Basins, and process control at the CVDS.

3.4.2.2 Multicanister Overpack Damage during Handling — Shear of a Multicanister Overpack. Subjecting the MCO to lateral forces that could cause failure is an operational accident that is postulated to occur as a result of movement of the MHM before the MCO has cleared the floor-MHM interface.

3.4.2.2.1 Scenario Development. During the handling operation, an MCO is positioned over a storage tube by the MHM. While the MCO is partially inserted in the tube, operator error or equipment failure results in the MHM moving sideways. The lateral force applied by the MHM may result in catastrophic failure of the MCO and/or compromise of the subcritical fuel geometry.

Uranium oxide is suspended as the MCO's contents fall onto the operating deck floor and into the tube. The storage tube will prevent release of the contents to the vault, but airborne particulate material is free to enter the operating deck area through the top of the tube and through the MHM floor seal as the MHM continues to move along the deck. No credit is taken for holdup in the building. Suspended material is assumed to leave the building and enter the environment.

The analysis presented below is performed for a nonpressurized MCO. This accident could occur with an MCO that is pressurized to any value up to the rupture disk relief pressure. Any amount of MCO pressurization would seem to provide additional energy to possibly propel radioactive particulate matter from the opening in the MCO and, therefore, increase the release fraction for this accident. Because the results of the analysis for the nonpressurized MCO led to the conclusion that safety-class preventive and/or mitigative equipment or administrative controls are required, the additional dose attributable to MCO's internal pressure was not calculated.

3.4.2.2.2 Source Term Analysis. Information and assumptions used to determine the amount of material released are as follows.

- The inventory at risk is 300 kg (660 lb) of UO_2 , which is a bounding estimate of the MCO particulate inventory. The portion of the MCO's contents that falls into the tube will be less available for release than that which falls on the operating deck. Therefore, for calculating the maximum release, it is assumed that the full contents of the MCO are spilled onto the operating deck.
- The ARF for the falling contents is determined using information from Section 4.4.3.1.3 of DOE-HDBK-3010-94 (Mishima 1994) for free-fall powder spills. The average spill height is taken to be from the center of mass of the MCO when positioned in the MHM such that the bottom of the MCO just extends into the storage tube. The average spill height is therefore estimated to be about one-half of the length of an MCO, which is about 2.0 m (6.5 ft). This is reasonable because

- This drop height is maximized by shearing the MCO at the lowest possible point, just above the top of the MCO lower closure; shearing the MCO at higher positions on the MCO will reduce the average spill height to the floor.
- Although it is currently planned to put a scrap basket only in the uppermost position in the MCO and the scrap basket contains 250% of the fuel oxide that is contained in a fuel basket, the geometric center of the volume occupied by the fuel baskets is less than 1.8 m (6 ft) above the lowest possible shear plane on the MCO. If the fuel oxide loading of each basket is assumed to be uniformly distributed within each basket, the center of mass of the oxide (skewed to the top of the MCO because of the higher loading in the scrap basket) would be about 2.0 m (6.5 ft) above the MCO shear plane. Since the oxide would have a tendency to fall toward the bottom of each basket, the value of 2.0 m (6.5 ft) for the fall height is reasonable.

DOE-HDBK-3010-94, Section 4.4.3.1.3 (Mishima 1994), states that for fall distances less than 3 m (10 ft), the measured combination of ARF and RF values that yields the highest fraction of material in the respirable range is 2×10^{-3} and 0.3. Therefore

$$(ARF)(RF) = (2.0 \times 10^{-3})(0.3) = 6.0 \times 10^{-4}$$

The released source term for the free fall of the MCO contents is that quantity of particulate matter released during the accident sequence. Considering the bounding estimate of 300 kg (660 lb) of uranium oxide in the damaged MCO, the amount of respirable material released from the fall is

$$ARF \times RF \times M_o = (6.0 \times 10^{-4})(300 \text{ kg})(1,000 \text{ g/kg}) = 180 \text{ g.}$$

Another source of respirable material is aerodynamic entrainment and resuspension of particles that are lying on the deck following the MCO shear event. From DOE-HDBK-3010-94, Section 4.4.4.1.2, "Experimentally Measured Resuspension Rates" (Mishima 1994), bounding ARF and RF for a homogeneous bed of powder exposed to ambient conditions (normal facility ventilation flow or less, or normal atmospheric conditions, wind speed less than 2 m/s with gusts up to 20 m/s) are 4.0×10^{-5} per hour and 1.0, respectively.

For the offsite receptor, a 24-hour exposure period is assumed. The amount of respirable material released in 24 hours is

$$(4.0 \times 10^{-5}/\text{h})(24 \text{ h})(300 \text{ kg})(1,000 \text{ g/kg}) = 288 \text{ g.}$$

For the onsite receptor, the exposure period is 8 hours, the duration of a standard shift. The amount of respirable material released in 8 hours is

$$(288 \text{ g}) / 3 = 96 \text{ g.}$$

The assumption that the MCO particulate is a finely divided powder in these models is more conservative than the assumption used in Section 3.4.2.1 for the MCO overpressurization accident. That analysis was based on air entrainment data for particles with mean diameter of 3 μm . The models for

free fall of powders are more conservative because they are based on experiments using light, finely divided powders that are freely available for air entrainment. For future versions of the SAR, experimental data on the physical characteristics of the K Basin canister particulate will be available to partially validate the conservatism of these assumptions. It is expected that a significant portion of the particulate in the MCO will be shown to be attached to fuel surfaces and residing in the fuel assembly annuli and beneath the cladding.

N Reactor experience indicates that the intact fuel elements will not shatter on impact. However, it is anticipated that a "shower" of particles will be produced as fuel elements are broken during a shearing accident. The particles would oxidize rapidly, but the mass of this additional oxide would be insignificant in comparison with the oxide loading of the MCO and is considered to be negligible.

3.4.2.2.3 Consequence Analysis. The amount of respirable material released was used to determine the radiological doses to onsite and offsite receptors. The CEDE for these receptors is calculated using the equation in Section 3.4.1.2 along with the following assumptions.

- The release is a result of spilling the MCO's contents.
- Only exposure effects resulting from inhalation are evaluated. Submersion and direct radiation pathways do not contribute significantly to the total dose and exposure via the ingestion pathway is limited by interdiction.
- For each of the onsite and the offsite receptors, two values of X/Q are applied. All of the X/Q values are for ground releases (i.e., without stack), but the dose resulting from that portion of the release due to free fall of the MCO's contents is based on X/Q without plume meander, and the dose resulting from that portion of the release due to resuspension of additional material over time following the spill is based on X/Q with plume meander.
- The dose per unit of respirable radioactive material inhaled is 4.3×10^3 Sv/g (4.3×10^5 rem/g).

For the onsite receptor the dose from the MCO's falling contents is

$$\begin{aligned}
 D &= M \times \frac{X}{Q} \times R \times C \\
 &= (180 \text{ g})(3.41 \times 10^{-2} \text{ s/m}^3)(3.3 \times 10^{-4})(4.3 \times 10^3 \text{ Sv/g}) \\
 &= 8.7 \text{ Sv (870 rem)}
 \end{aligned}$$

and the dose from resuspension of particulate from the MCO's spilled contents is

$$D = M \times \frac{X}{Q} \times R \times C$$

$$= (96 \text{ g})(1.13 \times 10^{-2} \text{ s/m}^3)(3.3 \times 10^{-4})(4.3 \times 10^3 \text{ Sv/g})$$

$$= 1.5 \text{ Sv (150 rem)}$$

The total dose is the sum of the dose from the falling contents and the dose from resuspension of spilled particulate lying on the CSB floor:

$$8.7 \text{ Sv} + 1.5 \text{ Sv} = 10.2 \text{ Sv (1,020 rem)}$$

Dose consequences for other selected receptors are calculated in a similar manner and are summarized in Tables 3-9, 3-10 and 3-11. Table 3-9 shows the dose attributed to free fall of the MCO contents, Table 3-10 shows the dose attributed to resuspension of the spilled particulate matter and Table 3-11 shows total dose to the indicated receptors for the MCO shear accident.

3.4.2.2 Single Multicanister Overpack Failure during Handling—Lateral Forces. Subjecting the MCO to lateral forces that could cause failure is an operational accident caused by movement of the MHM before the MCO has cleared the floor MHM interface. The accident is classified as confinement/containment failure.

3.4.2.2.1 Scenario Development. During the handling operation, an MCO is positioned over a storage tube by the MHM. While the MCO is partially inserted in the tube, operator error or equipment failure results in the MHM moving sideways. The lateral force applied by the MHM results in catastrophic failure of the MCO.

Table 3-9. Unmitigated Dose Consequences for Free Fall of Contents from a Sheared Multicanister Overpack.

Receptor location	Point source without stack or plume meander	
	X/Q (s/m ³)	CEDE Sv (rem)
Onsite (100 m E)	3.41 E-02	8.7 (870)
Hanford Site boundary (18.3 km E)	1.32 E-05	0.0034 (0.34)
Near riverbank (15.0 km E)	1.96 E-05	0.0050 (0.50)

CEDE = committed effective dose equivalent.

Table 3-10. Unmitigated Dose Consequences for Resuspension of Particulate from Spilled Multicanister Overpack Contents.

Receptor Location	Point source without stack and with plume meander	
	X/Q (s/m ²)	CEDE Sv (rem)
Onsite (100 m E)	1.13 E-02	1.5 (150)
Hanford Site boundary (18.3 km E)	1.11 E-05	0.0045 (0.45)
Near riverbank (15.0 km E)	1.55 E-05	0.0063 (0.63)

CEDE = committed effective dose equivalent.

Table 3-11. Total Unmitigated Dose Consequences for a Single Multicanister Overpack Failure during Handling - Lateral Forces.

Receptor Location	Total CEDE Sv (rem)	Guidelines Sv (rem)
Onsite (100 m E)	10.2 (1,020)	5.0 E-02 (5.0)
Hanford Site boundary (18.3 km E)	0.008 (0.8)	5.0 E-03 (0.5)
Near riverbank (15.0 km E)	0.011 (1.1)	5.0 E-03 (0.5)

CEDE = committed effective dose equivalent.

Uranium oxide is suspended as the MCO's contents fall onto the operating deck floor and into the tube. The storage tube will prevent release of the contents to the vault, but airborne particulate material is free to enter the operating deck area through the top of the tube. No credit is taken for holdup in the building. Suspended material is assumed to leave the building and enter the environment.

The analysis presented below is performed for a nonpressurized MCO. This accident could occur with an MCO that is pressurized to any value up to the relief device set pressure, 1.0 MPa gauge (150 lb/in² gauge). Any amount of MCO pressurization would seem to provide additional energy to possibly propel radioactive particulate matter from the opening in the MCO and, therefore, increase the release fraction for this accident. Because the results of the analysis for the nonpressurized MCO led to the conclusion that safety class preventive and/or mitigative equipment or administrative controls are required, the additional dose attributable to MCO internal pressure was not calculated.

~~3.4.2.2.2 Source Term Analysis. Information and assumptions used to determine the amount of material released are as follows.~~

- ~~• The inventory at risk is 300 kg (660 lb) of UO₂, which is a bounding estimate of the MCO particulate inventory. The portion of the MCO contents that falls into the tube will be less available for release than that which falls on the operating deck. Therefore, for calculating the maximum release, it is assumed that the full contents of the MCO are spilled onto the operating deck.~~
- ~~• The ARF for the falling contents is determined using the Ballinger model described in DOE HDBK 3010 94 (Mishima 1994), for free fall powder spills. The average spill height is taken to be from the center of mass of the MCO when positioned in the MHM such that the bottom of the MCO just extends into the storage tube. The average spill height is therefore about one half of the length of an MCO which is about 2.0 m (6.5 ft).~~

$$\text{ARF} = \frac{0.1064 M_p^{0.125} H^{2.37}}{\rho_{BP}^{1.02}}$$

where

- ~~M_p = mass of powder spilled (300 kg)~~
- ~~H = spill height (2.0 m [6.5 ft])~~
- ~~ρ_{BP} = bulk density of uranium oxide powder (4,000 kg/m³).~~

$$\text{ARF} = 2.4 \times 10^{-4}$$

- ~~• The RF is conservatively taken to be 1.0.~~
- ~~• ARF x RF = 2.4 x 10⁻⁴.~~

~~The released source term for the free fall of the MCO contents is that quantity of particulate matter released during the accident sequence. Considering the bounding estimate of 300 kg (660 lb) of uranium oxide in the damaged MCO, the amount of respirable material released from the fall is~~

$$\text{ARF} \times \text{RF} \times M_p = (2.4 \times 10^{-4})(300 \text{ kg})(1,000 \text{ g/kg}) = 72 \text{ g}$$

~~Another source of respirable material is aerodynamic entrainment and resuspension of particles that are lying on the deck following the MCO shear event. From DOE HDBK 3010 94, Section 4.4.4.1.2, "Experimentally Measured Resuspension Rates" (Mishima 1994), bounding ARF and RF for a homogeneous bed of powder exposed to ambient conditions (normal process facility ventilation flow or less, or normal atmospheric conditions, wind speed less than 2 m/s with gusts up to 20 m/s) are 4.0 x 10⁻² per hour and 1.0, respectively.~~

~~For the offsite receptor, a 24 hour exposure period is assumed. The amount of respirable material released in 24 hours is~~

$$(4.0 \times 10^{-5}/\text{hr})(24 \text{ hr})(300 \text{ kg})(1,000 \text{ g/kg}) = 288 \text{ g}$$

For the onsite receptor, the exposure period is 8 hours, the duration of a standard shift. The amount of respirable material released in 8 hours is

$$288 \text{ g/3} = 96 \text{ g}$$

The assumption that the MCO particulate is a finely divided powder in these models is more conservative than the assumption used in Section 3.4.2.1 for the MCO overpressurization accident. That analysis was based on air entrainment data for particles with mean diameter of 3 μm . The models for free fall of powders are more conservative because they are based on experiments using light, finely divided powders that are freely available for air entrainment. For future versions of the SAR, experimental data on the physical characteristics of the K Basin canister particulate will be available to partially validate the conservatism of these assumptions. It is expected that a significant portion of the particulate in the MCO will be shown to be attached to fuel surfaces and residing in the fuel assembly annuli and beneath the cladding.

N Reactor experience indicates that the intact fuel elements will not shatter on impact. However, it is anticipated that a "shower" of particles will be produced as fuel elements are broken during a shearing accident. The particles would oxidize rapidly, but the mass of this additional oxide would be insignificant in comparison with the oxide loading of the MCO and is considered to be negligible.

3.4.2.2.3 Consequence Analysis. The amount of respirable material released, calculated in Section 3.4.2.2.2, was used to determine the radiological doses to onsite and offsite receptors. The unmitigated effective dose equivalent for these receptors is calculated using the equation given in Section 3.4.1.2

$$D = M \times [X/Q] \times R \times C$$

along with the following assumptions:

- The release is a result of spilling the MCO contents.
- Only exposure effects resulting from inhalation are evaluated. As indicated in Section 3.4.1.2, submersion and direct radiation pathways do not contribute significantly to the total dose, and exposure via the ingestion pathway is limited by interdiction.
- The values of X/Q used in this analysis are given in Table 3-6. For each of the onsite and offsite receptors, two values of X/Q are applied. All of the X/Q values are for ground releases (i.e., without stack), but the dose resulting from that portion of the release caused by free fall of the MCO contents is based on X/Q without plume meander, and the dose resulting from that portion of the release caused by resuspension of additional material over time following the spill is based on X/Q with plume meander.

- ~~• The dose per unit of respirable radioactive material inhaled is the total given in Table 3-7 (4.3×10^{-3} Sv/g [4.3×10^{-5} rem/g]).~~

~~For the onsite receptor~~

- ~~• The dose from the falling MCO contents is~~

$$\{72 \text{ g}\} [3.41 \times 10^{-2} \text{ s/m}^3] [3.3 \times 10^{-4}] [4.3 \times 10^{-3} \text{ Sv/g}]$$

$$= 3.5 \text{ Sv (350 rem)}$$

- ~~• The dose from resuspension of particulates from the spilled MCO contents is~~

$$\{92 \text{ g}\} [1.13 \times 10^{-2} \text{ s/m}^3] [3.3 \times 10^{-4}] [4.3 \times 10^{-3} \text{ Sv/g}]$$

$$= 1.5 \text{ Sv (150 rem)}$$

- ~~• The total dose is the sum of the dose from falling MCO contents and the dose from resuspension of spilled particulates lying on the GSB floor~~

$$= 3.5 \text{ Sv (350 rem)} + 1.5 \text{ Sv (150 rem)}$$

$$= 5.0 \text{ Sv (500 rem)}$$

Dose consequences for other selected receptors are calculated in a similar manner and are summarized in Tables 3-10, 3-11, and 3-12. Table 3-10 shows the dose attributed to free fall of the MCO contents, Table 3-11 shows the dose attributed to resuspension of the spilled particulate matter, and Table 3-12 shows total dose to the indicated receptors for the MCO shear accident.

Table 3-10. Unmitigated Dose Consequences for Free Fall of Contents From a Sheared Multicanister Overpack.

Receptor location	Point source without stack or plume meander	
	X/Q (s/m ³)	EDE Sv (rem)
Onsite (100 m E)	3.41 E-02	3.5 (350)
Hanford Site boundary (18.3 km E)	1.32 E-05	0.0013 (0.13)
Near riverbank (15.0 km E)	1.96 E-05	0.0020 (0.20)

EDE = effective dose equivalent.

~~Table 3-11. Unmitigated Dose Consequences for Resuspension of Particulates from Spilled Multicanister Overpack Contents.~~

Receptor location	Point source without stack and with plume meander	
	X/Q (s/m ²)	EDE Sv (rem)
Onsite (100 m E)	1.13 E-02	1.5 (150)
Hanford Site boundary (18.3 km E)	1.11 E-05	0.0045 (0.45)
Near riverbank (15.0 km E)	1.55 E-05	0.0063 (0.63)

~~EDE = effective dose equivalent.~~

~~Table 3-12. Total Unmitigated Dose Consequences for a Single Multicanister Overpack Failure during Handling Lateral Forces.~~

Receptor location	Total EDE		Guideline Sv (rem)
	Sv	(rem)	
Onsite (100 m E)	5.0	(500)	5.0 E-02 (5.0)
Hanford Site boundary (18.3 km E)	0.006	(0.6)	5.0 E-03 (0.5)
Near riverbank (15.0 km E)	0.008	(0.8)	5.0 E-03 (0.5)

~~EDE = effective dose equivalent.~~

3.4.2.2.4 Comparison to Guidelines. If this accident is not mitigated or prevented by designed safety features, the radiological dose consequence to the onsite receptor 100 m (328 ft) east of the facility is ~~5.010 2 Sv (500.020 rem)~~. The onsite dose exceeds the guidelines discussed in Section 3.3.2.3.2. The dose to the offsite receptor at the riverbank is ~~0.0080 011 Sv (0.811 rem)~~. This exceeds the guideline (5.0×10^{-3} Sv [0.5 rem]) for safety-class mitigation or prevention of the release.

~~It is anticipated that the reliability of systems and controls designed to protect the confinement/containment function of the MCO will be shown to reduce the frequency of this event sufficiently that risk acceptance guidelines are met for both onsite and offsite receptors.~~

3.4.2.2.5 Summary of Safety-Class Structures, Systems, and Components and Technical Safety Requirement Controls. If conservative analysis does not show that the MCO's confinement/containment function and its ability to maintain the SNF in a subcritical geometry will withstand the challenges posed by this class of accidents, the risk from a catastrophic failure of the MCO while being placed in the tube must be reduced by either mitigation of the release or prevention of the event.

Safety-class interlocks and keys to prevent MHM sideways movement while the MCO is partially inserted into a storage tube, and design of the receiving area combined with TSR administrative controls that prevent a vehicle colliding with the MCO in the service area are effective preventive features. To prevent MCO shearing during a seismic event, a safety-class brake or locking device on the MHM will be provided or it will be shown that a design-basis seismic event will not cause MCO shear.

A key assumption in estimating the dose consequences of the release is that the particulate inventory of the MCO after the hot conditioning process is no greater than 300 kg (660 lb). Validation and/or implementation of the assumptions outlined in WHC-SD-SNF-TI-023 (Pajunen and Cowan 1996) are necessary to provide assurance that the quantity of particulates assumed bounds the MCO particulate inventory. The effectiveness of the fuel cleaning evolutions at the K Basins must be verified, and cleaning procedures must be followed for all fuel. The amount of free water left in the MCO after cold vacuum drying must be confirmed to be acceptable by monitoring at the CVDFES facility. Particulate drying curves from characterization efforts will help confirm this.

3.4.2.3 Multicanister Overpack Damage during Handling — Multicanister Overpack Drop Accident. The MCO is the primary confinement boundary for the fuel and also provides criticality control. The potential challenge to these functions is of concern with respect to accidents that involve dropping the MCO.

3.4.2.3.1 Scenario Development. In the CSB, the MCO is handled by the receiving crane when it is in the shipping cask and the MCO is handled by the MHM to transport the MCO within the CSB. Design analyses included in HNF-SD-SNF-SARR-005, *Multicanister Overpack Topical Report* (Lorenz 1997), show that the MCO in the cask will survive any credible drops from the receiving crane. They also show that the small annulus between the shipping cask and the MCO provides enough attenuation of free fall velocity to prevent MCO breach if the MCO is dropped back into the cask during unloading as long as the bottom of the MCO has not yet been withdrawn from the top of the cask. A chamfer has been added to the bottom of the MCO to facilitate the deflection of the MCO off the inner lip of the cask. Additional design analyses are being done to verify that cask and MCO design will not allow MCO breach for any drop from the MHM.

The structural integrity of the MCO shell, shield plug, and internals following design basis accident drops is essentially assured by analyses, and the MCO, therefore, maintains its fuel container, confinement, and criticality functions. However, several scenarios could lead to particulate release through the MCO pressure relief devices as a result of an MCO drop accident. The limiting scenario, with respect to doses to collocated workers on the site and to receptors at the Site boundary, is established on the basis of the amount of particulate expelled from the MCO and the potential for holdup of the particulate material as it travels to the receptors.

The MCO has two pressure relief devices: one device is a rupture disk, which is on an unfiltered flow path containing a 0.6-cm- (0.25-in.-) diameter orifice plate, and the other device is a pressure relief valve, which is on a flow path filtered through the MCO's internal HEPA filter and contains a

0.6-cm- (0.25-in.-) diameter flow path restriction in the shield plug. The nominal actuation set point pressure for the rupture disk is 1.0 MPa differential (150 lb/in² differential), and the setpoint for the relief valve will be sufficiently lower than the rupture disk setpoint to ensure that operation of the relief valve will prevent actuation of the rupture disk. Since the MCO's internal HEPA filter cannot be tested after installation and is, therefore, not safety class, failure of the filter (e.g., from corrosion) can be postulated, permitting unfiltered release through the relief valve. Since the flow rate through these two flow paths can be essentially the same, the limiting amount of particulate expelled from the MCO will be for the case that blows down from the highest MCO internal pressure. Blowdown through the relief valve will start at a lower pressure than required to rupture the rupture disk, and complete blowdown requires that the valve fail to reclose as designed. Blowdown through the rupture disk will occur from the maximum possible MCO pressure, which requires that the pressure relief valve fail to open. One component of the limiting scenario is that blowdown occurs through the rupture disk starting at approximately 1.0 MPa differential (150 lb/in² differential). This, alone, defines the limiting case for the unmitigated release dose calculation.

There are four MCO drop possibilities within the CSB: drop into the shipping cask, drop within the MHM, and drop into a storage tube (drop into a hot conditioning oven will be considered in the HCS addendum to the final SAR). The MCO drop accident has the potential to rupture the rupture disk if the MCO's internal pressure is on the verge of causing rupture and the small increase in MCO pressure that might be caused by the drop accident gets the pressure differential over the rupture threshold. Analyses performed for HNF-SD-SNF-SARR-005 (Lorenz 1997) also indicate that elastic deformation of the MCO during the drop accident could result in a short-lived (less than 1 second) pressure pulse that could increase MCO internal pressure approximately 5 lb/in².

Criteria for MCO acceptance at CSB receiving will ensure that MCO pressure will not be on the verge of rupturing the rupture disk when the MCO is being handled by the MHM in the CSB receiving area. Therefore, the limiting MCO drop case will be either dropping within the MHM or dropping into a storage tube. When the MCO is being transported by the MHM, the MHM provides secondary confinement for the MCO. When the MHM is in position over a storage tube and while raising or lowering an MCO, the MHM combined with the storage tube provides secondary confinement for the MCO's contents. Assuming that the decontamination factor associated with secondary confinement decreases as the confinement pressure during the accident increases, the limiting case will be that with the smallest secondary confinement volume. Therefore, the limiting case is dropping the MCO within the MHM.

3.4.2.3 Multicanister Overpack Failure during Handling—Crane Drop. Dropping the cask MCO from the receiving crane or dropping the MCO from the MHM into the shipping cask, into a tube, or onto the operating deck floor are operational accidents caused by human error or equipment failure. The accident is classified as a confinement/containment failure.

Design analyses to be included in the MCO Topical Report show that the MCO in the cask will survive any credible drops from the receiving crane. They also show that the small annulus between the shipping cask and the MCO

~~provides enough attenuation of free fall velocity to prevent MCO breach if the MCO is dropped back into the cask during unloading as long as the bottom of the MCO has not yet cleared the top of the cask. Additional design analysis is being done to verify that cask and MCO design will not allow MCO breach if the MCO is dropped from its highest position in the MHM. The MHM will be designed to preclude dropping the MCO to the operating area floor by providing a barrier beneath the MCO whenever it is being moved by the MHM. Therefore, the bounding MCO drop accident involves a drop into the storage tube.~~

~~3.4.2.3.1 Scenario Development. In the MCO drop accident, an unvented MCO with an internal pressure near the rupture disk set point is dropped by the MHM. As a consequence of the drop, the safety class rupture disk ruptures or the non safety class relief valve opens. The drop also produces accelerations on the fuel causing particulate matter to be shaken from the fuel and suspended in the MCO gas space. This particulate laden gas is then expelled from the MCO to the MHM, which may be connected to a storage tube, and then released to the environment. The flow rate from the MCO is limited by a 0.635 cm (0.25 in.) diameter orifice plate. The particulate matter is the radionuclide source term used for the dose calculations. The resulting onsite dose consequence is 1.45 Sv (145 rem) and the offsite dose consequence is 0.83 mSv (0.083 rem).~~

~~An MCO is vented and purged with inerting gas at the GSB receiving station before either being placed in a storage tube for staging or moved directly to a furnace in the hot conditioning facility. Following hot conditioning, an MCO is purged and backfilled with inerting gas at 1 atm absolute pressure just prior to return to the storage tube for interim storage.~~

~~If an MCO is staged before hot conditioning, it can be in staging for several years and the internal pressure will increase because of the production of gases from fuel corrosion and radiolysis. During staging, MCOs are not vented; they have an active pressure relief valve with an active safety class rupture disk to back up the relief valve. The only possible times the MHM would move an MCO having an internal pressure approaching the rupture disk rupture pressure are at the end of staging and during transport by the MHM if an abnormal condition causes the MCO to be kept in the MHM for an unusually long time. During interim storage, the MCOs will not be handled, with the possible exception of retrieving an MCO that has ruptured a rupture disk. In this case, only one pressurized MCO would be in the storage tube.~~

~~The following possible relief mechanisms would vent unfiltered gas from the MCO:~~

- ~~• The MCO is pressurized to just under the relief valve opening pressure, the drop accident causes the relief valve to open, the relief valve fails to reseat, and corrosion has caused the HEPA filter in the MCO to open to the extent that it does not filter the escaping gas~~
- ~~• The relief valve has failed closed and allowed the MCO's internal pressure to increase to a value just below the rupture disk rupture set point.~~

Blowdown of the MCO through either of these two paths would be very similar inasmuch as each path contains a 0.635 cm (0.25 in.) diameter restriction, but blowdown would start at a higher pressure for the case of the rupture disk rupturing. The higher pressure case will result in a higher source term; therefore the rest of this accident discussion is in terms of rupturing the rupture disk.

A dropped MCO with internal pressure near the rupture disk set point creates a dose consequence hazard only if the accident results in rupture of the rupture disk simultaneous with the MCO coming to a sudden stop, after the fall, in the MHM or the storage tube. If the MCO is dropped into a storage tube and the rupture disk ruptures, the gases within the MCO will carry radioactive particulate matter from the MCO into the confinement volume provided by the MHM storage tube. This MHM storage tube volume is vented to the CSB through a HEPA filter. A leak in the seal between the MHM and the top of the storage tube could provide a pathway for contaminants to bypass the filter and enter the CSB which could then leak airborne contaminants to the environment.

An MCO can be dropped into a storage tube already containing another MCO in the bottom position, or it can be dropped into an empty storage tube. If the drop occurs into a storage tube that already contains an MCO, the ensuing MHM tube pressure will be higher than if the drop occurs in a tube that does not contain another MCO because the confinement volume is larger with only one MCO, and the elevation of the MCO release path will be closer to the elevation of the MHM storage tube interface where a leak to the CSB could occur. Based on pressurization of the MHM and the elevation of the release point, it is conservative to assume that the MCO drop occurs in a storage tube that already contains an MCO in the bottom position.

Increasing pressure in the MCO to a value approaching but not exceeding the rupture disk rupture pressure requires several off normal conditions. First, the dropped MCO must contain a sufficient quantity of water to produce gases from radiolysis and chemical reactions to increase the MCO internal pressure to about 1.1 MPa (165 lb/in² absolute). During staging, the MCO is equipped with the 1.0 MPa (150 lb/in² absolute) rupture disk and a relief valve that is designed to open at about 0.9 MPa (135 lb/in² gauge) to relieve MCO pressure through a HEPA filter and then reseal (reseal pressure unknown). Increasing the MCO pressure to the rupture disk pressure, therefore, requires failure of the pressure relief valve to open.

In addition, impact limiters both above and below the bottom MCO will reduce impact forces on the bottom MCO and protect the pressure relief valve and the rupture disk on that MCO from mechanical failure. The rupture disk on the bottom MCO in the staging tube is assumed to withstand the effects of the dropped MCO and neither rupture because of internal pressure nor breach because of mechanical failure as a consequence of the accident. Rupturing of a rupture disk would require that the MCO's internal pressure be near the rupture disk setpoint differential pressure of 1.0 MPa (150 lb/in² absolute). Achieving MCO internal pressure of this magnitude requires that a sufficient quantity of gas be generated to increase the differential pressure to 1.0 MPa (150 lb/in²) and that the pressure relief valve failure to open. The probability of two such MCOs residing in the same storage tube and being

~~involved in the accidental drop of an MCO is sufficiently remote that it can be disregarded.~~

3.4.2.3.2 Source Term Analysis. ~~Because the bottom MCO does not rupture as a consequence of dropping another MCO on top of it, the dose consequences of the MCO drop accident are the result of release of particulate matter from just one MCO, pressurized to approximately 1.1 MPa (165 lb/in² absolute), with the contained fuel jostled simultaneously with the rupture of the rupture disk. This accident also is possible for the situation where the MCO is dropped within the MHM while being transported within the GSB. For this case, the particulate release from the MCO is assumed to be the same as dropping the MCO into a storage tube since the effect of jostling the fuel for a drop of a few feet or tens of feet cannot be differentiated. However, the confinement volume of the MHM is less than the confinement volume involved in dropping an MCO into a storage tube (the combination of the MHM and the storage tube). Consequently, pressure in the confinement volume will be higher for the "MHM only" confinement, resulting in a reduction of the amount of particulate holdup (of radioactive material from plateout and settling) for the smaller confinement volume. Holdup in confinement is not considered in the analyses for the MCO drop accident (at this time), but on the basis of the above argument, it is intuitively obvious that the limiting MCO drop accident, with respect to particulate released from the MHM, is the case where the MCO is dropped within the MHM.~~

~~Another factor that must be considered is the potential for leakage at the seal between the MHM and the storage tube or the MHM turret seal. The MHM is continuously vented to the GSB through a duct with a safety significant HEPA filter; inert purge gas is continuously fed into the MHM. Because the confinement volume for the drop within the MHM is smaller, the confinement pressure will be higher, the particulate concentration will be higher, the probability of plugging the HEPA filter and/or blowing the HEPA filter out, and the probability of failing the seal (assuming that the design pressure for both seals is the same) is greater for the case of dropping the MCO within the MHM.~~

~~The blowdown of the dropped MCO proceeds in a manner similar to that of an overpressurized MCO, but the effects of jarring the fuel in the dropped MCO must be taken into account in estimating the release from the dropped MCO. DOE-HDBK-3010-94, Subsection 4.4.3.3.1, "Vibration Shock" (Mishima 1994), identifies a bounding value for ARF of 0.001 for the suspension of powder-like surface contamination by shock-vibration. Experiments discussed in DOE-HDBK-3010-94, Subsection 4.4.3.3.2, "Large Falling Object Impact or Induced Air Turbulence" (Mishima 1994), involving the suspension of powders into flowing air caused by impact of large pieces of debris on plywood also indicated a maximum ARF of 0.001. DOE-HDBK-3010-94 (Mishima 1994) also states that particles comprising surface contamination are assumed to be more widely dispersed and not as agglomerated as "thick" layers of particles that represent powders. Therefore, for "clumps/piles" of powder, the bounding value for the RF is 0.1 (Mishima 1994, Subsection 4.4.3.3.1) because of the difficulty of deagglomerating powders.~~

~~An RF of 0.1 in this case is still a conservative RF value for the MCO particulate because of the inherent difficulty of removing some of the particulate from the fuel. This difficulty is indicated in the description of~~

assumptions used in the bounding particulate calculation (Wiborg 1996) (Pajunen and Cowan 1996). The bounding oxide inventory of an MCO of (300 kg [660 lb]) was determined on the basis of assumptions that particulate could theoretically remain in several locations on fuel assemblies, even after cleaning, and that additional oxide would be produced during handling, staging, and conditioning.

- Particulate could remain at the end of an assembly where the uranium metal has corroded away leaving a cladding shell filled with fuel particulate. (The end caps of the fuel elements in this calculation had to be assumed to be in place; this is a description of a "defective" fuel element. If more oxide was generated, the end cap would have been displaced, and the fuel element would have been classified as "bad" and put into a scrap basket.)
- Particulate could remain in a general corrosion layer covering the exterior surfaces of the assembly. (This is a 50 μ m thick layer of oxide that has been observed to be sustained on uranium metal without spalling. Note that this particulate layer is assumed to coat the major exterior assembly surfaces even though the majority of the exterior of most assemblies will consist of the Zircaloy 2 cladding.)
- Particulate could remain in pockets in the form of blisters under the cladding. (This inventory of particulate is material enclosed by essentially unbroken cladding.)
- Particulate could remain as a build up plug in the assembly flow channel regions. (This particulate is packed so tightly that it could not be removed by the cleaning process and was not shaken loose during handling.)

It can be seen that the The majority of the particulate that survived the fuel cleaning process (i.e., remained with the fuel) and is presumed to be in the bounding MCO before hot conditioning will be occluded under the cladding and not readily available for release as fine particles. Therefore, an ARF of 0.001 with an RF of 0.1 is considered conservative for the MCO drop accident. With material at risk (MAR) of 300 kg (660 lb) from the of uranium oxide inventory of assumed to be in an MCO, the amount of released respirable material, unmitigated by any safety features or passive confinement, is given by the following equation.

$$\begin{aligned}
 \text{Respirable material released from the MCO} &= (\text{MAR}) (\text{ARF}) (\text{RF}) \\
 &= (300 \text{ kg}) (0.001) (0.1) \\
 &= 0.030 \text{ kg} \\
 &= 30 \text{ g of respirable material released.}
 \end{aligned}$$

This 30 g of respirable particulate will be released into the MHM or MHM storage tube confinement. At the time of the MCO drop, the MHM confinement is being purged with an inerting gas. The presence of the MHM's HEPA filter and the assumption of the design leak rate for the MHM seals would provide for some additional holdup in MHM confinement.

3.4.2.3.3 Consequence Analysis. The following conditions are necessary for this accident to occur.

- The MCO being moved contains enough water to result in internal pressurization of the MCO to near the pressure required for rupture disk rupture 1.1 MPa (165 lb/in² gauge).
- The pressure relief valve for this MCO has failed to open, or the pressure relief valve fails open and the HEPA filter is corroded to the extent that it permits the flow of unfiltered gas.
- The MCO is dropped while being handled in the MHM.
- The effect of dropping an MCO increases the MCO pressure because of distortion of the MCO and/or stresses the rupture disk sufficiently to cause rupture of the rupture disk.

With the assumption of no holdup of particulate in the MHM or in the CSB, the onsite and offsite dose consequences are calculated from the following equation.

$$D = M \times \frac{X}{Q} \times R \times C$$

where

- ~~D = Dose (Sv)~~
- ~~M = Respirable mass released (kg)~~
- ~~X/Q = Integrated atmospheric dispersion coefficient (s/m³)~~
- ~~R = Breathing rate (m³/s)~~
- ~~C = 3.3 x 10⁻⁴ m³/s typical acute breathing rate (light activity)~~
- ~~ULDC = CEDE per unit respirable material inhaled (Sv/g)~~

For the onsite receptor ~~collocated worker~~

$$\begin{aligned} D \text{ (Sv)} &= (30 \text{ g}) (0.0341 \text{ s/m}^3) (3.3 \times 10^{-4} \text{ m}^3/\text{s}) (4,300 \text{ Sv/g}) \\ &= 1.45 \text{ Sv} \\ &= 145 \text{ rem.} \end{aligned}$$

For a receptor at the Hanford Site boundary

$$\begin{aligned} D \text{ (Sv)} &= (30 \text{ g}) (1.32 \times 10^{-5} \text{ s/m}^3) (3.3 \times 10^{-4} \text{ m}^3/\text{s}) (4,300 \text{ Sv/g}) \\ &= 0.56 \text{ mSv} \\ &= 0.056 \text{ rem.} \end{aligned}$$

For a receptor at the near riverbank

$$\begin{aligned} D \text{ (Sv)} &= (30 \text{ g}) (1.96 \times 10^{-5} \text{ s/m}^3) (3.3 \times 10^{-4} \text{ m}^3/\text{s}) (4,300 \text{ Sv/g}) \\ &= 0.83 \text{ mSv} \\ &= 0.083 \text{ rem.} \end{aligned}$$

Dose consequences calculated for this accident are given in Table 3-1213.

Table 3-1213. Unmitigated Dose Consequences for Failure of a Multicanister Overpacks during Handling.

Receptor location	Point source, without stack		Guidelines Sv (rem)
	X/Q without plume meander (s/m ³)	Total CEDE Sv (rem)	
Onsite (100 m E)	3.41 E-02	1.45 (145)	5.0 E-02 (5.0)
Hanford Site boundary (18.3 km E)	1.32 E-05	5.6 E-04 (5.6 E-02)	5.0 E-03 (0.5)
Near riverbank (15.0 km E)	1.96 E-05	8.3 E-04 (8.3 E-02)	5.0 E-03 (0.5)

CEDE = committed effective dose equivalent.

The total release calculated for the dropped MCO (300 g) is conservative because it is based on the flowing MCO gas simply entraining, or sweeping up, the particulate matter. This particulate, however, must then be transported upward, within the MCO, for distances ranging from a few inches to more than 4 m (13 ft), to a 2.5-cm- (1.0-in.-) diameter port in the MCO shield plug that has right angle bends and a 0.635-cm- (0.25-in.-) diameter orifice. The particulate matter is assumed, in the above calculation, to be carried along this path out of the MCO. No credit was taken for deentrainment or agglomeration and sedimentation of the particulate ~~during this process~~.

The storage tube and/or MHM confinement volume is a passive confinement system that is vented through a HEPA filter and has a mechanical seal at the bottom of the MHM turret. This confinement system must be in place during an MCO drop accident (the MCO is dropped by the MHM) and any leakage that bypasses the HEPA filter is expected to be less than one percent. Therefore, any release from the MCO can be expected to be further reduced by a factor of 100 because of holdup in the secondary confinement. The particulate is released from the MHM into the CSB atmosphere where dilution and further sedimentation take place before the material leaks out of the building to the environment.

3.4.2.3.4 Comparison to Guidelines. If this accident is not mitigated or prevented by designed safety features, the radiological dose consequence to the onsite receptor 100 m (328 ft) east of the facility is 1.45 Sv (145 rem). The dose to the offsite receptor at the Hanford Site boundary is 5.6×10^{-4} Sv (5.6×10^{-2} rem); and at the near riverbank it is 8.3×10^{-4} Sv (8.3×10^{-2} rem). This dose exceeds that provided in Section 3.3.2.3.2. for the onsite receptor. This warrants safety-significant features to mitigate or prevent the release.

Section 3.3.2.3.2 discusses application of risk-based assessment of accident consequences. If the estimated frequency of the event sequence of the accident can be shown to be low enough, an adequate safety margin relative to the risk acceptance guidelines could be shown. This risk-based approach to

accident analysis is not being applied at this stage of CSB design. However, an assessment of the estimated frequency of crane drops is given here to provide insight into the credibility of the scenario.

Cranes and hoists for the CSB are to conform to the codes and standards addressed in Section 2.5.1-2.4.2. The NRC equivalency review, WHC-SD-SNF-DB-003 (Garvin 1996), has identified ANSI/ANS-57.1-1992, *Design Requirements for Light Water Reactor Fuel Handling System* (ANSI/ANS 1992b), as a design requirement. In addition, as the design of the CSB and its MCO and shipping cask progresses, consideration will be given to specific features that can be included in the handling equipment to decrease the risk of crane failure that could lead to uncontrolled lowering of an MCO or shipping cask. Training and procedures for use of the handling equipment also will be augmented.

However, even with such steps taken to decrease the risk of failure of the MCO and cask handling equipment, this postulated event must be analyzed as a credible event. The risk of crane failure for a crane used in nuclear applications to which improved procedures and training have been applied is from 1.0×10^{-5} to 1.5×10^{-6} per lift (NRC 1980). During normal operations, each MCO will be lifted by the MHM a maximum of three times during transport from the receiving area to the tube for staging, during transport from the tube to hot conditioning, and during transport back to the tube from hot conditioning for interim storage. For a total of 440 MCOs, there would be up to 1,320 lifts before all MCOs are in interim storage. So the potential for dropping an MCO from the MHM is 1.3×10^{-6} to 2.0×10^{-7} for the duration of expected fuel movement operations. For two MCO shipments per day to the CSB (Swenson 1996), the risk of dropping an MCO or shipping cask is from 0.73×10^{-5} to 1.1×10^{-6} per year. While careful design, training, and procedure considerations may significantly reduce this risk, it is not expected that they would reduce the risk to less than 1×10^{-6} per year, the level at which the event could be considered as "beyond extremely unlikely," thereby requiring no analysis.

3.4.2.3.5 Safety-Class Structures, Systems, and Components and Technical Safety Requirements Controls. Reduction of the risk from an MCO release following a drop by the MHM requires safety-significant confinement around the MCO at all times while the MCO is being moved by the MHM. This would require safety-significant design of the MHM, the storage tube and the MHM-tube interface seal for confinement of the release.

~~Because the MCO is designated safety class for its confinement/containment function, it will be designed to sustain credible drops from handling equipment without catastrophic failure. The MCO design must be shown to resist breaching if another MCO is dropped upon it with the bottom impact absorber in place. The impact absorber is designated safety class.~~

The tube also is credited for a safety-class function to protect the MCO. Therefore, the tube design must also be shown to withstand, without breaching, the uncontrolled drop of an MCO into it.

The MCO has a safety-class function for ~~containment-confinement~~ of the SNF. Safety-class features are incorporated into the CSB design to maintain this function during credible accidents. Design analysis, ~~to be included in~~

HNF-SD-SNF-SARR-005 (Lorenz 1997) the MCO Topical Report, shows that the impact limiter absorber at the bottom of the tube will prevent catastrophic failure both of an MCO dropped to the bottom of the tube and of both MCOs if one is dropped into the tube with another already in place. The impact limiter absorber at the bottom of the tube must therefore be designated safety class for protection of the structural integrity of the MCO.

A second impact limiter absorber will be placed between the two MCOs. This impact limiter absorber is needed to protect the functioning of the pressure relief devices on the lower MCO and to prevent internal damage to the top MCO. The unfiltered pressure relief path provides a safety-class function to protect the MCO from catastrophic failure from excessive internal pressure. Therefore, the impact limiter absorber between the MCOs provides a safety-class function insofar as it protects against failure of the unfiltered pressure relief device to relieve MCO internal pressure.

MCO design will verify that dropping the MCO from the MHM to the operating area floor cannot occur must be prevented by safety class inter mechanical locks to prevent MHM travel when the turret is not positioned properly to enclose the MCO.

3.4.2.4 Hydrogen Gas Combustion. The MCO design, the conditioning processes, and the CSB design and processes will incorporate design features to reduce the potential for hydrogen combustion events in the CSB to the "beyond extremely unlikely" frequency category defined in DOE-STD-3009-94. Hydrogen combustion inside the MCO must be prevented to protect the safety-class functions of the MCO for containment of fuel containing the fuel and for maintenance of maintaining the fuel in a configuration that is shown to not support nuclear criticality.

Hydrogen gas will be produced in the MCO from the corrosion of uranium, radiolysis of water, and degradation of uranium hydride. The primary source of hydrogen in the MCO is water, which may be present as free water, water of hydration associated with oxides, or water that is chemically adsorbed on surfaces. Both fuel cleaning before packing into the MCO and the cold vacuum drying process are designed to limit the available water in the MCO before it the MCO is shipped to the CSB. The Hot conditioning process will remove additional water and hydrogen before the fuel is placed in interim storage.

The amount of water that remains in the MCO following cold vacuum drying and, to a lesser extent, following hot conditioning cannot be quantified accurately determined. Therefore, it must be assumed that hydrogen concentrations in the MCO atmosphere will increase during staging and again during interim storage. To avoid the potential for hydrogen combustion, the design must be shown to prevent the presence of oxygen in the MCO atmosphere in quantities that would support a sustained combustion reaction.

In addition to hydrogen, oxygen gas will be produced in the MCO by radiolysis of water. To prevent the MCO atmosphere from attaining a flammable mixture of hydrogen and oxygen, it will be shown by analysis that the oxygen gas will be removed from the atmosphere by reaction with the fuel surface available in the MCO, or by compounds or substrates added to the MCO for that purpose.

Hydrogen combustion events in the CSB have been postulated to occur whenever the MCO atmosphere has been isolated long enough that hazardous quantities of hydrogen may exist providing if the MCO containment is breached and the MCO atmosphere can mix with air, either inside the MCO or outside the MCO in the service enclosure, the MHM, or the tube. Prevention of flammable mixtures will be accomplished by purging and refilling the MCO with inert gas during receiving and by maintaining inert atmospheres around the MCO during staging, in the MHM during transport to hot conditioning, and during interim storage. This ensures that, under accident conditions, the MCO will exchange gases only with an environment deficient in oxygen. Criteria for acceptance of an MCO into the CSB will include evidence that the pressurization rate at the end of cold vacuum drying is low enough that, combined with controls on transportation time and conditions, MCO pressure will be low enough to prevent release of hydrogen into uninerted atmospheres before the MCO is placed in staging.

CSB systems to ensure adequate purging with inert gas during servicing, and maintenance of inert atmosphere during handling, staging, and interim storage would therefore be designated safety class. These systems include the storage tubes and tube plugs, MHM inert gas purge system, and some features of the tube vent and purge carts.

3.4.2.5 Multiple Multicanister Overpack-Tube Failures during Staging or Interim Storage. The CSB storage vault will be designed in such a way that natural air circulation will maintain MCO temperatures low enough to prevent failure. Unacceptably high temperatures could result in pressurization, and subsequent breach, of the sealed MCOs from gas expansion and accelerated gas generation from chemical reactions.

3.4.2.5.1 Scenario Development. Debris from high winds, or snow, frost, or ashfall accumulations, plug the inlet or outlet to the vault cooling plenums, or. Also, an external fire (e.g., range fire) could impact natural circulation cooling. The natural airflow is hampered or completely stopped. The MCOs begin to heat up and may reach a temperature at which chemical reactions of the fuel are accelerated. The product gases of the reactions, as well as the temperature increase, cause increased internal pressure in the vessel. Eventually one or more MCOs relieve pressure through the pressure relief device. The MCO gases vent to the storage tube and ultimately to the operating deck. Ultimately, the tube may also pressurize and breach, releasing the gases to the vault.

3.4.2.5.2 Source Term Development. This is an accident scenario in which a single event could lead to releases from multiple MCOs. During staging, the MCOs will be provided with a filtered pressure relief valve that will allow excess MCO gases to be released to the storage tubes. Both MCO and tube will be filled initially with inert gas. The MCOs will contain bound water that would be released at elevated temperatures, as well as residual free water that would vaporize. The water reacting with the fuel would increase temperatures further. Because the MCO is provided with pressure relief designed to prevent MCO overpressurization resulting in MCO breach would not occur. However, the gases would pressurize the tube and the tube could fail. The tube plug is also equipped with pressure relief designed to prevent tube failure.

During interim storage, the fuel in the MCO will be covered with an inert gas and the MCO will be sealed with only a rupture disk provided with one or more rupture disks for pressure relief. The storage tube will contain inert gas. The hot conditioning process will have removed both bound and free water and covered free metal surfaces with a nonreactive oxide layer. Therefore, the potential for accelerating chemical reactions is less during the interim storage phase.

An additional hazard from extended loss of cooling is the heatup of the vault walls to a temperature that would compromise their structural strength. Design calculations (FDI 1996, Calculation CSB-HV-0003) have shown that the maximum wall temperature, if cooling is lost, does not exceed the allowable limit for structural concrete.

The rate of MCO temperature increase and the maximum MCO fuel temperature that could be reached if vault cooling natural circulation flow through the vault is lost or reduced are still being assessed (FDI 1996, Calculation CSB-HV-0003). Table 3-13 shows the results of these analyses. The calculations show that loss or degradation of airflow to the vault result in MCO temperatures below the design limits. Additional calculations are in progress to determine that MCO integrity will not be challenged on the basis of fuel temperature (runaway fuel reactions) and that a radioactive and/or hydrogen release to the tubes and operating deck from simultaneous pressurization of multiple MCOs is not a credible event.

Table 3-13. 72-Hour Temperature Changes Due to Flow Blockage in the Canister Storage Building Vault (HV-003).

	Initial temperature	25% blockage	100% blockage	No blockage, no stack, no inlet
Maximum air temperature	145 °F	164 °F	244 °F	157 °F
MCO temperature (skin)	252 °F	268 °F	328	262 °F
Maximum tube temperature	204 °F	223 °F	290	216 °F
Maximum concrete temperature	132 °F	151 °F	228	144 °F

MCO = multiccanister overpack.

If it is determined that fuel temperatures could exceed 300 °C (572 °F) if passive cooling is lost, controls to ensure that adequate natural ventilation flow is maintained will be established. This measure of sensitivity of the MCO cooling to natural circulation flow will also allow for an assessment of the sensitivity of MCO cooling to range fires. The effects of a runaway fuel corrosion reaction under worst-case MCO reactivity and water inventory assumptions are calculated in HNF-SD-SNF-CN-005, *Bounding Temperatures and Gas Generation Rates during CSB Staging* (Thurgood 1997). The calculation is based on an assumption that only the water in the scrap basket is involved in the fuel reaction. In the analysis the reaction occurred at

summer staging temperatures without an initiating accident. However, the calculation shows that if a runaway reaction occurs, unsafe temperatures in the fuel and MCO are not credible. The reaction is limited by the depletion of water as a reactant. Therefore protecting the MCO and fuel from the effects of a runaway reaction does not depend on special measures in the event that passive cooling is lost.

3.4.3 Beyond Design Basis Accidents

Those events that are beyond the current design basis of the facility are not analyzed in detail at this time. They will be addressed in the final SAR as required by Section 3.4.3 of DOE-STD-3009-94. These beyond design basis accidents may include, but are not limited to, (1) spontaneous breach of an MCO during staging or interim storage, (2) fuel ignition events, (3) hydrogen combustion events, (4) collapse of the building's superstructure as a result of human-generated external events (e.g., crash of a light airplane) or natural phenomena (e.g., tornado and tornado-generated missiles, high winds, earthquake, or snow or ashfall loading of the roof), (5) potential failure of multiple MCOs (e.g., as a result of a seismic event), and (6) failure of identified safety-class accident prevention and mitigation features.

The MCO safety-class design must preclude the potential for rupture of the MCO under normal staging and interim storage conditions. The potential for MCO breach caused by internal pressure from chemically generated gases has been discussed in Section 3.4.2.1. Functioning of safety-class SSCs designed to protect the confinement/~~containment~~ function of the MCO ~~throughout the process~~ will prevent placing a damaged MCO in staging or interim storage.

The potential for fuel ignition, or runaway fuel oxidation, will be precluded by ~~process~~ design. This will be accomplished by limiting access of oxidants to the fuel. Some water will remain in the MCO after each step ~~throughout the process~~, but this is limited to residual free water after cold vacuum drying and the bound water associated with the oxides. After hot conditioning, ~~all residual free water and most of the bound water is assumed to have been reacted will be further reduced.~~ Any remaining water would be chemically bound water associated with oxides, and surface adsorbed water, too strongly bounded to be removed at hot conditioning temperatures. This water is not expected to be released from the fuel matrix at interim storage temperatures and therefore is expected to remain unavailable to support oxidation. ~~These amounts of water would be insufficient to support a runaway reaction.~~

Uranium fuel will theoretically burn in ambient air at room temperatures, because of the presence of hydrides. Limiting air availability to the fuel precludes the air-fuel reaction. The primary design feature to limit air availability to the fuel is the MCO, and commitment to protect the MCO confinement/~~containment~~ function except for rupture disk relief and potential breach of ~~process~~ lines. Preliminary analysis indicates that air ingress through small penetrations (maximum of two 2.5-cm [1-in.] penetrations), will not support ignition. Final analysis to confirm this conclusion with current MCO design and a range of MCO loading configurations is currently in progress.

Maintaining an inert atmosphere in the MCO and in the MHM and tube contributes additional assurance that enough oxidant to support fuel burning will not be present.

The vault, tubes, and operating deck floor are designed to withstand all the design basis external loading from human-generated or natural phenomenon events. Superstructure collapse from these events would therefore affect only those MCOs (one or two) in the servicing area or in the MHM at the time of the event. The safety-class SSCs that mitigate or prevent releases from the building, discussed in the other accidents, would presumably also be damaged by the building's collapse. If collapse of the superstructure while MCOs are in service or being handled above the operating deck could result in exceeding offsite dose limits, the structure must also be designed to safety-class standards.

3.4.4 Safety-Class Design Features

The accident analyses identified requirements for safety-class or safety-significant mitigation or prevention of MCO overpressurization events, and all MCO failure events. SSCs to mitigate or prevent the accidents have been suggested.

In the case of MCO overpressurization, the service station ventilation enclosure, the MHM, the storage tube, and MHM-tube interface seal ~~would be designed have been designated~~ safety significant for confinement of the overpressure release. The storage tube, the MHM, and MHM-tube interface seal must also be safety significant for mitigation of crane drop events.

MCO failure events ~~would be~~ are prevented by safety-class systems to protect the confinement function of the MCO. Interlocks on the MHM to prevent applying force to the MCO while it is partway in the tube, an MHM brake or locking device to prevent MCO shear during a seismic event, and impact absorbers at the bottom of the tube ~~would be~~ are safety-class SSCs.

Design features put in place to prevent a hydrogen deflagration in the service area, tube, or MHM need to be safety class. Releases from a hydrogen deflagration event in the service area ~~would be~~ are prevented by a safety-class system to sample the cask atmosphere before removing the cask lid ~~MCO atmosphere before removing the MCO flanges~~. Deflagration in the MHM or tube ~~would will~~ be prevented by safety-class MHM and tube inerting systems.

Safety-class and safety-significant design features identified by the accident analyses are summarized in Table 3-14.

3.5 REFERENCES

10 CFR 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," *Code of Federal Regulations*, as amended.

10 CFR 835, "Occupational Radiation Protection," *Code of Federal Regulations*, as amended.

Table 3-14. ~~Preliminary List of~~ Safety-Class and Safety-Significant Structures, Systems, and Components Required by Accident Analysis for the Canister Storage Building. (2 sheets)

Structure, system or component	Safety function	Referenced accident analysis	Safety classification
MCO	Confinement of releases	Important to safety designation as defined in Section 3.3.2.3.2	Safety class
Service station ventilation enclosure	Maintain a negative pressure with respect to the surrounding atmosphere for confinement of releases	3.4.2.1 Release of MCO Gases Under Pressure during Handling, Staging, or Interim Storage	Safety significant
Storage tubes and tube plugs	Confinement of releases	3.4.2.1 Release of MCO Gases Under Pressure during Handling, Staging, or Interim Storage 3.4.2.3 MCO Failure-Damage during Handling - Crane-MCO Drop Accident	Safety significant
	Ensure tube atmosphere remains nonflammable	3.4.2.4 Hydrogen Gas Combustion	Safety class
	Protection of MCO	3.4.2.3 MCO Damage during Handling - MCO Drop Accident	Safety class
MHM	Confinement of releases	3.4.2.1 Release of MCO Gases Under Pressure during Handling, Staging, or Interim Storage 3.4.2.3 MCO Failure-Damage during Handling - Crane-MCO Drop Accident	Safety significant
MHM-tube seal	Confinement of releases	3.4.2.1 Release of MCO Gases Under Pressure during Handling, Staging, or Interim Storage 3.4.2.3 MCO Failure-Damage during Handling - Crane-MCO Drop Accident	Safety significant
MHM inert gas purge	Ensure the MHM atmosphere remains nonflammable	3.4.2.4 Hydrogen Gas Combustion	Safety class
MHM interlocks	Prevent inadvertent MHM motion while the MCO is being inserted into or withdrawn from a tube; protect MCO	3.4.2.2 Single-MCO Failure Damage during Handling - Shear of an MCO Lateral Forces	Safety class
	Prevent MHM travel when turret is not positioned so that the MCO enclosure is closed; protect MCO and operating deck	3.4.2.3 MCO Failure during Handling - Crane Drop	Safety class
MHM brake or locking device	Prevent MCO shearing during a seismic event	3.4.2.2 Single-MCO Failure Damage during Handling - Shear of an MCO Lateral Forces	Safety class
Impact absorber at bottom of tube	Prevent catastrophic failure of MCO if MCO is dropped to the bottom of the tube; protect MCO confinement function	3.4.2.3 MCO Failure-Damage during Handling - Crane-MCO Drop Accident	Safety class
	Prevent failure of both MCOs if one MCO is dropped on another; protect MCO		

Table 3-14. ~~Preliminary List of Safety-Class and Safety-Significant Structures, Systems, and Components Required by Accident Analysis for the Canister Storage Building. (2 sheets)~~

Structure, system or component	Safety function	Referenced accident analysis	Safety classification
Impact absorber between MCOs	Protect against failure of the unfiltered pressure relief path on the bottom MCO to relieve MCO internal pressure	3.4.2.3 MCO Failure-Damage during Handling - Crane-MCO Drop Accident	Safety class
Tube vent and purge carts	Ensure the tube atmosphere remains nonflammable Confinement of releases	3.4.2.4 Hydrogen Gas Combustion 3.4.2.1 Release of MCO Gases Under Pressure during Handling, Staging, or Interim Storage 3.4.2.3 MCO Failure-Damage during Handling - Crane-MCO Drop Accident	Safety class Safety significant
MCO-atmosphere-Cask pressure measurement device-sampling-system	Ensure a flammable condition is not created when cask lid is removed-and MCO-flanges are-removed	3.4.2.4 Hydrogen Gas Combustion	Safety class

MCO = multicanister overpack.

MHM = multicanister overpack handling machine.

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4.0 SAFETY STRUCTURES, SYSTEMS, AND COMPONENTS

4.1 INTRODUCTION

Fluor Daniel, Incorporated, the architect-engineer, has designed the CSB using a safety classification for SSCs based on Chapter 9.0, Revision 1, of WHC-CM-4-46, *Safety Analysis Manual*. A graded approach has been used based on the potential accident for unmitigated consequences. The mitigating features for SSCs are designated as safety class 1, 2, or 3 based on their safety functions for the prevention or mitigation of potential accidents. In general, safety class 1 SSCs are those items required for protection of the offsite environment and the public. Safety class 1 SSCs include those items designated as safety class in accordance with DOE Order 6430.1A, *General Design Criteria*. Safety class 1 SSCs also encompass all of the items that are designated as "important to safety" in accordance with Title 10, *Code of Federal Regulations*, Section 72.3 (10 CFR 72), as implemented through 10 CFR 72.106. Safety class 2 items are those SSCs required for the protection of onsite personnel not directly involved in the facility operations. Safety class 3 items are those SSCs required for protection of the facility worker other than those required for industrial safety protection. Items that do not perform a safety function other than industrial safety are designated safety class 4, or non-safety class. Non-safety class is a term used in WHC-CM-4-46, Chapter 9.0, Revision 1, for items that serve no safety purpose.

While the CSB design was being developed, WHC-CM-4-46 was revised to reflect the safety classification methodology presented in DOE-STD-3009-94, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports*. In Revision 2 of WHC-CM-4-46, SSCs are identified as safety class and safety significant as applicable for the protection of offsite public and onsite workers respectively. WHC-CM-4-46 provides a correlation of the previous safety-class designations with the new designations. Items that were previously designated as safety class 1 are safety class with the exception of those SSCs whose safety function is prevention or mitigation of toxic chemical exposures. Items previously designated as safety class 2 or 3 and those required to mitigate exposure or prevent overexposure to toxic chemicals are safety significant. A correlation for the various sections is shown in Table 4-1.

The CSB project was granted a waiver from immediate implementation of the safety classification scheme in Revision 2 to WHC-CM-4-46, Section 9.0. The design description in CSB safety documentation has been developed consistent with the safety classifications established for the design. The waiver states that the CSB SAR will implement Revision 2 of WHC-CM-4-46 by June 1997. The final SAR for the CSB will fully implement the current safety classification designations.

4.2 REQUIREMENTS

This section lists the design codes, standards, regulations, and DOE orders that are required for establishing the safety basis of the facility. The intent is to provide only the requirements that are specific for this chapter and pertinent to the safety basis.

Table 4-1. Canister Storage Building Safety Classification.

DOE Order 6430.1A	WHC-CN-4-46 Current revision Chapter 3	WHC-CN-4-46 Revision 1 Chapters 2 and 4	10 CFR 72
Safety class	Safety class >0.5 at Site boundary	Safety class 1 > 0.5 rem at Site boundary	Important to safety > 5 rem at controlled area maintain condition for safe storage
Not safety class	Safety significant > 5 rem at 100 m • fatality or protection of large number of facility workers (not industrial safety)	Safety class 2 > 5 rem at 100 m Safety class 3 facility worker safety	Not important to safety
Not safety class	Not safety related	Safety class 4 Not safety related (non-safety class)	Not important to safety

Notes: Waiver for Canister Storage Building to use previous revision WHC-CN-4-46 expires June 1997.
 Safety class and safety significant are used to set quality assurance requirements and to select applicable codes and standards.

4.2.1 U.S. Department of Energy Orders and Standards

The following DOE orders and standards are applicable to the safety basis for the facility.

- DOE Order 6430.1A, 1989, *General Design Criteria*. Division 1300-3, "Safety Class Criteria," provides design, fabrication, and testing standards for safety-class items.
- DOE Order 5480.28, 1993, *Natural Phenomena Hazards Mitigation*. This order establishes mitigation requirements for NPHs and target probabilistic performance goals based on the facility performance category. Additional discussion of the NPH performance criteria is provided in Section 1.5.
- DOE-STD-1020-94, 1994, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*. This standard provides the methodology for design of the CSB for NPHs.
- DOE-RL-HPS-SDC-4.1, Revision 12, 1993, *Standard Architectural-Civil Design Criteria, Design Loads for Facilities*. This Hanford Site plant standard provides criteria for the design of the below-grade portion of the CSB. This document is invoked by WHC-S-0425, *Performance Specification for the Spent Nuclear Fuel Canister Storage Building* (Swenson 1996). Section 3.1 and Section 3.3 of this standard provide structural design criteria loads and load combinations for safety class 1 SSCs. These include nominal [sic] dead, live, snow, and soil loads; normal operating loads; and natural phenomena loading of extreme wind, earthquake, ashfall, and flood. The facility design has been evaluated for applicable natural phenomena loads listed on Table 1-23 of Section 1.5, "Natural Phenomena Threats," for the SSCs impacted. These loads are

higher than DOE-RL-HPS-SDC-4.1 loads, particularly those associated with tornado wind and PMP effects. For example, the tornado wind speed from Table 1-23 is given as 322 km/h (200 mi/h) total, versus the DOE-RL-HPS-SDC-4.1 reactor tornado wind speed of 282 km/h (175 mi/h). This higher wind speed on the superstructure transmits higher loads to the below-grade portion of the CSB.

4.2.2 U.S. Nuclear Regulatory Commission Rules and Guidance

The following NRC rule and guidance is applicable to the safety basis for the facility.

- 10 CFR 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," *Code of Federal Regulations*. The design bases for items identified as important to safety must reflect appropriate combinations of the effects of normal and accident conditions and the effects of natural phenomena. This is implemented by the application of the design criteria for safety-class items in DOE Order 6430.1A to those items identified as important to safety. Applying NRC equivalency requires that SSCs important to safety be identified in accordance with 10 CFR 72.3, as implemented through 10 CFR 72.106. Once SSCs important to safety have been identified, the requirements of safety-class (safety class 1) SSCs are imposed on them as defined in WHC-SD-SNF-DB-003, *Spent Nuclear Fuel Project Path Forward, Additional NRC Requirements* (Garvin 1996a). Revision 1 of WHC-CM 4-46, *Safety Analysis Manual*, Chapter 9-0, "Safety Classification of Structures, Systems, and Components." Additional discussion of the NRC criteria for mitigation of natural phenomena is provided in Section 1.2.3. An evaluation of the application of NRC equivalency requirements to the CSB is given in Letter 9652883 SNF CSB Application of NRC Equivalency Criteria (Bazin et al. 1996b), PDF 012, SNF CSB NRC Equivalency Evaluation (Bedell 1996b).
- NRC Regulatory Guide 1.26, 1976, *Quality Group Classifications and Standards for Water-, Steam-, and Radioactive Waste-Containing Components of Nuclear Power Plants*. This regulatory guide is invoked by WHC-SD-SNF-DB-003 (Garvin 1996a). For the CSB, it is used to assist in assigning the appropriate code class to systems and components designed to the *Boiler and Pressure Vessel Code* (ASME 1995a), Section III.
- NUREG-0800, 1987, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants*. This plan is used in WHC-SD-SNF-DB-009, *Canister Storage Building Natural Phenomena Hazards* (Tallman 1996), to establish probabilistic risk assessment techniques for tornado-generated missile protection of specific targets.
- NUREG-0554, 1979, *Single Failure Proof Cranes for Nuclear Power Plants*.

4.2.3 Industry Consensus Standards and Other Documentation

The following industry standard is applicable to the safety basis for the facility.

- ANSI/ANS-57.9-1992, 1992, *Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)*. The standard includes requirements for the design of major buildings and structures including physical security and safety features for ISFSIs. The architect-engineer has performed an assessment of ANSI/ANS-57.9-1992 (ANSI/ANS 1992a) requirements that are not included in the CSB design have been assessed. A complete list and justification is provided in Letter FRF-2792, ANSI 57.9 (Jacobs 1996a). The 5% dead load contingency has been included in the design of the CSB.
- ANSI/ACI 349-85, 1985, *Code Requirements for Nuclear Safety Related Concrete Structures*. The requirements of ANSI/ACI 349-85 (ANSI/ACI 1985) were applied to the design of safety class 1 and 2 reinforced concrete structures.
- ANSI/AISC N690-94, 1994, *Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities*. ANSI/AISC N690-94 (ANSI/AISC 1994) provides specifications that were applied to the design of safety class 1 and 2 steel structures.
- ANSI/ASME N509-1989, 1989, *Nuclear Power Plant Air Cleaning Units and Components New Construction and Modification Only*, and ANSI/ASME N510-1989, 1989, *Testing of Nuclear Air-Cleaning Systems*. These two standards govern the design of HEPA filter enclosures.
- ANSI/ANS-57.1-1992, 1992, *Design Requirements for Light Water Reactor Fuel Handling System*. ANSI/ANS-57.1-1992 (ANSI/ANS 1992b) provides requirements for lifting.
- ASCE-4-86, 1986, *Seismic Analysis of Safety-Related Nuclear Structures and Commentary on Standard for Seismic Analysis of Safety-Related Nuclear Structures*. ASCE-4-86 (ASCE 1986) provides acceptable methods for seismic analysis, which were used for analysis of safety class 1 and 2 structures.
- ASCE-7-95, 1995, *Minimum Design Loads for Building and Other Structures*. ASCE-7-95 (ASCE 1995) provides material loads and minimum dead, live, snow, and wind loads. This standard is used in the design basis document, *SNF Canister Storage Building* (Bedell 1996), for combinations of dead, live, wind, rain, and snow loads as required by DOE-RL-HPS-SDC-4.1.
- ASME B30.20-1993, 1993, *Below-the-Hook Lifting Devices*. ASME B30.20-1993 (ASME 1993a) provides requirements for the design and fabrication of lifting devices that attach to a crane lifting hook. This specification is used to establish the requirements for the receiving crane transport cask lifting yoke and the MMH's MCQ and shield plug grapples. This specification also is used for

seismic analysis and design of the MHM and receiving crane. ~~provides requirements for the design, fabrication, and erection of overhead cranes used in nuclear facilities. This specification is used to establish the requirements for the receiving crane and the MHM crane gantry and hoists.~~

- ~~ASME, 1995. *Boiler and Pressure Vessel Code*. The configuration, material design details, attachments, and connections for tanks, vessels, heat exchangers, and other items that contain fluids at pressures of 103 kPa gauge (15 lb/in² gauge) or more will be in accordance with the requirements of Section VIII, Division 1 of the Boiler and Pressure Vessel Code (ASME 1995). Safety class (safety class 1) vessels that contain fluids at pressures of 103 kPa gauge (15 lb/in² gauge) or more will be designed in accordance with the requirements of Section III, Class 3, of the Boiler and Pressure Vessel Code.~~
- ~~ASME NOG-1-1995/89, 1989, 1995. *Rules for the Construction of Overhead and Gantry Cranes*. ASME NOG-1-89 (ASME 1989) 1995 (ASME 1995c) provides requirements for the design, fabrication, and erection of overhead cranes used in nuclear facilities. This specification is used to establish the requirements for the receiving crane and the MHM crane gantry and hoists. ~~provides requirements for the design and fabrication of lifting devices that attach to a crane lifting hook. This specification is used to establish the requirements for the receiving crane transport cask lifting yoke and the MHM's MCO and shield plug grapples. This specification is also used for seismic analysis and design of the MHM and receiving crane.~~~~

4.2.4 Hanford Site Requirements

The following Hanford Site standards are applicable to the safety analysis.

- WHC-CM-4-46, *Safety Analysis Manual*, Revision 1, as modified by Letter 96-SFD-318, Contract No. DE-AC06-96RL13200: *Proposed Spent Nuclear Fuel Project Division (SFD) Risk Acceptance Guidelines (RAGs)* (Sellers 1996). Chapter 9.0 of WHC-CM-4-46 identifies the methodology for determining the safety classification of SSCs and the applicable design criteria. The safety class 1 requirements in Chapter 9.0 of WHC-CM-4-46 implement the criteria established in DOE Order 6430.1A for safety-class items and the requirements for 10 CFR 72 important-to-safety SSCs. The CSB SAR was originally written under a waiver to Chapter 9.0, Revision 2, of WHC-CM-4-46. The current revision of the SAR has begun incorporating the safety class/safety significant terminology of Revision 2. Both sets of terminology are used in the text of this chapter.
- ~~WHC-SD-SNF-DB-003, *Spent Nuclear Fuel Project Path Forward. Additional NRC Requirements*. WHC-SD-SNF-DB-003 (Garvin 1996a) provides guidance on the use of NRC equivalency. The major additional NRC equivalency items related to the CSB design and~~

construction are the seismic criteria contained in WHC-SD-SNF-DB-004, *Spent Nuclear Fuel Project Seismic Design Criteria, NRC Equivalency Evaluation Report* (Garvin 1996b). The other natural phenomena hazards that are required from WHC-SD-SNF-DB-003 (Garvin 1996a) are contained in WHC-SD-SNF-DB-009 (Tallman 1996). Other major additions to design caused by the additional NRC requirements are the use of ANSI/ANS-57.9-1992 (ANSI/ANS 1992a) for the application of 5% dead load contingency and the use of ANSI/ANS-57.1-1992 (ANSI/ANS 1992b) for lifting requirements for the receiving crane and MHM.

- WHC-SD-SNF-DB-004, 1996, *Spent Nuclear Fuel Project Seismic Design Criteria, NRC Equivalency Evaluation Report*. WHC-SD-SNF-DB-004 (Garvin 1996b) provides seismic design criteria the basis for the SNF's Project decision and justification that the criteria of DOE Order 5480.28 and its implementing standards, and the resulting performance category 3, provide adequate seismic design safety.
- WHC-SD-SNF-DB-009, 1996, *Canister Storage Building Natural Phenomena Hazards*. WHC-SD-SNF-DB-009 (Tallman 1996) supplements loads for use in the design and construction of the CSB. With the exception of seismic criteria, the compliance to both NRC and DOE requirements is accomplished with this document.

- WHC-S-0425, *Performance Specification for the Spent Nuclear Fuel Canister Storage Building*. WHC-S-0425 (Swenson 1996) requires that the CSB implement the spectra given in DOE-RI-HPS-SDC-4.1 in designing the facility for a DBE. Earthquake time histories for the safety class 1 DBE may be used to satisfy these loading requirements for design and analysis of safety class 1 (safety class) nonreactor nuclear systems and components as defined in DOE-RI-HPS-SDC-4.1. Safety class 2 (safety-significant) items shall be designed to withstand wind loading and wind-generated missiles according to DOE-RI-HPS-SDC-4.1. Features necessary to protect the offsite and onsite personnel shall be designed to withstand design basis wind and missiles, with the criteria for high-hazard usage applicable to safety class 1 (safety-class) items and moderate hazard usage applicable to safety class 2 (safety-significant) items.

4.2.5 Fluor Daniel, Incorporated, Requirements

- FRP-112, 1996, *SNF Canister Storage Building*. FRP-112 (Bedell 1996) provides information on the design intent, the design methods, and the functions to be performed by systems with the CSB, including the HCS Annex. The Design Basis Document supplements the SNF CSB Performance Specification (Swenson 1996) and provides more detail.

4.3 SAFETY-CLASS STRUCTURES, SYSTEMS, AND COMPONENTS

The safety-class (safety class 1) SSCs for below-grade and at-grade reinforced concrete structures are described in Sections 4.3.1 through 4.3.43 to provide an understanding of the safety function and the suitability of the

safety analysis inputs and assumptions. These safety-class (safety class 1) SSCs prevent and mitigate the potential offsite overexposures as a consequence of the postulated accidents summarized in Chapter 3.0. The safety-class (safety class 1) SSCs of the operating deck associated equipment are described in Sections 4.3.54 through 4.3.85. Structural drawings of the CSB can be found in Appendix 4A.

The safety-class (safety class 1) SSCs are summarized in Table 4-21 for the below-grade and at-grade reinforced concrete structures and in Table 4-32 for the operating deck-associated equipment. These items are considered important to safety in accordance with 10 CFR 72. These safety-class (safety class 1) items are designated as safety class 1 in accordance with Revision 1 of WHC CM 4-46, *Safety Analysis Manual*. WHC CM 4-46 requires that safety class 1 SSCs be designed to the criteria of DOE Order 6430.1A and DOE-RL-HPS-SDC-4.1 for loads that apply to the postulated accident criteria. WHC CM 4-46 also requires that safety class 1 SSCs also meet the single failure criteria of DOE Order 6430.1A, Section 1300-3.3. The remaining subsections provide details that expand upon the summary presentation in the table.

4.3.1 Canister Storage Building Subsurface Structure

4.3.1.1 Safety Function. The CSB will contain MCOs in the below-grade space described in Chapter 2.0 as CSB vault 1. Catastrophic failure of a single MCO could result in consequences over the safety-class (safety class 1) guidelines. The CSB is designed to prevent failure of MCOs from NRC equivalency design criteria NPH and DBA events and to maintain the MCOs below the design fuel centerline temperature. The potential consequences of an unmitigated release from the inventory at risk in the CSB were evaluated in Section 5.3 of WHC-SD-SNF-HC-007, *Hazard Category Analysis for the Canister Storage Building* (Kummerer 1995). Breach of a significant number of the MCOs could result in offsite consequences greater than the safety-class (safety class 1) guideline. The CSB substructure is designed to prevent failure of the MCOs during the DBAs and NPHs given in Chapter 3.0 and to maintain the SNF in a subcritical geometry.

4.3.1.2 System Description. The concrete base slab, exterior and interior walls, and air intake and exhaust plenums are safety-class (safety class 1) features of the CSB. These items provide protection from all applicable NPH and DBA events for the 220 tubes containing MCOs in vault 1 (and for the 6 overpack tubes that may eventually contain overpacked MCOs) and provide an integral part of the convective cooling system needed air flow to maintain the MCOs below the design fuel centerline temperature.

4.3.1.3 Functional Requirements. The reinforced concrete structures have been designed to withstand all applicable NPH and DBA events to the extent required to ensure that the MCOs and the storage tubes are not damaged. The applicable NPH and DBA events are the natural phenomena established for safety-class (safety class 1) SSCs as discussed in Section 1.5.

Table 4-21. Safety-Class Structures, Systems, and Components of the Below-Grade and At-Grade Reinforced Concrete Portion of the Canister Storage Building.

Safety-class SSC	Safety function	Functional requirements	Performance criteria (TSR applicability)
Subsurface structure (concrete walls and base slab)	Prevent common cause failure of multiple MCOs	Withstand applicable NPHs and DBAs to extent required to prevent multiple MCO failures	To be developed Not applicable
Air intake and exhaust plenums	Provide enclosure for convective cooling of MCOs	Prevent overheating and failure of multiple MCOs	To be developed Not applicable
Carbon steel base slab embeds	Provide anchor point for seismic restraints for tubes	Prevent failure of one or more tubes and failure of one or more MCOs	Not applicable
Operating deck structure	Provide seismic restraint for storage tubes <u>Maintain structural integrity of CSS</u>	Prevent failure of one or more storage tubes and failure of one or more MCOs during all applicable NPH and DBA events	Not applicable
Intake structure and exhaust stack bases	Provide cooling passages to intake and exhaust plenums for MCO convective cooling; provide attachment of exhaust stack and intake structure inlet cruciform	Prevent loss of convective cooling air flow; prevent overheating and failure of multiple MCOs	To be determined Not applicable
Hot Conditioning System Annex	Maintain structural integrity of deck, vault, and operating shelter Maintain structural integrity of MCS equipment and MCO Provide location for hot conditioning of SNF to reduce probability of overpressurization of MCOs	Withstand loadings associated with NPHs and DBAs Allow hot conditioning in CSS operating area without jeopardizing other CSS superstructure functions	Not applicable Settlement measurement plan in force
Load-in/load-out area	Maintain structural integrity of deck, vault, and operating shelter Maintain structural integrity of MCS equipment and MCO Provide location for receipt and transfer of MCO	Withstand loadings associated with NPHs and DBAs Maintain confinement of MCOs and provide continuity of superstructure functions	Not applicable Ensure cask pedestal is in place
Support building foundation* (3-over-12)	Provide safe location for CSS operation and support	Prevent failure of safety class 2 and safety class 3 items that could cause from causing failure of the safety class (safety class 1) deck and vault* or of 3-over-12 designed superstructure	Not applicable

*The support building foundation is not designated a safety-class SSC, but it has been designed to safety-class standards. Safety-class design ensures that foundation failure will not occur and will not prevent safety-class items from adequately performing their safety functions. A 3-over-12 designation means that a safety-class 3 item is designed to not fail and thereby cause a safety-class 1 item not to adequately perform its safety function. For example, design of a safety-class 3 item to not fail under the safety-class 1 design basis earthquake requires a safety-class 1 design feature.

CSB = Canister Storage Building.
DBA = design basis accident.
MCO = multicanister overpack.
NPH = natural phenomena hazard.
SSC = structure, system, and component.
TSR = technical safety requirement.

Table 4-32. Safety-Class Structures, Systems, and Components of the Canister Storage Building Operating Deck.

Safety-class SSC	Safety function	Functional requirements	Performance criteria (TSR applicability)
Tube vent and purge cart	Ensure the tube atmosphere remains nonflammable Maintain hydrogen concentration levels below LEL	Withstand applicable NPHs and DBAs to extent required to prevent MCO failures by precluding air ingress	Hydrogen monitoring system must be operational before evacuating a storage tube Not applicable
Bottom impact absorbers (included in storage tube system)	Prevent failure of MCO and tube due to dropped MCO (bottom absorber) Prevent failure of relief devices on bottom MCO (intermediate absorber)	Absorb energy from drop of a single MCO onto bottom of empty tube (bottom absorber) or onto second MCO (intermediate absorber)	Ensure correct placement of impact absorbers Design verification testing (35 ft/sec) of MCO drop - 750 lb/in ² loads to tube wall
Carbon-steel Storage tube assemblies (standard storage tubes, bases, and bellows, and tube plugs)	Prevent common cause failure of an MCO Preclude loss of inert gas to the extent that air ingress is precluded	Withstand applicable NPHs and DBAs to the extent required to prevent MCO failure Maintain inert gas atmosphere	Not applicable Each tube must have an impact absorber in place before placement of an MCO in that tube Ensure tube lock down devices are in place Acceptable relief valve testing to be developed Acceptable tube plug seal leak rate to be determined
MCO	Confinement	Withstand applicable DBAs	To be determined Not applicable

CSB = Canister Storage Building.
 CVDF = Cold Vacuum Drying Facility.
 DBA = design basis accident.
 LEL = lower explosive limit.
 MCO = multicanister overpack.
 NPH = natural phenomena hazard.
 SSC = structure, system, and component.
 TSR = technical safety requirement.

The design basis of the CSB vault (below-grade and at-grade structure) is as follows:

- Reinforced concrete dead load, includes insulating concrete in vaults 2 and 3
- Live load on deck, 488 kg/m² (100 lb/ft²) plus purge carts' load
- All three exhaust stacks, insulating concrete on the vault 2 and 3 stacks

- All three air-intake structures, steel and concrete portions; includes amplification of top steel canopy structure
- Steel standard (220) and overpack (6) plugs (3,850 kg [8,500 lb]), dead load supported by tube, seismic horizontal forces at deck, vertical at basemat
- Steel standard (220) and overpack (6) tubes (3,250 kg [7,167 lb]) dead load supported by tube base assemblies located in basemat embeds
- 440 MCOs, deadweight plus impact absorbers
 - MHM load, 4.5×10^5 kg (1×10^6 lb), includes 10% contingency
 - MCO cask transporter weight, 47,200 kg (104,000 lb) live load in load-in/load-out truck vestibule
 - Receiving crane, 149,687 kg (330,000 lb) in load-in/load-out area (includes 54,432 kg [120,000 lb] lift load)
 - HCS Annex with seven pits; six process modules, weight 80,067 N (18 kips) each; one process enclosure, weight 266,893 N (60 kips); six ovens, weight 133,446 N (30 kips) (using dynamic soil pressures similar to those used for the vault walls); MHM (live load), differential temperature across pit wall of 11 °C (52 °F)
 - Operating shelter structure weight as reconfigured for tornado loads, 980 kg (2,160 lb); includes dead load, live load, tornado wind, seismic loads; 5% dead load contingency in operating shelter in accordance with ANSI/ANS-57.9-1992 (ANSI/ANS 1992a); 24 kg/m² (5 lb/ft²) dead load contingency for fireproofing operating area ceiling
 - Soil pressure (at-rest) and surcharge load, 9.6 kPa (200 lb/ft²)
 - Thermal operating loads from 192 kW heat load (FDI 1996c, Calculations CSB-S-0002 and CSB-S-0003)
 - 8,800 kg (19,400 lb) MCO concentric drop, 13.4 m (44 ft) into storage tube, impact absorber 66 cm (26 in.) diameter, 82.7 MPa (12,000 lb/in²)
 - Cask-MCO dead load (27,215 kg [60,000 lb]) in service pit
 - Future service pits (FFTF cask [110,000 lb], MHM maintenance) in load-in/load-out area
 - DBE response spectral analysis with input motion at top of competent layer (2.4 m [8 ft] from surface) and dynamic soil shear modulus variation of 1.5 and 1 over 1.5 times the best estimate value with confirmatory analysis using $C_v = 1.0$
 - Tornado wind loads on stacks and intake structures.

4.3.1.4 System Evaluation. The CSB below-grade and at-grade structures are designed to withstand the DOE-designated natural phenomena specified in Section 1.5. The CSB basement foundation coincides with a soil profile identified as stratum 3 in Section 3.6.1.9 of WHC-SD-HWV-PSAR-001, Hanford Waste Vittrification Plant Preliminary Safety Analysis Report (WHC 1994). This layer exhibits light cementation and is typically in a dense to very dense condition. The formation extends to a depth of approximately 76 m (250 ft) below grade. Geotechnical investigations reported in WHC-SD-HWV-PSAR-001 (WHC 1994) characterized the soil properties at the elevation of interest as having high strength and low compressibility. Stratum 3 has a vertical static subgrade modulus value of $8.1 \times 10^2 \text{ kN/m}^2$ (518 kip/ft²) based on a 1-ft² plate. This is adjusted for the actual foundation size by the equation given in the geotechnical report (Dames and Moore 1989).

The structural loading to the foundation, assuming all vaults fully loaded with SNF, is well within the allowable soil bearing values. Details of the analysis of the adequacy of the soil to carry the anticipated foundation loading are documented in Calculation CSB-S-0023 (FDI 1996c). The soil-bearing pressures beneath the vault are less than $3.8 \times 10^2 \text{ N/m}^2$ (8 kip/ft²), which is well within the allowable bearing capacity of $6.7 \times 10^2 \text{ N/m}^2$ (14.0 kip/ft²). The factor of safety against sliding during a DBE event is approximately 1.8 as determined in Calculation CSB-S-0024 (FDI 1996c). Further soil compaction and settling and vault sliding analyses were performed because of the cantilever on soil design of the HCS Annex. These analyses are documented in FDI-011, Deck Cantilever Settlement and Vault Sliding Estimates (FDI 1996b), which included a report prepared by Dames and Moore. The report concludes that only negligible settlement will occur in the compacted soils around the CSB and under the HCS Annex and that vault wall pressures during a DBE are adequately considered.

Additional natural phenomena requirements are associated with NRC equivalency: notably, tornado hazards, ashfall, and increased PMP amounts as listed on Table 1-23. The CSB's superstructure is non-safety class (safety class 3). Under the HWVP CSB mission, the building's superstructure was not required to be hardened to protect any interior equipment from NPHs or DBAs imposed by NRC equivalency. Under the SNF CSB criteria, the structure was designed to prevent damage to safety-class equipment under the NPH design loads (e.g., ashfall, PMP, and tornado wind) criteria selected by the Regulatory Requirements Team as being NRC equivalent. The weight and wind loads of a tornado-resistant superstructure (including the extension over the HCS Annex) were evaluated along with the 5% increase in dead weight load required by ANSI/ANS-57.9-1992 (ANSI/ANS 1992a). Structural design information follows.

4.3.1.4.1 Soil Structure Interaction. Several steps were used to determine the effects of soil-structure interaction (SSI) on the seismic response of the SNF CSB. Initially, parametric studies were conducted to evaluate the seismic response of the site soils and to determine the level of the soil stress-strain properties for the given level of input ground motion. This was accomplished by finite element methods using the SHAKE computer code analysis. One-dimensional models of the soil properties were developed and equivalent linear soil properties compatible with the strains developed in each layer. These properties were then used in the next step as an initial estimate of soil properties used in the SSI analysis. The SSI was defined by

finite element methods using the FLUSH computer code (Lysmer et al. 1975) analysis.

Two-dimensional models of the soil and structure were developed and gross motion SSI responses for the structure and loads in the below grade walls and basemat were assessed. These results served as verification of the 3-D dynamic (SAP90 [CSI 1995]) model that included the SNF CSB underground vault with surrounding soil and a massive soil column representing "free field." The outer perimeter nodes of the soil elements surrounding the vault were slaved to the elements of the massive soil column thus simulating the transmitting boundary as in the FLUSH (Lysmer et al. 1975) analysis. This forced the outer perimeter boundaries of the soil surrounding the vault to move with the free field. This analysis approach provided a one-step-process method to account for SSI effects and yielded three-dimensional shear and moment force distributions over the underground vault structure. The 3-D analysis used input (response spectra and time histories) at the bottom of the vault generated from the free field ground motions acting at the top of the competent layer, deconvoluted to the bottom of the vault using the SHAKE program.

Uncertainty in the accurate prediction of dynamic soil properties was accounted for by employing a parametric analysis using a range of soil dynamic shear moduli values. The range of soil dynamic shear moduli was bounded by the best estimate dynamic shear modulus $\times 1.5$, the best estimate dynamic modulus / 1.5, and the best estimate shear modulus $\times 1.0$ (ASCE 1986). Confirmatory analyses for soil dynamic shear moduli ranging from 2 and 0.5 times the best estimate were also done. Strain-dependent soil shear modulus and damping values were used in SSI analysis.

The SAP90 computer program (CSI 1995) in itself is not normally used to account for SSI. However, forcing boundaries of soil elements, constructed with appropriate properties, to conform to the free field motion for the surface and below provided soil pressures and response spectra that were consistent with the FLUSH (Lysmer et al. 1975) analysis values. It is on this basis that the SAP90 computer model is deemed reasonable and the analysis results appropriate. The comparison results were documented in Letter FRF-092, DOE SAR Team Review Request for Structural Analysis (Jacobs 1996b).

4.3.1.4.2 Time Histories. ABB Impell Corporation was a subcontractor to the architect-engineer on the HWVP Project. They provided the artificial earthquake time history that was used in the design of the HWVP CSB and is being used in the SNF CSB Project. *Seismic Acceleration Time Histories in Support of Fluor Daniel, Inc.* (Salmon et al. 1990) indicates that a single synthetic time history was created to simulate the DBE. The resulting time history is shown to meet NRC acceptance criteria for a single design time history (NRC 1987). All important ground motion characteristics, including check for power spectral density content, were included in the developed time history.

4.3.1.4.3 Asymmetric Loading Effects on the Substructure. The seismic analysis considered all three vaults to be filled with MCOs and all three intake structures and exhaust stacks to be in place. In addition to all the actual above-grade eccentricities (e.g., MHM, superstructure, and receiving

crane), the model included a 5% accidental eccentricity. A dominant feature of these below-grade vaults is the participation of the soil mass in the wall flexure and in-plane shears. Since the stored SNF, intake structures, and exhaust stacks account for less than 1% of the total seismic model mass (soil, structure, and stored fuel) and approximately 32% of the vault structure and stored fuel system, it was judged that the effective eccentricity was small and that the governing configuration for seismic analysis would be the condition in which all three vaults are full and all three intake and exhaust structures in place. A two-dimensional, 1-ft strip model of the vault-deck section was evaluated for the skip gravity and temperature loads. The results of the analysis confirmed that the demand in moments and shears did not exceed the capacity (Jacobs 1996b).

The design of the basemat and below-grade walls is in accordance with governed by the ANSI/ACI 349-85, Code Requirements for Nuclear Safety Related Concrete Structures (ANSI/ACI 1985), using a load combination of $1.4D + 1.4T$, where T signifies operating self straining thermal loads. A load combination of $1.4D + 1.2T$ (ASCE 1995) is more appropriate when considering the thermal loads caused by extreme maximum (115°F) and minimum (-27°F) temperatures whose duration is 6 hours. The high temperature condition governs the exterior face reinforcing and the low temperature condition governs the interior face reinforcing. Table 4-43 gives the demand to capacity ratios and the governing controlling load combination. In general the governing design condition for the concrete deck, below-grade walls, and basemat design were was based on thermal and seismic rather than tornado loads. The extreme high-temperature condition only occurs when the vault is completely full and the extreme low-temperature condition occurs only when the vault is completely empty. Any thermal skip loading of the vault (e.g., all tubes in one or two vaults full of heat-source material, but not all three vaults loaded) relaxes the self-straining thermal stresses in the vault structure and reduces thermal demand. Based on this reasoning, it was judged that the governing condition for the design of the basemat and below-grade walls was either all the vaults full with high temperature inlet air or all vaults empty with low temperature inlet air. Therefore, the designs of the basemat and below-grade walls are bounded by the two extreme conditions and are not governed by a checkerboard loading pattern because of the dominance of thermal loads.

The internal forces due to temperature used in the design are based on the design basis extreme ambient temperature of 46°C (115°F) maximum and -33°C (-27°F) minimum occurring for a duration of 6 hours during the service life of the CSB. Therefore the demand-capacity ratios with the temperature load T include conservatism as loads caused by extreme temperature conditions have been used in lieu of normal operating temperatures as required by ANSI/ACI 349-85 (ANSI/ACI 1985). The demand-capacity ratios given are for seismic confirmatory analysis done with seismic input at the top of the competent layer (2.4 m [8 ft] below the surface) and using soil shear modulus variations between best estimate values multiplied by $(1 + C_s)$ and best estimate values divided by $(1 + C_s)$, where C_s is a factor that accounts for uncertainties in the SSI analysis and soil properties. The minimum value of C_s according to ASCE-4-86 (ASCE 1986) is 0.5; however, for confirmatory analysis, $C_s = 1.0$ was used.

Table 4-4. Summary of Below-Grade and At-Grade Analysis Results. (6 sheets)

Region		Demand/ capacity ratio	Governing load combination
Vault Walls and Basement (Calculation CSB-S-0042)*			
West wall	Horizontal flexural shear	0.73	3C: 1.05FD+L+H+Tol+Ed/FU
	Vertical flexural shear	0.84	11A: 0.9ED+L+H+Tol+Ed/FU
	Horizontal inside face reinforcing	0.98	9A: 1.05ED+L+H+Tol+Ed/FU
	Horizontal outside face reinforcing	0.98	4A: 0.9FD+L+H+Tol+Ed/FU
	Vertical inside face reinforcing	0.82	2B: 1.05*1.05FD+1.3L+1.3H+1.05Tol
	Vertical outside face reinforcing	0.61	4A: 0.9FD+L+H+Tol+Ed/FU
East wall	Horizontal flexural shear	0.70	4C: 0.9FD+L+H+Tol+Ed/FU
	Vertical flexural shear	0.41	3D: 1.05FD+L+H+Tol+Ed/FU
	Horizontal outside face reinforcing	0.81	3A: 1.05FD+L+H+Tol+Ed/FU
	Horizontal inside face reinforcing	0.82	2B: 1.05*1.05FD+1.3L+1.3H+1.05Tol
	Vertical outside face reinforcing	0.48	4C: 0.9FD+L+H+Tol+Ed/FU
	Vertical inside face reinforcing	0.81	8: 1.05*1.05ED+1.3L+1.3H+1.05Tol
North wall	Horizontal flexural shear	0.67	11A: 0.9ED+L+H+Tol+Ed/FU
	Vertical flexural shear	0.49	4A: 0.9FD+L+H+Tol+Ed/FU
	Horizontal south face reinforcing	0.91	11B: 0.9ED+L+H+Tol+Ed/FU
	Horizontal north face reinforcing	0.63	4A: 0.9FD+L+H+Tol+Ed/FU
	Vertical south face reinforcing	0.95	11B: 0.9ED+L+H+Tol+Ed/FU
	Vertical north face reinforcing	0.53	3A: 1.05FD+L+H+Tol+Ed/FU
Interior north wall	Horizontal flexural shear	0.55	9A: 1.05ED+L+H+Tol+Ed/FU
	Vertical flexural shear	0.39	11B: 0.9ED+L+H+Tol+Ed/FU
	Horizontal south face reinforcing	0.74	11B: 0.9ED+L+H+Tol+Ed/FU
	Horizontal north face reinforcing	0.67	10A: 1.05ED+Ed/FU
	Vertical south face reinforcing	0.76	4C: 0.9FD+L+H+Tol+Ed/FU
	Vertical north face reinforcing	0.95	9A: 1.05ED+L+H+Tol+Ed/FU
South wall	Horizontal flexural shear	0.63	9A: 1.05ED+L+H+Tol+Ed/FU
	Vertical flexural shear	0.43	3C: 1.05FD+L+H+Tol+Ed/FU
	Horizontal south face reinforcing	0.59	3C: 1.05FD+L+H+Tol+Ed/FU
	Horizontal north face reinforcing	0.90	9B: 1.05ED+L+H+Tol+Ed/FU
	Vertical south face reinforcing	0.62	3C: 1.05FD+L+H+Tol+Ed/FU
	Vertical north face reinforcing	0.90	4B: 0.9FD+L+H+Tol+Ed/FU
Basement	E/W flexural shear	0.38	3D: 1.05FD+L+H+Tol+Ed/FU
	N/S flexural shear	0.49	7: 1.05*1.4ED+1.7L+1.7H
	E/W top reinforcing	0.70	3D: 1.05FD+L+H+Tol+Ed/FU
	E/W bottom reinforcing	0.57	3A: 1.05FD+L+H+Tol+Ed/FU
	N/S top reinforcing	0.69	3D: 1.05FD+L+H+Tol+Ed/FU
	N/S bottom reinforcing	0.65	4A: 0.9FD+L+H+Tol+Ed/FU

Table 4-4. Summary of Below-Grade and At-Grade Analysis Results. (6 sheets)

Region		Demand/ capacity ratio	Governing load combination
Vault Operating Floor (Calculation CS6-S-004f)			
Operating floor at tubes	E/W flexural shear	0.53	$0.90ED + Ed/Fu$
	E/W top reinforcing	0.88	$1.05ED + L + H + ToH + Ed/Fu$
	E/W bottom reinforcing	0.86	$1.05ED + L + H + ToL + Ed/Fu$
	N/S flexural shear	0.82	$1.05ED + L + H + ToH + Ed/Fu$
	N/S top reinforcing	0.76	$1.05FD + L + H + ToH + Ed/Fu$
	N/S bottom reinforcing	0.64	$1.05ED + L + H + ToL + Ed/Fu$
Operating floor at crane rails	E/W flexural shear	0.84	$1.05FD + L + H + ToH + Ed/Fu$
	E/W top reinforcing	0.65	$1.05FD + L + H + ToH + Ed/Fu$
	E/W bottom reinforcing	0.85	$1.05ED + L + H + ToL + Ed/Fu$
	N/S flexural shear	0.99	$1.05ED + L + H + ToL + Ed/Fu$
	N/S top reinforcing	0.71	$1.05FD + L + H + ToH + Ed/Fu$
	N/S bottom reinforcing	0.82	$1.05ED + L + H + ToH + Ed/Fu$
Operating floor at intake plenum	E/W flexural shear	0.98	$1.05FD + L + H + ToH + Ed/Fu$
	E/W top reinforcing	0.99	$1.05FD + L + H + ToH + Ed/Fu$
	E/W bottom reinforcing	0.69	$1.05FD + L + H + ToL + Ed/Fu$
	N/S flexural shear	0.85	$1.05ED + L + H + ToL + Ed/Fu$
	N/S top reinforcing	0.43	$1.05ED + L + H + ToL + Ed/Fu$
	N/S bottom reinforcing	0.99	$1.05ED + L + H + ToH + Ed/Fu$
Operating floor at exhaust plenum	E/W flexural shear	0.95	$1.05FD + L + H + ToH + Ed/Fu$
	E/W top reinforcing	0.42	$1.05FD + L + H + ToH + Wmax$
	E/W bottom reinforcing	0.95	$1.05ED + L + H + ToL + Ed/Fu$
	N/S flexural shear	0.84	$1.05ED + L + H + ToL + Ed/Fu$
	N/S top reinforcing	0.99	$1.05ED + L + H + ToL + Ed/Fu$
	N/S bottom reinforcing	0.82	$1.05ED + L + H + ToL + Ed/Fu$
Hot Conditioning System Area (Calculation CS6-S-004g)			
Hot conditioning pits			
Walls	Vertical flexural shear with reinforcing (out of plane radial)	0.89 ^b	$9C: 1.05ED+L+To+H+Ed/Fu$
	Horizontal flexural shear (out of plane radial)	0.14 ^c	$12A: 0.9ED+Ed/Fu$
	Vertical flexural shear (out of plane radial)	0.97 ^d	$9C: 1.05ED+L+To+H+Ed/Fu$
	Outside horizontal reinforcing	0.83	$9C: 1.05ED+L+To+H+Ed/Fu$
	Inside horizontal reinforcing	0.18	$10D: 1.05ED+Ed/Fu$
	Outside vertical reinforcing	0.92	$9C: 1.05ED+L+To+H+Ed/Fu$
	Inside vertical reinforcing	0.97	$10D: 1.05ED+Ed/Fu$

Table 4-4. Summary of Below-Grade and At-Grade Analysis Results. (6 sheets)

Region		Demand/ capacity ratio	Governing load combination
Pits basement	N/S flexural shear (out of plane)	0.53	3A: 1.05FD+L+Tc+H+Ed/Fu
	E/W flexural shear (out of plane)	0.44	3A: 1.05FD+L+Tc+H+Ed/Fu
	N/S top reinforcing	0.44	3A: 1.05FD+L+Tc+H+Ed/Fu
	N/S bottom reinforcing	0.66	3D: 1.05FD+L+Tc+H+Ed/Fu
	E/W top reinforcing	0.12	9C: 1.05ED+L+Tc+H+Ed/Fu
	E/W bottom reinforcing	0.70	3A: 1.05FD+L+Tc+H+Ed/Fu
South cantilever deck	E/W flexural shear (out of plane)	0.76	8A: 1.05ED+Ed/Fu
	N/S flexural shear with reinforcing (out of plane)	0.79 0.88 ^a	8B: 1.05ED+Ed/Fu 9B: 0.9ED+L+H+Ed/Fu+Shear
	E/W top reinforcing	0.66	7B: 1.05ED+L+H+Ed/Fu
	E/W bottom reinforcing	0.60	3A: 1.05FD+Ed/Fu
	N/S top reinforcing	0.96	9B: 0.9ED+L+H+Ed/Fu
	N/S bottom reinforcing	0.67	3A: 1.05FD+Ed/Fu
Load-In/Load-Out Area (Calculation CS8-S-0044)			
FTF Service Pit			
Walls	Flexural shear with reinforcing (out of plane)	0.95	1.05ED+L+H+Ed
	Flexural reinforcing	0.74	1.05ED+L+H+Ed
Basemat	flexural shear (out of plane)	0.80	1.05ED+L+H+Ed
	flexural reinforcing	0.82	1.05ED+L+H+Ed
MM Service Pit			
Walls	Flexural shear with reinforcing (out of plane)	0.69	3A: 1.05FD+Ed/Fu
	Flexural reinforcing	0.96	3A: 1.05FD+Ed/Fu
Basemat	E/W flexural shear (out of plane)	0.90	10A: 0.9ED+Ed/Fu
	N/S flexural shear (out of plane)	0.82	2B: 1.05FD+L+H+Ed/Fu
	E/W top reinforcing	0.58	10B: 0.9ED+Ed/Fu
	E/W bottom reinforcing	0.61	3A: 1.05FD+Ed/Fu
	N/S top reinforcing	0.61	8B: 1.05ED+Ed/Fu
	N/S bottom reinforcing	0.42	4A: 0.9FD+L+H+Ed/Fu
MCD Service Pit			
Walls	Vertical flexural shear with reinforcing (out of plane radial)	0.89 ^f	9C: 1.05ED+L+Tc+H+Ed/Fu
	Horizontal flexural shear (out of plane radial)	0.14 ^g	12A: 0.9ED+Ed/Fu
	Vertical flexural shear (out of plane radial)	0.97 ^h	9C: 1.05ED+L+Tc+H+Ed/Fu
	Outside horizontal reinforcing	0.83	9C: 1.05ED+L+Tc+H+Ed/Fu
	Inside horizontal reinforcing	0.18	10D: 1.05ED+Ed/Fu
	Outside vertical reinforcing	0.92	9C: 1.05ED+L+Tc+H+Ed/Fu
	Inside vertical reinforcing	0.97	10D: 1.05ED+Ed/Fu

Table 4-4. Summary of Below-Grade and At-Grade Analysis Results (6 sheets)

Region		Demand/ capacity ratio	Governing load combination
Basemat	N/S flexural shear (out of plane)	0.48	3A: 1.05FD+L+Tc+H+Ed/Fu
	E/W flexural shear (out of plane)	0.39	3A: 1.05FD+L+Tc+H+Ed/Fu
	N/S top reinforcing	0.40	3A: 1.05FD+L+Tc+H+Ed/Fu
	N/S bottom reinforcing	0.62	3D: 1.05FD+L+Tc+H+Ed/Fu
	E/W top reinforcing	0.12	9C: 1.05ED+L+Tc+H+Ed/Fu
	E/W bottom reinforcing	0.67	3A: 1.05FD+L+Tc+H+Ed/Fu
North cantilever deck	E/W flexural shear (out of plane)	0.90	10B: 0.9ED+Ed/Fu
	N/S flexural shear with reinforcing (out of plane)	0.84 0.96 ¹	7A: 1.05ED+L+H+Ed/Fu 7A: 1.05ED+L+H+Ed/Fu+shear
	E/W top reinforcing	0.58	10B: 0.9ED+Ed/Fu
	E/W bottom reinforcing	0.61	3A: 1.05FD+Ed/Fu
	N/S top reinforcing	0.96	7B: 1.05ED+L+H+Ed/Fu
	N/S bottom reinforcing	0.46	3A: 1.05FD+Ed/Fu
Exhaust Stack Pedestals (Calculation CS8-S-0045) ⁸			
Walls	Horizontal flexural shear with tie reinforcing (out of plane radial)	0.95	4D: 0.9FD+L+H+Tc+Ed/Fu
	Vertical flexural shear with tie reinforcing (out of plane radial)	0.97	14A: 0.9FD+L+H+Tc+H+Ed/Fu
	Vertical inside reinforcing	0.65	14D: 0.9FD+L+H+Tc+H+Ed/Fu
	Vertical outside reinforcing	0.64	14B: 0.9FD+L+H+Tc+H+Ed/Fu
	Horizontal inside reinforcing	0.99	3B: 1.05FD+L+H+Tc+H+Ed/Fu
	Horizontal outside reinforcing	0.84	3C: 1.05FD+L+H+Tc+H+Ed/Fu
Intake Concrete Towers (Calculation CS8-S-0046) ¹			
Vault 1 tower walls ⁸	Horizontal flexural shear	0.43	10A: 0.9ED+Ed/Fu
	Vertical flexural shear	0.84	4A: 0.9FD+L+H+Ed/Fu
	Inside horizontal reinforcing	0.18	8A: 1.05ED+Ed/Fu
	Outside horizontal reinforcing	0.20	3A: 1.05FD+Ed/Fu
	Inside vertical reinforcing	0.48	5B: 0.9FD+Ed/Fu
	Outside vertical reinforcing	0.53	5A: 0.9FD+Ed/Fu
Structural element		Demand/ capacity ratio	Governing load combination
Intake Steel Structure (Calculations CS8-S-0015, CS8-S-0028, and CS8-S-0047)			
Anchor bolts		0.86	0.9D+Ed/Fu
		0.47	0.9D+Ht
Shear plate at base		0.22	D+Ed/Fu
Roof plate flexure		0.22	D+S+V
		0.30	D+S+Ht
Columns		0.15	D+S+V
		0.11	D+Ed
		0.27	D+S+Ht
Braces		0.66	D+Ed
		0.50	D+S+Ht

Table 4-4. Summary of Below-Grade and At-Grade Analysis Results. (6 sheets)

Structural element		Demand/ capacity ratio	Governing load combination
Exhaust Stack for Vault 1 (Steel) (Calculation CSB-S-0012)			
Stack flexure at base		0.83	1.05D+1+WT
Anchor bolts		0.82	0.90+WT
Support Building (Calculation CSB-S-0019)			
Frame girders	Combined stress	0.69	1.05D+Ed/FJ
		0.62	0.90D+WT
		0.67	1.05D+S+WT
Columns	Combined stress	0.67	1.05D+Ed/FJ
		0.67	0.90D+WT
		0.71	1.05D+S+WT
Exhaust stack	Flexure	0.84	1.05D+WT
	Anchor bolts	0.92	0.90D+WT
Operating Building (Calculation CSB-S-0048)			
Structural element	Element no.	Demand/ capacity ratio	Governing load combination
Columns W30X235 W/2Mc18X42.7	1553	0.52 C	D+S+WT
	1553	0.75 T	D+S+WT
	1552	0.75 C	D+Ed
	1553	0.76 T	0.90+WT
	1553	0.27 SH	D+S+V
Columns W30X235	1554	0.65 C	D+S+WT
	1554	0.64 T	D+S+WT
	1452	0.83 C	D+Ed
	1353	0.69 T	D+Ed
	1507	0.27 SH	D+S+V
Truss top chord W14X90	1569	0.37 C	D+S+WT
	1374	0.32 T	D+S+WT
	1370	0.66 C	D+Ed
	1374	0.41 T	0.90+WT
	1569	0.1 SH	D+Ed
Truss bottom chord W14X61	1567	0.51 C	D+S+WT
	1560	0.51 T	D+S+WT
	1560	0.92 C	D+Ed
	1560	0.61 T	0.90+WT
	1560	0.06 SH	D+Ed
Truss web W18X33.5	1586	0.45 C	D+S+WT
	1380	0.58 T	D+S+WT
	1580	0.97 C	D+Ed
	1580	0.71 T	0.90+WT
Truss diagonal W18X33.5	1389	0.86 C	0.90+WT
Vertical bracing W18X33.5	1713	0.79 C	D+S+WT
	1713	0.96 C	D+Ed
	1713	0.67 T	D+S+WT
Horizontal bracing W17X21.5	1830	0.69 C	D+S+WT
	1827	0.81 C	D+Ed
	1827	0.72 C	0.90+WT
Column anchor bolts			
16-1 in. diameter bolts		0.72	0.90+Ed
8-1 in. diameter bolts		0.85	0.90+Ed
Crane rail and anchor bolts		0.8	0.90+Ed

Table 4-4. Summary of Below-Grade and At-Grade Analysis Results. (6 sheets)

Tube Base (Calculation CSB-3-0007A) ^a			
Structural element		Demand/ capacity ratio	Governing load combination
Vertical stiffeners	Flexural and axial stress	0.53	MCO drop on impact absorber
	Shear	0.17	P+L
	Weld	0.68	1.05D+Ed+Fu 1.05D+Ed/Fu
Embed weld studs	Shear	0.76	1.05D+Ed/Fu
	Concrete embedment	0.76	1.05D+Ed/Fu
Basemat			
	Punching shear	0.31	MCO drop on impact absorber 1.4D+1.7L

^aThe design basis extreme temperature maximum and minimum are assumed to occur for a duration of 6 hours.

To = Normal operating temperature.

ToL = Internal forces as a result of normal low operating temperature. They are assumed equal to the forces determined for the extreme low ambient temperature of -27 F.

ToH = Internal forces as a result of normal high operating temperature. They are assumed equal to the forces determined for the extreme high ambient temperature of 115 F.

b The maximum ratio is at 7.5 ft down from the top of the deck slab.

c The maximum ratio is at 17.5 ft down from the top of the deck slab.

d The maximum ratio is at 12.5 ft down from the top of the deck slab.

e In the south cantilever deck area two values are given:

- 0.79 indicates a demand/capacity ratio for the global SAP 90 model.

- 0.88 reflects a demand/capacity ratio for a conservative analysis where global SAP 90 results were supplemented with local RISA-3D analysis (RISA 1996) results considering the most critical MHM crane locations and utilizing 1/2 of the recommended soil subgrade modulus.

f The maximum ratio is at 7.5 ft down from the top of the deck slab.

g The maximum ratio is at 16.5 ft down from the top of the deck slab.

h The maximum ratio is at 12 ft down from the top of the deck slab.

i In the north cantilever slab area where two values are given:

- 0.54 indicates a demand/capacity ratio from the global SAP 90 analysis.

- 0.90 reflects a demand/capacity ratio for a conservative analysis where global SAP 90 results were supplemented with local RISA-3D analysis (RISA 1996) results considering the most critical MHM crane locations and utilizing 1/2 of the recommended soil subgrade modulus.

j The thermal loads are negligible since the ambient temperature inside and outside is same.

k Only Vault 1 tower will be constructed for the SNF project.

l Dead load ^m includes 3% contingency per ANSI 57.9.

1. Assumes two MCOs at 18,100 lb each.

2. Tube assembly weight is 5,450 lb.

3. Assumes two impact absorbers at 500 lb each.

FFTF = Fast Flux Test Facility.

MCO = Multicanister overpack.

MHM = Multicanister overpack handling machine.

C = Compression.

D = Dead load.

Ed = Design basis earthquake.

ED = Dead load, vaults empty with multicanister overpacks.

FD = Dead load, vaults full with multicanister overpacks.

Fu = Inelastic energy absorption capacity factor.

H = At-rest soil pressure load.

L = Live load (floor, roof, snow, ashfall).

S = Snow load.

Sh = Shear.

T = Tension.

V = Volcanic ashfall load.

Wt = Tornado wind load.

Table 4-3. Summary of Below Grade and At Grade Analysis Results. (3 sheets)

Element		Demand/capacity ratio	Governing condition
Vault (Calculation CSB-S-00252b)			
Base-mat	N-S top reinforcing	0.91	$1.4D_F + 1.4T_{ET}$
	N-S bottom reinforcing	0.70	$1.4D_F + 1.4T_{EN}$
	N-S flexural shear	0.67	$D_F + L + T_{ET} + H - Ed / F_U$
	E-W top reinforcing	0.80	$1.4D_F + 1.4T_{ET}$
	E-W bottom reinforcing	0.69	$1.4D_F + 1.4T_{EN}$
	E-W flexural shear	0.38	$D_F + L + T_{ET} + H - Ed / F_U$
North exterior wall, south exterior wall	Vertical outside reinforcing	0.76	$1.4D_F + 1.4T_{EN}$
	Vertical inside reinforcing	0.87	$1.05D_F + 1.3L + 1.05T_{ET} + 1.3H$
	Vertical flexural shear	0.70	$D_F + L + T_{EN} + H - Ed / F_U$
	Horizontal outside reinforcing	0.81	$1.4D_F + 1.4T_{EN}$
	Horizontal inside reinforcing	$\frac{1.03}{(0.87)C}$	$\frac{1.4D_F + 1.4T_{ET}}{(1.4D_F + 1.4X0.85T_{ET})}$
	Horizontal flexural shear	0.34	$D_F + L + T_{EN} + H - Ed / F_U$
Interior walls	Vertical reinforcing	0.95	$1.4D_F + 1.4T_{EN}$
	Vertical flexural shear	0.22	$1.4D_F + 1.4T_{ET}$
	Horizontal reinforcing	0.95	$1.4D_F + 1.4T_{ET}$
	Horizontal flexural shear	0.32	$1.4D_F + 1.4T_{EN}$
East exterior wall	Vertical outside reinforcing	0.68	$1.4D_F + 1.4T_{EN}$
	Vertical inside reinforcing	0.91	$1.4D_F + 1.4T_{ET}$
	Vertical flexural shear	0.52	$D_F + L + T_{ET} + H - Ed / F_U$
	Horizontal outside reinforcing	0.93	$1.4D_F + 1.4T_{EN}$
	Horizontal inside reinforcing	$\frac{1.05}{(0.89)C}$	$\frac{1.4D_F + 1.4T_{ET}}{(1.4D_F + 1.4X0.85T_{ET})}$
	Horizontal flexural shear	0.95	$D_F + L + T_{EN} + H - Ed / F_U$
West exterior wall	Vertical outside reinforcing	0.77	$1.4D_F + 1.4T_{EN}$
	Vertical inside reinforcing	$\frac{1.04}{(0.80)C}$	$\frac{1.4D_F + 1.4T_{ET}}{(1.4D_F + 1.4X0.85T_{ET})}$
	Vertical flexural shear	0.66	$D_F + L + T_{ET} + H - Ed / F_U$
	Horizontal outside reinforcing	$\frac{1.05}{(0.93)C}$	$\frac{1.4D_F + 1.4T_{ET}}{(1.4D_F + 1.4X0.85T_{ET})}$
	Horizontal inside reinforcing	$\frac{1.11}{(0.92)C}$	$\frac{1.4D_F + 1.4T_{ET}}{(1.4D_F + 1.4X0.85T_{ET})}$
	Horizontal flexural shear	0.61	$D_F + L + T_{EN} + H - Ed / F_U$

Table 4-3. Summary of Below Grade and At Grade Analysis Results. (3 sheets)

Element		Demand/capacity ratio	Governing condition
Operating Floor (Calculation CSB-S-0014, CSB-S-0026, and CSB-S-0026A) ^{a,b}			
Operating floor over tubes (CSB-S-0026 ^a)	N-S top reinforcing	0.81	$1.40P + 1.4T_{EN}$
	N-S bottom reinforcing	0.77	$1.40P + 1.4T_{ET}$
	N-S flexural shear	0.70	$D_T + L + T_{ET} + H + Ed / F_{UT}$
	E-W top reinforcing	0.92	$1.40P + 1.4T_{ET}$
	E-W bottom reinforcing	0.94	$1.40P + 1.4T_{ET}$
	E-W flexural shear	0.35	$D_T + T_{ET} + H + Ed / F_{UT}$
Operating floor, outside tube region (CSB-S-0026 ^a)	Two-way shear from MNM loading	0.67	$D_T + Ed / F_{UT}$
	Flexural shear	0.82	$D_T + L + T_{ET} + H + Ed / F_{UT}$
HCS Annex deck (CSB-S-0026A ^a)	N-S top reinforcing	0.80	$1.05D + L + H + Ed / F_{UT}$
	N-S bottom reinforcing	0.99	$1.05D + L + H + Ed / F_{UT}$
	N-S flexural shear	0.99	$1.05D + L + H + Ed / F_{UT}$
	E-W top reinforcing	0.71	$1.05D + L + H + Ed / F_{UT}$
	E-W bottom reinforcing	0.69	$1.05D + L + H + Ed / F_{UT}$
	E-W flexural shear	0.97	$1.05D + L + H + Ed / F_{UT}$
Lead-in/lead-out deck (CSB-S-0014)	N-S top reinforcing	0.72	$1.05D + L + H + Ed / F_{UT}$
	N-S bottom reinforcing	0.91	$1.05D + L + H + Ed / F_{UT}$
	N-S flexural shear	0.78	$1.05D + L + H + Ed / F_{UT}$
	E-W top reinforcing	0.73	$1.47D + 1.7L + 1.7H$
	E-W bottom reinforcing	0.99	$1.05D + L + H + Ed / F_{UT}$
	E-W flexural shear	0.54	$1.05D + L + H + Ed / F_{UT}$
Support Building (Calculation CSB-S-0019) ^{a,b}			
Frame girders	Combined stress	0.62	$0.90 + U_F$
	Shear	0.29	$0.90 + U_F$
Columns	Combined stress	0.67	$0.90 + U_F$
	Shear	0.17	$0.90 + U_F$
Foundation	Soil bearing	0.61	$0.90 + U_F$
	Stability	0.93	$0.90 + U_F$
Operating Area Building (Calculation CSB-S-0029) ^{a,b}			
Column-W30x235	Combined stress	0.89	$D + E_{CD}$
	Shear	0.26	$D + S + V$

Table 4.3. Summary of Below Grade and At Grade Analysis Results. (3 sheets)

Element		Demand/capacity ratio	Governing condition
Column-W30x235-MC18x12.7	Combined stress	0.82	$D+E_d$
	Shear	0.27	$D+S+V$
Truss-top chord	Combined stress	0.80	$D+E_d$
	Shear	0.15	$D+E_d$
Truss-bottom chord	Combined stress	0.99	$D+E_d$
	Shear	0.05	$D+E_d$
Truss-vertical (web)		0.84	$D+E_d$
Truss-diagonals		0.87	$D+E_d+U_T$
Vertical bracing		0.90	$D+E_d$
Horizontal bracing		0.86	$D+E_d$
Soil Bearing Pressures at Basement (Calculation CSB-S-0023 ^B)			
Location	Maximum pressure (Kips/ft ²)	Minimum pressure ^C (Kips/ft ²)	
North and south exterior wall end	7.73 ($D_F+L+H+E_d$)	0.93 (D_F+E_d)	
North and south exterior wall center	5.57 ($D_F+L+H+E_d$)	2.32 (D_F+E_d)	
East and west exterior wall center	6.49 ($D_F+L+H+E_d$)	1.90 (D_F+E_d)	
Vault 1 center	4.79 ($D_F+L+H+E_d$)	1.76 (D_F+E_d)	
Vault 2 center	4.67 ($D_F+L+H+E_d$)	1.61 (D_F+E_d)	
Interior wall center	5.42 ($D_F+L+H+E_d$)	1.52 (D_F+E_d)	

^ARPT, 1996, Design Calculations for the SNF Canister Storage Building Project, Fluor Daniel, Incorporated, Richland, Washington.

^BValues are based on seismic control motion input at the top of the competent soil layers (2.4 m (8 ft) below the surface).

^CThe values shown in parentheses are more appropriate when considering extreme ambient air temperatures of -27 °F and +115 °F. For extreme temperature (T_e), the load factor used, 1/4, is conservative. A load factor of 1.2 as specified in ASCE-7² is considered appropriate. Conservation also exists in the assumption of the initial maximum concrete surface temperature within the vault. The structural thermal analysis (CSB-S-0023^B) used a maximum deck ceiling temperature of 187 °F versus 152 °F calculated by the vault cooling analysis (CSB-WV-0001^C).

^DThe minimum soil bearing pressure is based on DBE with all vaults full.

^EASCE, 1995, Minimum Design Loads for Building and Other Structures, ASCE-7-95, American Society of Civil Engineers, New York, New York.

^FRPT, 1996, A Canister Storage Building Vault Thermal Analysis, CSB-WV-0001, Rev. 0, Fluor Daniel, Incorporated, Richland, Washington.

HCS = Hot Conditioning System.

MHM = multicanister overpack handling machine.

D_e = Dead load, vaults empty of multicanister overpacks

D_F = Dead load, vaults full with multicanister overpacks

D_T = Dead load

L = Live load (floor, roof, snow, ashfall)

H = At-rest soil pressure load

S = Snow load

T_{EL} = Design basis temperature (low case) load

T_{EH} = Design basis temperature (high case) load

E_H = Design basis earthquake

W_d = Tornado wind load

V = Volcanic ashfall load

The high mass of the generally box-like configuration formed by the below-grade concrete CSB structure, the deck, and the above-grade concrete features (the concrete portion of the inlet structure and the exhaust stack bases) makes it susceptible to DBE forces. When combined with thermal stresses, governing load combinations result for many of these components. This is evident in Table 4-4.

The deck has been designed to provide an adequate safety margin for combined thermal and tornado wind loading to prevent a 320 km/h (200 mi/h) tornado wind load from creating unacceptable loads on areas where the bending moment is transmitted from the above-grade structures to the deck. Tornado wind loading by itself is governing for some features of the operating area shelter as well as for the support building. This is shown in Table 4-4.

4.3.1.4.4 Modeling of the Deck, Superstructure, Ventilation Stacks, and the Multicanister Overpack Handling Machine — Effects on the Substructure. As severe as tornado loading may be, the forces transmitted to the below-grade structure are well below the forces transmitted by seismic forces. Calculations indicate that the below-grade design controlling values of soil pressures, member stresses, displacements, or other parameters are not affected by tornado wind (Wt) loads. None of the governing conditions given in Table 4-43 for below grade items (the substructure) were based on tornado wind loads. The weight of the MHM is included in the seismic calculation that affects the seismic response of the CSB below-grade and at-grade structures. The design also includes evaluations of the deck and related structures, such as the stacks and inlets for tornado wind effects as well as the 5% dead load increases required by ANSI/ANS-57.9-1992 (ANSI/ANS 1992a). The designs were modified as appropriate to accommodate those loads before releases for construction of the below-grade and at-grade reinforced concrete structures.

4.3.1.4.5 Vault Sliding Resistance and Passive Wall Pressures. Analysis to determine the level of strain required to slide (FDI 1996b), as compared with calculated strain values, was performed to demonstrate that relevant passive wall pressures were used in the design of the below-grade walls sliding will not occur and, therefore, to validate that the SAP90 calculated wall moments and shears (FDI 1996c, Calculation CSB-S-0024) are properly accounted for. The analysis (FDI 1996b) estimates that full frictional resistance of the vault basemat-soil interface occurs at a displacement of only 3.8 mm (0.15 in.), whereas full passive soil pressures on the wall is activated at a movement of approximately 356 mm (14 in.) for a 14.3-m- (47-ft-) deep vault wall.

FLUSH analysis (FDI 1996c, Calculation CSB-S-0032), indicates that the maximum shear strain and shear modulus in the soil elements below the vault basemat result in a DBE shear stress at the soil basemat interface of $7.37 \times 10^3 \text{ N/m}^2$ (1.54 kip/ft²). Obtaining the frictional resistance of the mass concrete on coarse sand and gravel ($1.14 \times 10^5 \text{ N/m}^2$ [2.38 kip/ft²]) results in a factor of safety against sliding of 1.55. The 3.8-mm (0.15-in.) displacement for full frictional resistance to be activated and the ratio of shear stress to frictional resistance of 0.65 results in a displacement of 2.54 mm (0.10 in.) due to DBE shear. For shear deformation of 0.15 or less, the passive pressure coefficient is given as 0.50 (FDI 1996b). The CSB walls were designed for a passive pressure coefficient of 0.62, which is greater than the passive pressure occurring from vault displacement during a DBE.

In summary, the CSB vault walls have been designed for larger soil pressures than the passive pressures developed during a DBE.

4.3.1.5 Controls (Technical Safety Requirements). TSRs are not applicable for this system. TSRs dealing with soil washout from the fire water main will be developed after construction.

4.3.2 Air Intake and Exhaust Plenums

4.3.2.1 Safety Function. The CSB ~~will~~ contains MCOs in the below-grade space described in Chapter 2.0 as CSB vault 1. The CSB is designed to prevent failure of MCOs. Catastrophic failure of a single MCO could result in consequences over the safety-class guidelines. The potential consequences of an unmitigated release from the inventory at risk in the CSB were evaluated in Section 5.3 of WHC-SD-SNF-HC-007 (Kummerer 1995). Failure of a significant number of the MCOs could result in offsite consequences greater than the safety-class (safety class 1) guideline. The MCOs must be protected against overheating (fuel centerline temperature greater than 204 °C [400 °F]) that could result in reactions with the fuel or compromise the structural integrity of the MCO. The air intake and exhaust plenums are integral features of natural convection cooling.

4.3.2.2 System Description. The below-grade concrete structure forms the major portion of the natural convection cooling design for the CSB. Design of the natural convection cooling features is based upon two-dimensional thermal analysis using two-dimensional modeling software and assuming the maximum design air inlet temperature of 115 °F. Results of the vault thermal analysis indicate that the maximum air temperature inside the vault is less than the 65 °C (150 °F) concrete limitation in ANSI/ACI 349-85, Appendix A (ANSI/ACI 1985). See Figure 4-1 for more temperature profiles. Detailed design calculations have not addressed solar heat gain and wind effects because they are of minor importance. The underground storage vault is not affected by solar heat. The exhaust stack and the air intake being exposed to the same incidence of instantaneous solar exposure has a negligible though positive effect on the thermal analysis. This is because of the slight increase in density differential created by the stack effect. The analysis did not include this effect and has considered this a part of the safety factor in the calculation. Appendix G of CSB-HV-0001, *A Canister Storage Building Vault Thermal Analysis* (FDI 1996a), provides the wind tunnel test results for the CSB. Adding the deflector at the top of the exhaust stack and optimizing the intake structure (design, height, and cruciform structure) will provide a net positive pressure to the vault's cooling system regardless of wind direction. The current intake structure configuration with canopy and cruciform will create a positive wind pressure effect at the intake under any wind condition.

4.3.2.3 Functional Requirements. The air intake and exhaust plenums withstand all applicable NPHs and DBA events, including natural phenomena, to the extent required to ensure that cooling is maintained to the MCOs. The MCO wall temperature is to be kept at less than 132 °C (270 °F) to protect the structural integrity of the MCO (Swenson 1996). The DBAs NPHs applicable to the intake and exhaust plenums are the natural phenomena established for

safety-class (safety class 1) SSCs as ~~summarized discussed in Table 1-23 of~~ Section 1.5.

The air inlet and exhaust plenums ~~are will be~~ designed to withstand the DOE-designated natural phenomena specified in Section 1.5. Additional natural phenomena requirements are associated with NRC equivalency. Notably, tornado hazards and suspended ashfall were added, and PMP amounts increased.

4.3.2.4 System Evaluation. The above-grade structures that rest on the below-grade intake and exhaust plenums are designed (~~elevation, overhanging roof, screen size~~) to prevent plugging caused by ice, snow, ashfall, and windborne debris. The substructure effects of greater ashfall, higher PMP, tornado wind loading, and pressure changes upon the SNF CSB air intake and exhaust plenums were evaluated and included in the operating deck design.

Structural design information for the current design is provided in Section 4.3.1.4.

4.3.2.5 Controls (Technical Safety Requirements). ~~TSRs are not applicable for this system. TSRs for the intake structure and exhaust stacks will be developed and provided with the final SAR if found to be needed.~~

4.3.3 Carbon Steel Base Slab Embeds

4.3.3.1 Safety Function. The 220 tubes (and 6 overpack tubes) of vault 1 ~~are will be~~ seismically restrained through the use of tube base assemblies that bolt to carbon steel embeds in the base slab of the CSB. In vault 1 these embeds ~~will serve~~ the safety function of maintaining horizontal stability of the tubes containing MCOs during a DBE. The embeds are present in vaults 2 and 3 for future use. Their safety function for future use has not been evaluated.

4.3.3.2 System Description. Two rows of carbon steel embed strips are located under each row of tubes as shown in Figure 4-2. The embeds ~~will serve~~ as the welding plates for threaded weld studs to which the tube base assemblies ~~are will be~~ bolted. The tube base assemblies ~~are will not be~~ affixed to the tubes but will restrain the tubes. Each completed alignment fixture ~~will consists~~ of a 2.5-cm (1-in.) carbon steel plate bolted to the embed strips in four places and topped by a short (about 15 cm [6 in.] tall), right-circular cylinder of 1.3-cm (0.5-in.) thick carbon steel of a diameter slightly larger than the tube and welded to the plate. The tubes ~~will rest~~ on top of the carbon steel plates and ~~are be~~ seismically restrained within the 15-cm- (6-in.-) tall cylindrical band.

4.3.3.3 Functional Requirements. The embeds in vault 1 must remain in place during the DBE to provide horizontal stabilization of the tubes. Functional requirements for embeds in the base slab areas of vaults 2 and 3 were based on seismic loading for the HWVP CSB mission and will require reevaluation for future uses.

4.3.3.4 System Evaluation. The carbon steel embeds for vault 1 are evaluated for the DBE specified in Section 1.5 based on the seismic loading from the storage tubes and the ~~current reracked~~ MCOs, which contain SNF and weigh up to

9,090 kg (20,000 lb). Embed-tube interface design will accommodate the current DBE for tubes loaded with MCOs. The embeds and tube base assemblies work in concert to restrain the storage tube at the basement elevation. Seismic analysis and design of the embeds was performed to ANSI/ACI 349-85 standards (ANSI/ACI 1985) and included the seismic interaction loads from assuming two MCOs per tube. Any future use of embeds in vaults 2 and 3 must be evaluated against their original design, which was for seismic loading associated with the HWVP CSB mission.

4.3.3.5 Controls (Technical Safety Requirements). TSRs are not applicable for this system.

4.3.4 Canister Storage Building At-Grade Structures

The at-grade reinforced concrete structures are the operating area deck, the HCS Annex, the load-in/load-out area, and the support building foundation.

4.3.4.1 Safety Function. As an integral part of the CSB vault, the operating area deck shares the design functions of the vault. Those functions are to maintain the MCOs in a subcritical geometry, to ensure the functionality of the natural convection cooling system, and to protect the staged and stored MCOs from damage arising from any applicable DBA that could exceed the safety-class (safety class 1) limits in WHC CM 4-46. The deck embed sleeves in the operating area deck provide a finished surface for resting the storage tube's bellows assembly. A 1.3-m (4-ft, 4-in.) wide by 0.9-m (3-ft) high curb borders the operating floor area (operating deck, HCS Annex, and load-in/load-out areas) on the east, west, and south. The curb's height is increased to 2.4 m (8 ft) at the north end to meet shielding requirements for the transportation cask to allow unlimited occupancy in the support building.

4.3.4.2 System Description. The at-grade reinforced concrete structures have overall dimensions of 86.9 m by 57.7 m (285 ft, 0.5 in. by 189 ft, 5.5 in.). The operating area deck is a 1.5-m- (5-ft-0-in.-) thick reinforced concrete structure. The deck is 55.2 m by 50.5 m (181 ft, 2 in. by 165 ft, 9 in.). The deck embeds locate the openings for the 220 standard and 6 overpack storage tube locations. Deck embeds in vault 1 are fitted with plug covers designed to provide shielding and to provide access to service connections at the tube plug for servicing the storage tubes. Deck embeds in vaults 2 and 3 are fitted with embed covers to provide personnel protection. The load-in/load-out area is located at the north end of the operating deck. Its dimensions are 57.7 m by 13.0 m (189 ft, 5.5 in. by 42 ft, 7 in.) at the truck vestibule and 57.7 m by 9.1 m (189 ft, 5.5 in. by 29 ft, 9.5 in.) at the MCO service station.

The HCS Annex is an extension to the south of the operating deck with overall dimensions of 42.3 m by 10.7 m (138 ft, 11 in. by 35 ft, 3 in.). A loading-staging area is provided at the west side of the HCS Annex. Its dimensions are 8.3 m by 7.6 m (27 ft, 4 in. by 24 ft, 11 in.). The support building is an extension to the north of the operating deck and the MCO load-in/load-out area. Its foundation dimensions are 45.7 m by 16.5 m (150 ft by 54 ft, 3 in.). The foundation system consists of reinforced concrete spread footings. The HCS Annex is an extension to the south of the operating deck with overall dimensions of 42.3 m by 10.7 m (138 ft, 11 in. by

35 ft, 3 in.). The load in/load out area's dimensions are 57.7 m by 13.0 m (189 ft, 5.5 in. by 42 ft, 7 in.) at the truck vestibule and 57.7 m by 9.1 m (189 ft, 5.5 in. by 29 ft, 9.5 in.) at the MCO service station. The control building foundation dimensions are 45.7 m by 16.5 m (150 ft by 54 ft, 3 in.). A loading staging area is provided at the west side of the HCS Annex. Its dimensions are 8.3 m by 7.6 m (27 ft, 4 in. by 24 ft, 11 in.).

The deck embeds locate the openings for the 220 standard and 6 overpack storage tube locations. Deck embeds in vault 1 are fitted with will receive plug covers designed to provide shielding and to provide access to service connections at the tube plug for servicing the storage tubes. Deck embeds in vaults 2 and 3 are fitted with will receive embed covers to provide personnel protection.

The support building is a steel framed structure approximately 45.7 m by 16.5 m by 4.9 m (150 ft by 54 ft by 16 ft) high enclosed by insulated metal siding and a roof deck. The structure is moment frame in the north south direction and braced frame in the east west direction. The steel framing, roof deck, and siding are designed to resist wind pressures from a 322 km/h (200 mi/h) tornado and the primary framing is also designed for a safety class (safety class 1) DBE. The foundation system consists of reinforced concrete spread footings. The demand capacity ratios of the primary structural elements are given in Table 4.43.

4.3.4.3 Functional Requirements. The operating deck acts together with the vault walls and basemat to support the loads associated with the MHM, the superstructure operating building, and the tube vent and purge carts. The operating deck is designed to the same safety-class (safety class 1) criteria as the below-grade vault. The load-in/load-out area and HCS Annex are designed to the same safety-class (safety class 1) criteria as the operating deck.

The operating shelter design basis is as follows:

- Roof dead load, includes 5% contingency plus 24 kg/m² (5 lb/ft²) fireproofing at ceiling for a total of 107 kg/m² (22 lb/ft²)
- Snow load at ground level, 98 kg/m² (20 lb/ft²); roof snow load, considering drifts at low roofs
- Roof live load, 90 kg/m² (20 lb/ft²)
- Volcanic ashfall, 117 kg/m² (24 lb/ft²) ground load and ashfall roof drift
- Siding dead load calculated to be 39 kg/m² (8 lb/ft²); however, 59 kg/m² (12 lb/ft²) used in design
- Wind loads, 145 km/h (90 mi/h); wind-driven missile (2 x 4 x 15 lb wood plank) at 80 km/h (50 mi/h), horizontal velocity up to 15 m (50 ft) high, vertical velocity equal to two-thirds horizontal

- Seismic load, horizontal response spectra of 0.35 g ("free field" used in Calculation CSB-S-0029); vertical is two-thirds of horizontal spectra; confirmatory analysis (FDI 1996c, Calculation CSB-S-0048) used in-structure response spectra at deck level based on seismic input at top of competent layer and soil properties at mean, mean x 2, and mean x 1/2
- Tornado loads
 - Wind, 322 km/h (200 mi/h)
 - Pressure drop, 6.2 kPa (0.9 lb/in²).

The support facility design basis, against which the facility has been evaluated, is as follows:

- Roof dead load, 103 kg/m² (21 lb/ft²), includes 49 kg/m² (10 lb/ft²) for electrical and HVAC equipment
- Roof live load, 98 kg/m² (20 lb/ft²)
- Floor live load, 488 kg/m² (100 lb/ft²)
- Roof snow load based on ground-level snow load of 98 kg/m² (20 lb/ft²) plus drift
- Siding dead load, 49 kg/m² (10 lb/ft²)
- Equipment weight (consideration for vibration and/or overturning accounted for in the foundation design)
- DBE seismic for safety class (safety class 1) free field response spectra due to interaction with operating deck
- Tornado loads, wind 320 km/h (200 mi/h)
- Extreme wind, 145 km/h (90 mi/h), including 2 x 4 x 15 lb missile at 80 km/h (50 mi/h).

4.3.4.4 System Evaluation. The CSB below-grade and-at-grade reinforced concrete structures have been designed for all applicable loads and load combinations as defined in the SNF CSB Detailed Design Basis Document, Section 10 (Bedell 1996a). The loads include normal loads, severe and extreme environmental loads, natural phenomena loads, and any DBAs identified by safety analysis. A summary of loads considered is given below. A summary of the results (demand to capacity ratios) of structural analysis and design for the operating floor, operating area building, and support building is provided in Table 4-4.

4.3.4.4.1 Operating Deck. The operating deck has been designed using an isotropic plate model with a reduced modulus of elasticity derived from a comparison of the natural frequencies of a beam (grillage) model and a plate element model. The operating deck has been designed to perform at the temperatures expected from the below-grade storage of MCOs. The design analysis results, as shown on Figure 4-3, indicate that for a fully loaded

vault, the highest calculated concrete temperature on the operating floor surface is 41 °C (106 °F), coincident with a site ambient temperature of 46 °C (115 °F). The highest calculated temperature for the operating floor deck slab (vault side) is 51 °C (132 °F). This temperature occurs at the underside of the deck slab next to the storage tube. These temperature values were obtained from Appendix E of CSB-HV-0001 (FDI 1996a). The operating pressure range for the gas in the tube during staging or interim storage is 6.9 kPa gauge (1.0 lb/in² gauge) to 524 kPa gauge (76 lb/in² gauge). The storage tubes are only at vacuum while being purged by a service cart, a time period that is too short to impact heat transfer and temperature profiles in the deck. Thermal analysis has been performed with all three candidate inerting gases (helium, nitrogen, and argon) (FDI 1996a).

The deck addition for the HCS Annex has been analyzed and designed as integral with the vault for all loads. Soil springs for the compacted stratum I were used. Any imported soil used as backfill is consistent with the stratum I soils. Dames and Moore, a geotechnical engineering company, estimated the total and differential settlement expected between the vault and the north and south cantilevers during different stages of construction and operation. Estimates of expected settlement are provided in FDI-011, Deck Cantilever Settlement and Vault Sliding Estimates (FDI 1996b).

The geotechnical predicted settlement values (FDI 1996b) were compared with the settlement values computed by the structural analysis (FDI 1996c, Calculation CSB-S-0026A). The differential settlements computed by the structural analysis were found to be generally larger than in the geotechnical analysis. The maximum anticipated differential settlement is on the order of 2.5 mm (0.10 in.) across the 9.1 to 10.7 m (30 to 35 ft) of the south cantilever deck. Although the predicted differential settlements are small, a crack control joint at the interface with the vault's north and south walls has been included in the design.

The cantilever soil springs used in the structural analysis model were based on an initial vertical coefficient of 150 pci (pounds per cubic inch) and adjusted for the plan dimensions of the basemat to 29 pci. The vault basemat soil springs were based on an initial vertical coefficient of 300 pci and adjusted for plan dimensions to 74 pci. A review of the fill material used and the compaction results suggests that the coefficient of subgrade reaction for the overhang soil springs would be 25% higher than values previously given for stratum I soils and used in the design (FDI 1996c, Calculation CSB-S-0026A). The design has this additional conservatism.

The quality of backfill material being used and the field compaction tests conducted to date have been reviewed and found to meet or exceed the project specification requirements (FDI 1996b). To account for uncertainty in the execution of construction, settlement measurements at the north and south vault walls and at the edges of the north and south deck cantilevers will be taken and evaluated after construction and during operation.

Specific tornado wind loads were developed for the intake and exhaust stacks to evaluate their impact on the vault deck. Structural calculations are documented in CSB-S-0012 for exhaust stack, CSB-S-0028 and CSB-S-0028A for intake structure, and CSB-S-0026 for deck design (FDI 1996c).

Using NRC-accepted tornado missile probability methodology provided by the design authority (Bazinet 1996c), the architect-engineer completed a probabilistic risk analysis of tornado-wind-driven missiles becoming credible impact loads for the CSB assuming no resistance provided by the superstructure. Further adjustments to the probabilistic risk analyses were made using a survey of the site for potential missiles (Beary 1996a and 1996b). The revised estimated frequency of 4×10^{-2} for a missile strike on the CSB is well below the NRC criterion of 1×10^{-6} (Jacobs 1996d). Therefore, the CSB is not subject to missile impacts, and the structures are designed for the tornado wind and atmospheric pressure change.

~~[This material has been moved to Section 4.3.1.3.] 4.3.4.4.1 Canister Storage Building Vault. The CSB vault design basis is as follows:~~

- ~~• Dead load, includes insulating concrete in vaults 2 and 3~~
- ~~• Live load on deck, 488 kg/m^2 (100 lb/ft^2) plus purge carts' load~~
- ~~• All three exhaust stacks, insulating concrete on the vault 2 and 3 stacks~~
- ~~• All three air intake structures, steel and concrete portions~~
- ~~• Steel standard and overpack plugs ($3,850 \text{ kg}$ [$8,500 \text{ lb}$]), dead load supported by tube, seismic horizontal forces at deck, vertical at basemat~~
- ~~• MHM load, $4.5 \times 10^5 \text{ kg}$ ($1 \times 10^6 \text{ lb}$), includes 10% contingency~~
- ~~• MCO cask transporter weight, $47,200 \text{ kg}$ ($104,000 \text{ lb}$) live load in load in/load out truck vestibule~~
- ~~• Receiving crane, $149,687 \text{ kg}$ ($330,000 \text{ lb}$) in load in/load out area (includes $54,432 \text{ kg}$ [$120,000 \text{ lb}$] lift load)~~
- ~~• HCS Annex with seven pits, process modules, process enclosure, ovens (maximum exterior oven temperature of 50°C [122°F] in the pits using dynamic soil pressures similar to those used for the vault walls), MHM (live load)~~
- ~~• Equipment weight for modules and enclosure, $21,772 \text{ kg}$ ($48,000 \text{ lb}$) per HCS pit~~
- ~~• Operating shelter reconfigured for tornado loads, includes dead load, live load, tornado wind, seismic loads~~
- ~~• Soil pressure (at rest) and surcharge load, 9.6 kPa (200 lb/ft^2) 0.6 m (2 ft)~~
- ~~• Composite concrete and steel standard plug ($2,630 \text{ kg}$ [$5,800 \text{ lb}$]) ($3,850 \text{ kg}$ [$8,500 \text{ lb}$]), drop height $2.72\text{--}2.85 \text{ m}$ ($9\text{--}9.5 \text{ ft}$) impact on storage tube~~

- Thermal operating loads from 192 kW decay heat load (F01 1996c, Calculations CSB S 0002 and CSB S 0003) (HWVP design)
- 9,000,900 kg (20,000,19,400 lb) MCO concentric drop, 13.4 m (44 ft) into storage tube, impact absorber 66 cm (26 in.) diameter, 82.7 MPa (12,000 lb/in²)
- Cask MCO dead load, 49,900 kg (110,000 lb) in service pit
- Eccentric drop (2.1 m [7 ft]) of the MCO (8,900 kg [19,400 lb]) onto storage tube flange bellows assembly
- 5% dead load contingency in operating shelter in accordance with ANSI/ANS 57.9-1992 (ANSI/ANS 1992a)
- 24 kg/m² (5 lb/ft²) dead load for fireproofing operating area ceiling
- Future service pits (FFIF cask, MMH maintenance) in load in/load out area
- DBE response spectral analysis with input motion at top of competent layer (2.4 m [8 ft] from surface) and dynamic soil shear modulus variation of 1.5 and 1 over 1.5 times the best estimate value with confirmatory analysis using $\zeta = 1.0$
- Tornado loads.

[This material has been moved to Section 4.3.4.3.] 4.3.4.2 Operating Shelter. The operating shelter design basis is as follows:

- Roof dead load, includes 5% contingency plus 24 kg/m² (5 lb/ft²) fireproofing at ceiling for a total of 107 kg/m² (22 lb/ft²)
- Roof snow load at ground level, 98 kg/m² (20 lb/ft²); roof snow load, considering drifts at low roofs, 117 kg/m² (24 lb/ft²); 117 kg/m² (24 lb/ft²), drift considered at low roofs
- Roof live load, 98 kg/m² (20 lb/ft²) or 132 kg/m² (27 lb/ft²) ashfall
- Volcanic ashfall, 98 kg/m² (20 lb/ft²) ground load and; 132 kg/m² (27 lb/ft²) ashfall roof drift
- Siding dead load calculated to be 39 kg/m² (8 lb/ft²); however, 52 kg/m² (12 lb/ft²) used in design
- Extreme wind 145 km/h (90 mi/h), 2 x 4 x 15 lb wood plank missile at 80 km/h (50 mi/h), horizontal velocity up to 15 m (50 ft) high, vertical velocity equal to two thirds horizontal
- Seismic load, horizontal response spectra of 0.35 g ("free field" used in Calculation CSB S 0020); vertical is two thirds of horizontal spectra, confirmatory analysis (Calculation CSB S 0049, used in structure response spectra at deck level based on seismic

~~input at top of competent layer and soil properties at mean, mean $\times 2$, and mean $\times 1/2$~~

— • Tornado loads

- Wind, 322 km/h (200 mi/h)
- Pressure drop, 6.2 kPa (0.9 lb/in²).

4.3.4.4.2 Operating Shelter. A three-dimensional model of the operating shelter was created using SAP90 (CSI 1995). The building was subjected to the basic static load cases, including the 322 km/h (200 mi/h) tornado load with atmospheric pressure change, and to a response spectra dynamic analysis. The horizontal response spectra applied was developed using the SAP90 vault model with the control motion being applied at the competent soil layer and the soil properties varied between one-half mean, mean, and two times mean properties. For vertical response, the building was subjected to two-thirds of the free field control motion. Loads were combined using SAP90 and the demand-to-capacity ratios for the structure were developed using the SAP90 code checking module SAPSTL.

~~[This material has been moved to Section 4.3.4.3.] 4.3.4.4.3 Support Facility.~~ The support facility design basis, against which the facility has been evaluated, is as follows:

- • Roof dead load, 54 kg/m² (11 lb/ft²)
- • Live load, 98 kg/m² (20 lb/ft²) (100 psf)
- • Roof snow load, 117 kg/m² (24 lb/ft²) plus drift based on ground level snow load of 98 kg/m² (20 lb/ft²)
- • DBE seismic for safety class (safety class 1) free field response spectra due to interaction with operating deck
- • Tornado load, 320 km/h (200 mi/h) wind
- • Extreme wind, 145 km/h (90 mi/h).

4.3.4.4.3 Support Facility. The support building is a steel framed structure approximately 45.7 m by 16.5 m by 4.9 m (150 ft by 54 ft by 16 ft) high enclosed by insulated metal siding and a roof deck. The structure is moment frame in the north-south direction and braced frame in the east-west direction. The steel framing, roof deck, and siding are designed to resist wind pressures from a 322 km/h (200 mi/h) tornado and the primary framing is also designed for a safety-class (safety class 1) DBE. The demand-capacity ratios of the primary structural elements are given in Table 4-4. Because of its proximity to the operating area shelter, the main frame is subjected to safety-class (safety class 1) design basis loading for DBE and tornado wind. The support facility is designed to not fail and cause failure of any CSB SSC. The support building is designed to not fail and cause failure of any CSB SSC. The structure was analyzed and the demand-to-capacity ratios determined using RISA-3D (RISA 1996) two-dimensional frame models for the north-south ordinary moment frames and east-west braced frames.

[This section has been moved to Section 4.3.4.4.1.] 4.3.4.4.4 Operating Deck. The operating deck has been designed using an isotropic plate model with a reduced modulus of elasticity derived from a comparison of the natural frequencies of a beam (grillage) model and a plate element model. The operating deck has been designed to perform at the temperatures expected from the below-grade storage of MCOs. At present the design analysis results, as shown on Figure 4-3, indicate that for a fully loaded vault, the highest calculated concrete temperature on the operating floor surface could be 41 °C (106 °F), coincident with a site ambient temperature of 46 °C (115 °F). The highest calculated temperature for the operating floor deck slab (vault side) is 51 °C (132 °F). This temperature occurs at the underside of the deck slab next to the storage tube. These temperature values were obtained from Appendix E of CSB HV 0001 (FDI 1996a). The operating pressure range for the gas in the tube during staging or interim storage is 6.9 kPa gauge (1.0 lb/in² gauge) to 524 kPa gauge (76 lb/in² gauge). The storage tubes or MCOs are only at vacuum while being purged by a service cart, a time period that is too short to impact heat transfer and temperature profiles in the deck. Thermal analysis has been performed with all three candidate inerting gases (helium, nitrogen, and argon) (FDI 1996a). The selected thermal analysis temperature (69 °C [157 °F]) for structural envelopes the results of the thermal analysis.]

A summary of the results (demand to capacity ratios) of structural analysis and design for the vault, operating floor, operating area building, and support building is provided in Table 4-43.

The deck addition for the HCS Annex has been analyzed and designed as integral with the vault for all loads. Soil springs for the compacted stratum I were used. Any imported soil used as backfill is consistent with the stratum I soils. Dames and Moore, a geotechnical engineering company, estimated the total and differential settlement expected between the vault and the north and south cantilevers during different stages of construction and operation. Estimates of expected settlement are provided in FDI 011, Deck Cantilever Settlement and Vault Sliding Estimates (FDI 1996b). The estimates were based on a strain distribution method using both an embedment factor and a time dependent factor. Based on settlement observations at WPPSS Unit 1 (FDI 1996b) and on low bearing loads and soil capacity, the magnitude of the time dependent settlement was estimated as being negligible.

The geotechnical predicted settlement values (FDI 1996b) were compared with the settlement values computed by the structural analysis (FDI 1996a, Calculation CSB S 0026A). The differential settlements computed by the structural analysis were found to be generally larger than in the geotechnical analysis. The maximum anticipated differential settlement is on the order of 2.5 mm (0.10 in.) across the 9.1 to 10.7 m (30 to 35 ft) of the south cantilever deck. Although the predicted differential settlements are small, a crack control joint at the interface with the vault's north and south walls has been included in the design.

The cantilever soil springs used in the structural analysis model would were based on an initial vertical coefficient of 150 pci (pounds per cubic inch) and adjusted for the plan dimensions of the basement to 29 pci. The vault basement soil springs were based on an initial vertical coefficient of 300 pci and adjusted for plan dimensions to 74 pci. A review of the fill

material used and the compaction results suggests that the coefficient of subgrade reaction for the overhang soil springs would be 25% higher than values previously given for stratum 1 soils and used in the design (FDI 1995c, Calculation CSB S 0026A). The design has this additional conservatism.

The quality of backfill material being used and the field compaction tests conducted to date have been reviewed and found to meet or exceed the project specification requirements (FDI 1995b). To account for uncertainty in the execution of construction, settlement measurements at the north and south vault walls and at the edges of the north and south deck cantilevers will be taken and evaluated after construction and during operation.

Specific tornado wind loads were developed for the intake and exhaust stacks to evaluate their impact on the vault deck. Table 4.4 provides calculated increases as a ratio (tornado/SNF CSB) of the magnitude of change that tornado loads impose. As a result, the stack and intake structure (steel and concrete) have been strengthened for the increased demands and areas of deck around them have been reinforced. Structural calculations are documented in CSB S 0012 for exhaust stack, CSB S 0028 and CSB S 0028A for intake structure, and CSB S 0026 for deck design (FDI 1996b).

Table 4.4. Summary of Results and Comparison of Analyses: Spent Nuclear Fuel Canister Storage Building Load Demand Versus Tornado Loads.

Item	SNF-CSB loads		Tornado loads		Increase due to tornado loading
	Load case	(k, k-ft)	Load case	(k, k-ft)	
Exhaust stack	Wind	Vw = 82	Tornado	Vt = 159	1.94
		Mw = 8,020		Mt = 13,700	1.71
Intake structure	Wind	Vw = 33.7	Tornado	Vt = 236	7.0
		Mw = 1,432		Mt = 9,520	6.65

NOTE: Wind speed for wind is 145 km/h (90 mi/h); wind speed for tornado loading is 322 km/h (200 mi/h); units for shear (V) and overturning moment (M) are in k and k-ft, respectively.

CSB = Canister Storage Building,
SNF = spent nuclear fuel.

Using NRC accepted tornado missile probability methodology provided by the design authority (Bazin et al. 1996b), the architect engineer completed a probabilistic risk analysis of tornado wind driven missiles becoming credible impact loads for the CSB assuming no resistance provided by the superstructure. Further adjustments to the probabilistic risk analyses were made using a survey of the site for potential missiles (Beary 1996a and 1996b). The revised estimated frequency of 4×10^{-9} for a missile strike on the CSB is well below the NRC criterion of 1×10^{-6} (Jacobs 1996d). Therefore, the CSB is not subject to missile impacts, and the structures are designed for the tornado wind and atmospheric pressure change.

4.3.4.5 Controls (Technical Safety Requirements). TSRs are not applicable for this system.

4.3.5 Storage Tube, Bellows Assembly, Tube Plugs, Impact Absorbers, and Tube Base Assemblies

4.3.5.1 Safety Function. The storage tube and tube plugs form the secondary confinement for the SNF-containing MCOs. The storage tube and tube plugs have three safety functions:

- Maintain the geometric configuration relied on for cooling and criticality control
- Maintain an inert atmosphere to preclude combustion of hydrogen in the tube, which protects against damage to the MCO and propagation of combustion into the MCO
- Confine any particulate radionuclides released from MCOs during normal storage operations or as the result of DBAs or NPHs

The storage tube also provides the confinement boundary between the vault and the MCO. The bellows isolates the operating area atmosphere from the vault's natural convection cooling and allows for the thermal expansion of the storage tube. The tube plug seals against the tube to prevent the egress of the storage tube's inert atmosphere and the ingress of oxygen, as well as to contain releases from the MCO (see Figures 4-4 and 4-6). The tube plug also provides shielding for the operators. The bottom and intermediate impact absorbers mitigate the effects of an MCO drop of an MCO to keep the drop from breaching the MCO wall and/or the storage tube, thus preventing the release of radionuclides into the vault atmosphere, which is cooled by natural convection (see Chapter 3.0, paragraph 3.4.2.3.2). The intermediate impact absorbers protect the relief devices on the bottom MCO. The storage tubes and the tube base assemblies provide structural support for the MCOs during DBAs and a geometric array for cooling and criticality prevention control. Tube base assemblies are provided with cooling passages to ensure that the storage tube does not overheat the concrete floor of the vault's basemat.

4.3.5.2 System Description. The storage tubes are 0.013 m (0.5 in.) thick and 12.6 m (41 ft, 4 in.) long. The 220 standard tubes have an outside diameter of 0.7 m (28 in.) and the 6 overpack tubes have an outside diameter of 0.86076 m (34.30 in.). Standard storage tube plugs provide sealing confinement of tube overpressure and shielding a confinement seal, shielding, and protection against tube overpressurization. Overpack storage tube plugs provide radiation shielding only. The standard tube plugs contain two main penetrations manifolded together with four connection points in the tube top. Two of these connections are for pressure relief through HEPA filters. The third connection is for testing the tube plug seals, and a fourth is for venting, purging, and inerting operations during staging. One of the HEPA filter connections incorporates a tube pressure indicator. MCO overpacks will provide the same pressure relief as an MCO. The design of the overpack is not complete at this time. However, the overpack storage tubes have provisions for being adapted in the future to accept a lockdown plug similar to that on the standard tube plug. The tube plugs are protected by tube plug covers that support vehicular traffic (tube vent and purge cart) and protect the valves and filters on the tube plug from impacts. Each cover is uniquely numbered to identify its tube location. Embed covers prevent personnel and equipment from falling into vaults 2 and 3.

The standard plugs are mechanically fastened to the tubes to prevent an MCO rupture disk burst from lifting them off of their sealing surfaces, thereby allowing radioactive releases to bypass the plug HEPA filters and subsequent backflow of air into the tube. Mechanical fastening of each tube plug to the tube is accomplished using an eight-clamp lockdown mechanism; each of the eight clamps is hand tightened into place using a captive screw. Hand tightening the clamps is not required in order to ensure the plug-to-tube seal is effective. The clamps are provided to prevent the plug from lifting during overpressurization and seismic events. The clamping system includes an arrangement (spider) to prevent inadvertent attachment by the MMH grapple. The plug lockdown is designed to maintain the confinement function of the tube assembly system for all credible pressurization events, including the worst-case pressurization scenario. The plug lockdown is designed to hold the tube plug in place if the tube pressure reaches 524 kPa gauge (76 lb/in² gauge), which could occur if the MCO rupture disk burst. The lockdown mechanism is shown on Figure 4-5.

Impact absorbers are provided at the base of all storage tubes (bottom impact absorbers) and between the MCOs in the standard storage tubes (intermediate impact absorbers). A stainless steel bellows seals the operating area atmosphere from the vault. The bellows allows the storage tube to expand vertically. Tube base assemblies locate and attach the base of the storage tubes to the vault basemat. Storage tube center-to-center distances are the same as the embed dimensions, which are provided in Section 2.4.2 and shown on Figure 4-2. Released fabrication drawings for these components can be found in Appendix 4B.

4.3.5.3 Functional Requirements. The bottom impact absorbers protect the MCO from exceeding its structural integrity during an accidental drop from heights up to 13.4 m (44 ft) by limiting its deceleration to 35 g. Bottom impact absorbers also are required to protect the storage tube from exceeding the pipe wall material working strength of 5,170 kPa (750 lb/in²) during an MCO drop. Intermediate impact absorbers are provided to protect the pressure relief devices located atop the MCO shield plug and to ensure a gap through which the release of the lower MCO can be relieved.

The bellows are shall be designed to accommodate the calculated storage tube expansion of 0.01 m (0.432 in.) at -7 °C through 66 °C (20 °F through 150 °F). The architect-engineer has specified a maximum axial compression of 38 mm (1.5 in.) for the bellows. The tube and tube plugs are designed to ensure the tube atmosphere remains nonflammable by providing lines and an inerted enclosure. As stated in Section 2.4.4, the tube plug seals are specified to provide a leak rate less than 1×10^{-4} std cm³/s (3.5×10^{-9} std ft³/s) at a tube seal interstitial pressure of 27 kPa gauge (4 lb/in² gauge). The tube plug seals are will be designed to have a maximum leak-inleakage rate of 2.3×10^{-4} m³/s (8×10^{-3} ft³/s) at a storage tube pressure of 1.3 kPa (10 torr) relative to the operating area. Tube plugs are bolted to the storage tube and are designed to provide for 0.5 MPa gauge (76 lb/in² gauge) pressure containment of a burst MCO rupture disk. Calculations using the MCO volume of 1.0 m³ (35 ft³) indicate that 0.5 MPa gauge (76 lb/in² gauge) would be the resultant pressure in a storage tube. The storage tube, base assemblies, and slab embeds provide lateral restraint of the MCOs. Storage tube and plug process requirements are as follows.

- Design basis MCO (see also Bazinet 1996a)
 - Unvented MCO with 1.0 MPa gauge (150 lb/in² gauge) rupture disk
 - 61 cm (24.125 in.) outside shell diameter, 64 cm (25.25 in.) shield plug diameter, 406 cm (160 in.) length (without cover cap), or (165.6 in.) length (with cover cap)
 - Internal gas volume 0.5 m³ (17.9 ft³) minimum, 1.0 m³ (35.3 ft³) maximum
 - Hydrogen generation rate 0.4 g/s (10 standard ft³/min) maximum
 - Hydrogen generation quantity 1.1 kg (1.203 lb-moles)
 - Decay heat 80% of the average and 20% of the maximum MCO heat loads, which are given as 852 W maximum and 396 W average
 - Helium tube fill gas at 7 kPa to 28 kPa gauge (1 to 4 lb/in² gauge) normal pressure
 - Respirable Maximum 36 g release of particulate loading 100 mg/m³ from into the tube in the event of a burst MCO rupture disk
- Design basis impact absorbers (Bazinet 1997)
 - 6661 cm (2624 in.) maximum outside diameter and 122 cm (48 in.) maximum total combined length (maximum); 76 cm (30 in.) nominal length, bottom impact absorber (bottom and intermediate absorber lengths added together ≤ 122 cm (≤ 48 in.))
- Tube volume
 - 68.4 cm (26.93 in.) inner diameter, minimum
 - 11.1 m (36.375 ft) minimum clear length when empty with plug in place
- Tube design pressure
 - Full vacuum at 96 °C (205 °F)
 - 525 kPa gauge (76 lb/in² gauge) at 149 °C (300 °F)
- Plug relief set pressure
 - 62 kPa gauge (9 lb/in² gauge) for primary relief valve
 - 76 kPa gauge (11 lb/in² gauge) for back-up relief valve

- Sized for 0.3 m³/min (10 standard ft³/min) minimum flow at 483 kPa gauge (70 lb/in² gauge) tube pressure (Circle Seal¹ models 500-1M-9 and 500-1M-11 are acceptable)
- HEPA filters
 - HEPA efficiency (99.97% removal of 0.3 μm particles) required at full relief valve flow
 - 0.3 m³/min (10 standard ft³/min) minimum flow each at less than 1.7 MPa (7 in. of water [clean])
 - 1.3 grams minimum particulate capacity each
- Nonflammable atmosphere
 - 28 kPa gauge (4 lb/in² gauge) helium atmosphere to prevent air leakage
 - Reinerting with helium via a tube plug (see Figure 4-4) using the tube purge and vent cart (described in Section 4.3.7)
 - Tube plug seals designed to confine helium (leak rate < 1 × 10⁻⁴ standard cm³/s [3.5 × 10⁻⁹ standard ft³/s]) at a tube pressure of 28 kPa gauge (4 lb/in² gauge).

4.3.5.4 System Evaluation. The storage tube and base assemblies (which attach to the slab embeds) are designed to provide adequate restraint of the MCOs during all DBAs, including seismic. The storage tubes and bellows, tube base assemblies, plugs, and impact absorbers are classified safety-class (safety class 1) in accordance with approved procedures—Revision 1 of WNC CM 4-46.

The standard storage tube and tube plug are designed to Boiler and Pressure Vessel Code (ASME 1995a), Section VIII, Division 1, Subsection NE, Class MC. Supporting analysis is performed in accordance with ~~ANSI/AISC N690-94, Specification for the Design, Fabrication, and Erection of Steel Safety Related Structures for Nuclear Facilities (ANSI/AISC 1994).~~ The storage tube bellows are designed fabricated to ASME Section III, Division 1, Article NE-4800 (ASME 1995a), for high reliability. The standard tube plug body is designed, fabricated, inspected, and tested in accordance with the Boiler and Pressure Vessel Code (ASME 1995a), Section III, Subsection NE, Class MC. Standard tube plug valves and piping are designed, fabricated, inspected, and tested in accordance with ASME B31.3, *Chemical Plant and Petroleum Refinery Piping* (ASME 1995b). Piping material is in accordance with ASTM A53, *Standard Specification for Pipe, Steel, Black and Hot Dipped, Zinc-Coated, Welded and Seamless* (ASTM 1995b). The standard plug has a cast steel top (in accordance with ASTM A27/A27M [ASTM 1993c], Grade N2, Class 1, and ASTM A781/A781M [ASTM 1995a]) and concrete lower portion. The concrete barrel of the standard plug is constructed of SA36 material. The tube interior is accessed through two 5-cm (2-in.) holes drilled into the casting that connect

¹Circle Seal is a trademark of James-Pond-Clark.

to two 3.8-cm (1.5-in.-) diameter tubes. All structural welds on the plug are full penetration welds and are designed to withstand a 2.9-m (9.5-ft) drop of the plug onto the storage tube. The storage tube plug lifting lug is designed in accordance with ASME B30.20-1993, *Below-the-Hook Lifting Devices* (ASME 1993a). The tube base assemblies are designed to ANSI/AISC N690-94 (ANSI/AISC 1994).

The storage tube impact absorbers are specified to be drop tested to prove their ability to protect the MCO during a drop accident so as not to exceed 35 g MCO deceleration or any tube wall contact pressures. The impact absorbers are custom designed by the supplier to customer specified crush strength and dimensional envelope requirements. A candidate impact absorber material is a corrugated 304 stainless steel (ASTM A240) cell and core configuration that is metallurgically bonded by furnace brazing using nickel/chromium filler metal. The foil gauge ranges from a minimum of 0.0009 to 0.0060 in. The corrugation height ranges are 1/16 to 3/32 in. The crush strength of this type of impact absorber material is 150 to 8,000 lb/in². Final design configuration will be based on customer review of supplier proposed absorber material and actual drop test performance data.

The storage tube plug lifting lug is designed in accordance with ASME B30.20-1993, *Below-the-Hook Lifting Devices* (ASME 1993a). The tube plug uses two ethylene propylene O-rings for radiation resistance and to meet the leak rate requirement stated in Section 4.3.5.3. The O-rings have a service temperature range of -54 °C to 149 °C (-65 °F to 300 °F) and a resistance of 1×10^5 rad of gamma radiation (Parker 1989). The tube plug seals are exposed to 4.83×10^5 rad/yr (FDI 1996c, Calculation CSB-SH-2002). The anticipated O-ring service temperature is less than 65 °C (150 °F), which is the maximum expected air temperature inside the vault. The leak rate impacts only the frequency of tube purging/reinerting and is not an important parameter for evaluating facility safety of this system. The O-rings can be inspected, tested, and replaced if necessary using the MMH and second service pit the MMH service trench or FTF pit.

The tube has safety class functions for structural support of the MCOs and to maintain an inert gas envelope. These safety class functions are "important to safety" and NRC equivalency applies. Application of NRC Regulatory Guide 1.26 (NRC 1976), required by WNC SD SNF DB 003 (Garvin 1996a), to the latter function indicates a quality group-D classification. Therefore, API 5L pipe is acceptable for the storage tube material. Tube confinement of radioactive material is required for either an MCO rupture disk failure or MCO drop event. Unmitigated consequence calculations show these events to require safety significant mitigation features. The Boiler and Pressure Vessel Code (ASME 1995), Section VIII, is applicable to this case. The API 5L material will be qualified to A 36 under paragraph UG-10 of Section VIII (ASME 1995).

The storage tube assemblies comprise a stainless steel bellows assembly and a carbon steel tube assembly. The storage tube is specified to be fabricated from API 5L grade BCS material. This manufactured component has been evaluated by a consulting team for compliance with the intent of the requirements in the Boiler and Pressure Vessel Code (ASME 1995a), Section III, Division I, Subsection NE, Class MC (Williams 1997). The evaluation team also compared the applicability of Subsection NE (ASME 1995a) against Subsection NC (ASME 1995a). The comparison of Subsection NE (ASME 1995a) with Subsection NC

(ASME 1995a) concluded that there was no significant difference (Williams 1997). The evaluation team concluded that the plate materials used, the manufacturing processes employed, and the inspections performed by the tube fabricator in accordance with their quality assurance procedures (NAPA 1996) comply with the intent of the Boiler and Pressure Vessel Code (ASME 1995a), Subsection NE code. One noted exception to Subsection NE (ASME 1995a) or Subsection NC (ASME 1995a) equivalency is in the final weld examination. The manufactured pipe sections from which the storage tube assemblies are to be fabricated will be examined using the ultrasonic test method, in accordance with the Boiler and Pressure Vessel Code (ASME 1995a), Section V, as permitted by Section III, Subsection NE-5211.1(b), using acceptance criteria contained in Section III, Subsection NE-5330.

The material properties of candidate tube materials are listed in Table 4-5. The table includes use of API 5L (both standard and as procured plate) pipe as an acceptable substitute for the storage tube. Fabrication and testing requirements for the four three candidate materials are listed in Table 4-6. Standard and overpack storage tube assemblies are required to be pneumatic pressure tested by the fabricator, in accordance with the requirements of the Boiler and Pressure Vessel Code (ASME 1995a), Section III, Division 1, Class MC, Subsection NE, Article NE-6300, using helium gas at a pressure of 82 kPa gauge (12 lb/in² gauge). Ongoing safety analyses for the MCO drop accident indicate that the unmitigated offsite release is less than 0.5 rem. The reduction in risk from a pressurized release from an MCO only requires a safety significant function, as shown in Section 3.4.2.1. Project criteria require that the tube material be compatible with ASME Section VIII (ASME 1995). Existing API 5L material can be recertified by the manufacturer or qualified by a commercial grade item dedication process.

Table 4-5. Storage Tube Material Properties.

Property	Pipe SA-671 Grade CC60	Roller-plate SA-36	Pipe API 5L	NAPA pipe (API 5L) submitted data
Yield strength	> 32 ksi	> 36 ksi	> 35 ksi	39.8 - 44.5 ksi
Tensile strength	60 - 80 ksi	58 - 80 ksi	> 60 ksi	57.5 - 62.0 ksi
Carbon	< 0.21%	< 0.25%	< 0.27%	0.06 - 0.09%
Manganese	0.60 - 1.20%	Not controlled	< 1.15%	0.43 - 0.56%
Phosphorus	< 0.035%	< 0.040%	< 0.030%	0.002 - 0.007%
Sulfur	< 0.035%	< 0.050%	< 0.030%	0.004 - 0.006%
Silicon	0.15 - 0.40%	< 0.40%	Not controlled	0.22 - 0.27%

CSB - Canister Storage Building.

Table 4-6. Storage Tube Fabrication and Testing.

	Pipe SA-671 Grade-CC60	Rolled plate SA-36	Pipe ARIEL	CSB
Weld (circumferential and longitudinal)	Double-welded full penetration butt	Double-welded full penetration butt	Full penetration butt may be double-welded	Straight seam, double submerged arc, full penetration butt weld
Welder qualification	ASME IX ¹	ASME IX ¹	Not controlled	In-plant certified
Diameter tolerance	$\pm 5\%$ based on circumference	$\pm 1\%$	$\pm 1\%$	$\pm 0.75\% - 0.25\%$
Out of roundness	$\pm 1\%$	$\pm 1\%$	$\pm 1\%$	$\pm 0.75\%$
Alignment	$< 1/8$ in. in 10 ft	$< 0.2\%$ of length from a straight line	0.2% of length from a straight line	$< 0.198\%$ of length (0.04 in. in 20 ft, 7 in.)
Thickness	Not less than 0.01 in. of nominal pipe wall and standard plate tolerance	Not less than 0.01 in. of nominal pipe wall and standard plate tolerance	Not less than 0.1 in. or 28% greater than nominal pipe wall	Not less than 0.01 in. or 28% greater than nominal pipe wall
Product inspection	100% radiography	100% radiography	100% radiography	100% radiography
Product testing	<ul style="list-style-type: none"> ▲ Mill certs of plate ▲ Chemical analysis of weld each 300 ft ▲ Tensile test each lot of finished pipe ▲ Bend test each lot 	<ul style="list-style-type: none"> ▲ Mill certs of plate 	<ul style="list-style-type: none"> ▲ Mill certs of plate ▲ Chemical analysis of weld each heat ▲ Tensile test each 100 lengths of pipe (weld, longitudinal, and transverse) ▲ Bend test each 10 lengths ▲ Hydrostatic test (at 750 TSI/ft²) ▲ Dimensional testing 	<ul style="list-style-type: none"> ▲ Mill certs of plate ▲ Visual inspection ▲ Cold expansion ▲ Hydrostatic test at 750 TSI/ft² ▲ Dimensional inspection ▲ Film radiographic examination of pipe ends ▲ Ultrasonic inspection of weld ▲ Ultrasonic inspection of pipe ends ▲ Joints will not be furnished ▲ Mechanical testing of first pipe from each heat or lot ▲ Transverse pipe body tensile test ▲ Weld tensile test ▲ Guided bend test ▲ Certified test report

¹ASME, 1995, Boiler and Pressure Vessel Code, American Society of Mechanical Engineers, New York, New York.

CSB = Canister Storage Building.

The vault is designed to ensure that the fuel centerline temperature never exceeds 204 °C (400 °F) under steady state conditions (Heard 1996). The highest calculated storage tube temperature is 96 °C (204 °F) (Figure 4-3), coincident with a site ambient temperature of 46 °C (115 °F) (Figure 4-1) and a flow rate through the vault of 775 m³/min (27,340 ft³/min). This value, shown on Figure 4-3, is These values are from information contained in Appendix E of Calculation CSB-HV-0001 (FDI 1996a). Other temperature values of interest can be found on Figure 4-3. The cooling passages in the tube base assemblies provide thermal isolation of the concrete vault basemat and of the steel embeds from the storage tube to ensure that the concrete's temperature limit of 66 °C (150 °F) is not exceeded.

After cold vacuum drying, residual water will not be readily released from the MCO. There will be gradual chemical reactions of hydrides and radiolysis of bound water. Periodic storage tube purging and venting is expected to maintain the storage tube atmosphere below saturation and thereby eliminate corrosion from condensation on the carbon steel tube surfaces. The reader is asked to refer to WHC-SD-SNF-TI-029, *Multi-Canister Overpack (MCO) Pressurization Analysis* (Duncan Bergsman 1996), Section 2.3, which states, "The vacuum drying process operating at 50 °C and 0.5 torr is designed to effectively remove all free water." Any water that is generated in the CSB by decomposition of hydrates at higher temperatures will quickly react with the excess uranium metal present, as discussed in Sections 4.2.2 through 4.2.4 of WHC-SD-SNF-TI-029 (Duncan 1996) the analysis.

MCO storage tube interaction Analysis of the interaction of the MCO with the storage tube during a DBE event was performed (Jacobs 1996c). The storage tube materials consulting team evaluated the allowable stresses used in Calculation CSB-S-0007 (FDI 1996c). The storage tube analyses were performed to ASME Section VIII in accordance with Revision 5 of the SAR. The consulting team noted that designs using the formula approach of NE-33000 (ASME 1995a) are 1.1 times the values that would be allowed under the Section VIII rules (Williams 1997). The Section III report will not affect the adequacy of the design as noted above. The nonlinear dynamic analysis determined the maximum stress in the storage tube and the reactions at the top and bottom supports of the tube.

- Maximum results, east-west direction (seismic only, no offsets)

- Bending stress in tube, 10.9 ksi (Node 9 [see Figure 2])
- Top reaction, 32.3 kips (Node 40 [top node])
- Bottom reaction, 42.7 kips (Node 1 [bottom node])

- Maximum results, north-south direction (seismic only, no offsets)

- Bending stress in tube, 10.4 ksi (Node 10 [see Figure 2])
- Top reaction, 30.9 kips (Node 40 [top node])
- Bottom reaction, 43.9 kips (Node 1 [bottom node])

The results presented above are for an individual storage tube, and the worst stresses resulted from the input motions having mean soil properties times two. Subsequent analyses for the effects of tolerances and offsets (FDI 1996c, Calculation CSB-S-0007A, Appendix L) for these soil properties resulted in a maximum stress of 11.9 ksi (MCO offset -0.4375 in.) A maximum

seismic bending stress of 12.0 ksi was used in further investigations in Calculation CSB-S-0007A, Appendix K (FDI 1996c).

The storage tube assembly was investigated for compliance with the requirements of the Boiler and Pressure Vessel Code (ASME 1995a) for operational conditions only without seismic. These calculations are included as a reference in Calculation CSB-S-0007A, Appendix K (FDI 1996c). Modifications to the storage tube assembly design as identified in this investigation were incorporated and form the basis for the design used in this current analysis. This current analysis supplements the previous one by incorporating the effects of seismic.

Operational conditions of the storage tube assembly present during the seismic event included an elevated operating temperature of 104 °C (220 °F), an operating pressure of 690 kPa (100 lb/in² gauge), plug weight and gravity. This maximum combined loading condition resulted in a maximum combined stress in the storage tube assembly of 13.4 ksi. This maximum combined tension stress occurred in the vertical wall section of the storage tube assembly corresponding to element 8. The allowable for this combined stress condition according to the requirements of the Boiler and Pressure Vessel Code (ASME 1995a), Section VIII, Division 1, is 29.0 ksi. Calculations for demonstrating this are included in Calculation CSB-S-0007A, Appendix K (FDI 1996c).

The governing condition turned out to be that for seismic + thermal + gravity (no internal pressure). This resulted in a maximum compression stress for design of approximately 12.0 ksi (FDI 1996c, Calculation CSB-S-0007A, Appendix K), which governed. The allowable for compression is only 17.0 ksi according to the requirements of the Boiler and Pressure Vessel Code (ASME 1995a), Section VIII, Division 1.

Since the maximum combined stress is less than the allowable, the storage tube assembly design is in compliance with the requirements of the Boiler and Pressure Vessel Code (ASME 1995a), Section VIII, Division 1. Table 4-7 provides the demand and capacity of the storage tube.

Table 4-7. Storage Tube Demand and Capacity Ratios.

Location	Demand	Capacity	Demand/capacity ratio
Tube bending (between MCOs)	14.8 ksi	32.6 ksi	0.45
Top reaction	36.7 kip	129 kips	0.28
Bottom reaction	44.2 kip	83.2 kip	0.53

MCO = multicanister overpack.

Analysis of eccentric and concentric tube plug drops and of an eccentric MCO drop into a storage tube were performed (FDI 1996c, Calculation CSB-S-0050). These analyses were performed using a three-dimensional finite

element model of the storage tube assembly, including details of the top flange and concrete deck embed. The model was analyzed using MARC software (MARC 1996), a nonlinear finite element code capable of performing nonlinear buckling analyses.

The results of the analysis of an eccentric tube plug drop from a 2.9-m (9.5-ft) height (FDI 1996c, Calculation CSB-S-0050, Appendix B) indicate that a significant amount of local damage to the contacted portion of the tube flange occurs. The resulting net diameter decrease was determined to be 1.35 cm (0.53 in.), which results in a decrease of the inner tube to MCO radial clearance to 1.09 cm (0.43 in.) from 1.75 cm (0.69 in.). The resulting tube to tube plug radial clearance is reduced to 0.13 cm (0.05 in.) from 0.81 cm (0.32 in.). These deformations occur at approximately 30.48 cm (12 in.) below the flange. The tube plug can be reinserted (although it is a tight fit) and the MCO placed or removed.

Results of the analysis of a concentric tube plug drop onto the tube flange (FDI 1996c, Calculation CSB-S-0050, Appendix D) indicate that negligible permanent damage occurs. The resultant net decrease in the inner diameter was determined to be negligible. The drop of a concentric tube plug will not affect tube plug or MCO placement.

Results of the analysis of an eccentric drop of an MCO onto the tube flange (FDI 1996c, Calculation CSB-S-0050, Appendix C) indicate that significant damage occurs to the tube assembly. In case 1, the maximum tube net diameter decrease when the tube flange is in full contact with the concrete was determined to be 2.08 cm (0.82 in.). This results in an MCO to tube radial clearance of 0.71 cm (0.28 in.). In case 1, approximately 40% of the dropping MCO kinetic energy is absorbed in deforming the tube. The remaining 60% is absorbed in deforming the MCO and displacing the concrete. Tube plug reinsertion is prevented by a 0.25 cm (0.1 in.) radial interference. In case 2, allowing the concrete to deform up to an additional 2.54 cm (1 in.) after full flange contact with the concrete results in a minimum radial clearance of 0.05 cm (0.02 in.) around the MCO from a permanent tube deformation of 3.43 cm (1.35 in.). This permanent deformation occurs at approximately 45.72 cm (18 in.) below the tube flange and is equivalent to the tube absorbing 75% of the dropped MCO's kinetic energy. This would still allow removal of the MCO, but barely. Placement of the tube plug is precluded by the tube deformation, an average radial interference of 0.89 cm (0.35 in.) for the case 2 results. A summary of the results is found in Table 4-5.

Analyses of concentric MCO drops have shown that the MCO shell when fully loaded will not yield when exposed to accelerations below 150 g and will not buckle (become unstable) until the accelerations reach 700 g (Hyde 1996). By review of the analysis results, it is apparent that the MCO wall does not expand to values greater than 1.3 cm (0.5 in.) until exposed to more than 300 g. Analysis of the postulated MCO drops into the storage tubes shows that the accelerations on the MCO when dropped into the CSB storage tube with impact absorbers is well below 100 g (Hyde 1996). Thus the MCO will not impose any lateral loads on the storage tube because of wall deformation resulting from a drop.

Table 4-5. Summary of Average Clearances Resulting from Tube Plug and Multicanister Overpack Drop.

Drop case	Tube inner diameter reduction (in.)	Resulting average clearances (in.)	
		MCO	Plug
Undamaged condition		+0.69	+0.32
Eccentric tube plug	0.53	+0.43	+0.05
Concentric tube plug	nil	+0.53	+0.32
Eccentric MCO (40% KE)	0.82	+0.28	-.1 (interference)
Eccentric MCO (75% KE)	1.35	+0.02	-.35 (interference)

KE = kinetic energy.
MCO = multicanister overpack.

Each plug is supported by the top inclined face of the tube below the bellows (Figure 4-52-10). If moisture were present, the area where the steel plug rests on the steel tube could rust together and potentially prevent plug removal; moisture and rust, however, have been prevented by the building design. During building construction, the contractor is responsible for preventing rust or other damage to the polished sealing surfaces on the tubes and plugs (see note on Drawing H-2-120394, DCN-029, sheet 5 [Appendix 4B]). The corrosion protection applied to the tube and plug sealing surfaces will not be removed until the building superstructure and heating, ventilating, and air conditioning (HVAC) system are complete. This precaution is necessary mostly to ensure the necessary leak-tightness quality of the seals. The presence of rust or grit will prevent proper sealing. The superstructure roof and walls are especially essentially leak-proof, designed to withstand the NRC-equivalent design basis tornado or rainfall. No systems or equipment in the operating area contain water or can deliver water by accident into the operating area. Furthermore, after the tubes are installed, water is not required for construction, startup, or maintenance in the operating area.

Moisture from the air cannot condense on a surface unless the temperature of the surface is at or below the dew point of the air. Since dew point measurements were begun in 1946, the dew point at the Hanford Site has exceeded 13 °C (55 °F) for only a few hours during one month of July, and has never exceeded 21 °C (70 °F) (Stone et al. 1983). Once the HVAC system is started up, the building operating shelter temperature will be maintained at an average of 22 °C (+6 °C) (72 °F [+12 °F]). Therefore, before fuel is loaded into the vault, the operating deck temperature will average 22 °C (72 °F), which is well above the recorded maximum dew point. After fuel is loaded, the decay heat from the MCOs will warm the deck above 24 °C (75 °F) but below 66 °C (150 °F). In the relatively dry climate at the site, it is unlikely that the amount of corrosion that will occur will prevent plug removal.

The shock wave created by hydrogen deflagration in the tube has the potential of breaking the tube plug seal and bursting the rupture disk on the MCO, creating a pathway for the unfiltered release of fuel particulate with possible safety-class consequences. This is prevented by requiring that the tube be pressure-purged until the hydrogen concentration in the tube is below its lower flammability limit in air.

4.3.5.5 Controls (Technical Safety Requirements).— Meeting the requirement to maintain the MCO pressure below its 1.0 MPa gauge (150 lb/in² gauge) design pressure and the ability of the vault design to keep the fuel temperature low enough to prevent spontaneous decomposition depends on factors outside the CSB. The hydrogen generation rate inside the MCO relates directly to the quantity of free water and to the chemical composition of fuel and crud and to the tube service intervals. These factors are controlled by K Basin fuel washing or sorting and MCO loading and CVDS process of water removal. Maintaining the storage tube pressure above the operating area atmosphere pressure is credited with keeping air (oxygen) from entering the tube and creating a flammable atmosphere. Therefore, the tube pressure must be periodically monitored by visual tube pressure gauge readings for the normal pressure conditions (6.9 kPa to 27.6 kPa gauge [1.0 lb/in² to 4.0 lb/in² gauge]) and the inert gas replenished periodically as inert gas from the storage tube leaks out past the seals. Excess pressure in the tube (above 27.6 kPa gauge but below 55.2 kPa gauge [above 4.0 lb/in² gauge but below 8.0 lb/in² gauge]) may indicate MCO pressure relief valve actuation. The tube vent and purge cart is provided to control periodic pressure purging and, thereby, the tubes' gas concentration and pressure. Administrative procedures need to be in place to ensure that the tube lockdown devices are in place and, thereby, ensure that the plug will not lift as a result of seismic events or of MCO pressure relief into the tube. TSRs that address tube seal failure, recovery actions, and relief valve testing will be developed and included in the final SAR. The eccentric drop of a tube plug or MCO, if not precluded by the MHM hoist and grapple, must be precluded by the design of the MHM positioning system. Administrative procedures need to be in place to ensure a bottom or intermediate impact absorber(s) are in place before placement of an MCO.

4.3.6 Canister Storage Building Above-Grade Structures (Intake Structure, Exhaust Stack, and Operating Area Shelter)

4.3.6.1 Safety Function. The intake structure and exhaust stack are integral parts of the CSB's safety-class (safety class 1) passive cooling system, and as such, they are designed for safety-class (safety class 1) DBE and tornado wind loads. The operating area shelter is considered defense in depth classified as safety-class 3, however, it is designed so that its failure will not result in failure of the safety-class (safety class 1) deck below. Therefore the operating area shelter is designed for safety-class (safety class 1) DBE and tornado wind loads.

4.3.6.2 System Description. The CSB intake structure is a 5.2 m x 5.5 m x 6.7 m high (17 ft x 18 ft x 22 ft high) welded steel structure weighing 867,000 lb mounted on top of a 4.6 m x 6.1 m x 17.4 m high (15 ft x 20 ft x 57 ft high) reinforced concrete tower that is constructed monolithically with the CSB vault. The steel portion of the intake structure (tower) is a

combination of a braced tubular steel frame with steel shear panels at the base. ~~(This sentence has been moved to Section 4.3.6.4.)~~ The tower is analyzed and designed as an integral part of the CSB vault structure (Calculation CSB-S-0029A). Intake structure drawings, H-2-119294 and H-2-119298, are included in Appendix 4A.

The exhaust stack is a self-supporting 49.2-m (161.5-ft) tall cantilevered structure. The diameter at the base of the stack is 4.0 m (13 ft); the diameter at the top of the stack is 2.1 m (7 ft). The bottom section of the 4.0-m- (13-ft-) diameter stack base rises 16.8 m (55 ft) and is constructed of 16-mm- (5/8-in.-) thick steel plate. The bottom section of the exhaust stack is attached to a reinforced concrete foundation 3.5 m (11 ft, 6 in.) in diameter and 1.4 m (4 ft, 6 in.) thick. The middle section continues upward 10.1 m (33 ft) and tapers from 4.0 m to 2.1 m (13 ft to 7 ft) in diameter. The middle section is constructed of 16-mm- (5/8-in.-) thick steel plate. The 2.1-m- (7-ft-) diameter top section of the stack continues upward another 17.4 m (57 ft) and is constructed of 9-mm- (3/8-in.-) thick steel plate. The upper 13.4-m (44-ft) section of the stack is provided with vertical wind spoilers that are each 0.2 m tall by 3.4 m long (7 in. tall by 11 ft long). The spoilers are also made of 9-mm- (3/8-in.-) thick steel plate and are designed to ASCE-7-88 guidance (ASCE 1988). Stack material is ASTM-242 or ASTM-A588 Grade A (345 MPa [50,000 lb/in²] yield). ~~(The following sentence has been moved to Section 4.3.6.4.)~~ Thermal gradients across the stack are of minimal design concern for the materials and temperatures involved. The stack is topped by a wind deflector tip as shown on drawing H-2-119300 (sheet 2). This drawing and the drawing showing the entire exhaust stack, H-2-119300 (sheet 1) are included in Appendix 4A.

The operating area shelter is a steel-framed enclosure that covers the vault operating deck, the load-in/load-out area on the north and the HCS Annex on the south. The building is approximately 70.1 m long, 41.5 m wide, and 16.8 m high (230 ft long, 136 ft wide, and 55 ft high) and sits on a 0.9-m- (3-ft-) high concrete curb around the vault deck. The structural system consists of load-carrying roof trusses spanning the east-west direction and supported by columns spaced typically at 6.2 m (20 ft, 4 in.) centers. Seismic and tornado lateral forces are resisted through truss-column frame interaction in the east-west direction and through a vertical bracing system along the east and west walls in the north-south direction. Building plan and elevation drawings, H-2-119311, H-2-119312, H-2-119313 (sheets 1 and 2), and H-2-119314 (sheet 1), are included in Appendix 4A.

4.3.6.3 Functional Requirements. The intake structure and exhaust stack for the CSB vault must provide airflow adequate to prevent overheating of the SNF materials caused by damage from the DBE, tornado winds, or other NPH events such as ashfall. The operating area shelter must not be damaged by the DBE or other events so that safety-class (safety class 1) items under shelter (i.e., the vault deck) can maintain their safety functions.

Operating shelter design basis loads are given in Section 4.3.4.3. A summary of loads considered in the design of the intake structure and exhaust stack is given below.

- Intake structure

- Roof and structure dead load, 64 kips
 - Roof live load 98 kg/m^2 (20 lb/ft^2)
 - Snow load at ground level 98 kg/m^2 (20 lb/ft^2)
 - Extreme wind 145 km/h (90 mi/h)
 - Tornado wind 320 km/h (200 mi/h)
 - DBE seismic safety class (safety class 1) free-field response spectra applied at base of supporting tower analyzed as part of the vault-CSB building model
 - Volcanic ashfall roof-ground load 117 ~~132~~ kg/m^2 (24 ~~27~~ lb/ft^2), dry uncompacted
- Exhaust stack
 - Structure dead load
 - Extreme wind 160 km/h (100 mi/h)
 - Tornado 320 km/h (200 mi/h)
 - DBE seismic safety class (safety class 1) free-field response spectra applied at base of stack.

4.3.6.4 System Evaluation. The intake structure, exhaust stack and operating area shelter are designed to be resistant to safety-class (safety class 1) DBE and tornado winds. These structures have been designed for all applicable loads and load combinations as defined in Section 10 of the Design Basis Document (Bedell 1996). The loads include normal loads, severe and extreme environmental loads, natural phenomena loads, and any DBAs identified to date by safety analysis.

The tower is analyzed and designed as an integral part of the CSB vault structure (Calculation CSB-S-0028A). In the vault gravity and seismic analysis, the intake housings were modeled as lumped masses located at the proper elevation on top of the concrete towers, which were modeled using plate elements. The reinforced concrete towers were designed based on the loads from the vault gravity and seismic load models. In-structure-response-spectra at the base of the towers enveloping 1/2 mean, mean, and 2 x mean soil properties were developed using the vault seismic model. To design the steel housing, a single model was created that included a detailed model of the steel housing on top of a stick model of the intake tower. The enveloped response spectra at the base of the towers developed from the vault model were used as input motion for the intake structure-tower model. Gravity and tornado loads were applied as static loads in the design of the steel structure. Deflections representative of tornado wind and seismic loads are listed in Table 4-6.

Table 4-6. Deflections at Top of Intake Structure and Exhaust Stack.

	Tornado loading			Seismic loading				
	East-west (in.)	North-south (in.)	Vertical (in.)	Soil properties	East-west (in.)	North-south (in.)	Vertical (in.)	SRES (in.)
Intake structure top of concrete	0.04	0.02	0.00	Enveloped response spectra	0.13	0.09	0.00	0.16
Intake structure top of steel	0.10	0.07	0.01		0.25	0.18	0.00	0.31
Exhaust stack top of steel stack	13.37	13.31	0.03	1/2 x mean	4.95	4.96	0.03	7.00
				Mean	5.43	5.35	0.07	7.62
				2 x mean	5.26	5.34	0.02	7.50

SRES = square root of the sum of the squares.

The exhaust stack was redesigned for tornado loading in Revision 1 of Calculation CSB-S-0012 (FDI 1996c). At that time, the internal loads and moments for the 322 km/h (200 mi/h) tornado load were developed and the stack design was modified as required. The "CV=1.0 and Top of Competent Layer" confirmatory analysis of the exhaust stack was performed in Calculation CSB-S-0045 (FDI 1996c). The general procedure was to compare shears and moment results for the exhaust stack obtained from the three-dimensional SAP90 vault model with the design shears and moments for tornado from Calculation CSB-S-0012 (FDI 1996c). The results for the exhaust stack for the 1/2 mean, mean, and 2 x mean soil property analyses of the vault were obtained. These loads were then compared with the tornado design loads from Calculation CSB-S-0012 (FDI 1996c). It was found that the tornado loads were 55% higher at the base of the stack and 14% higher at the bottom of the 2.1-m- (7-ft-) diameter section. Based on these results, the stack was deemed adequate for the revised seismic loads. In addition, the adequacy of the anchor bolts for the heavier stacks (due to concrete shielding on the lower segments) for vaults 2 and 3 was checked using the revised vault seismic loads. Thermal gradients across the stack are of minimal design concern for the materials and temperatures involved.

Loads considered for the functional requirements of the operating area shelter are summarized in Section 4.3.4.3. The operating shelter structure was designed for the design basis wind and DBE (free-field response at the bottom of base plates) used in Calculation CSB-S-0010 (FDI 1996c). In response to a change in project criteria, the operating shelter was redesigned to include the design basis tornado in used in Calculation CSB-S-0029 (FDI 1996c). Subsequent to that, enveloped base plate response spectra for the design of the operating shelter were developed, based on a soil property coefficient of variation of 1.0 and the application of the control motion to the top of the competent layer (FDI 1996c, Calculation CSB-S-0040). In Calculation CSB-S-0048 (FDI 1996c), the three-dimensional model of the shelter was subjected to the enveloped response spectra, and the members and connections were re-evaluated. The demand-to-capacity ratios reported in Table 4-4 include the tornado and revised seismic loads. With reference to the operating area shelter, the combination of dead plus live load with

tornado wind results in demand to capacity ratios that are lower than dead load plus tornado wind. This is because the dead plus live loads result in compression loading, whereas the tornado wind loads result in tension loading. Tornado wind loads, therefore, unload the column members from compressive loading to tension loading. Thus, the limiting governing load combinations for tension are those with dead load plus tornado wind, and the limiting governing load combinations for compression are the ones where earthquake is combined with dead load alone. Demand to capacity ratios of load combinations for dead plus live with tornado wind are shown on Table 4-4. Demand to capacity ratios of dead load plus earthquake (free-field and at top of competent layer with $C_e = 1.0$), dead plus tornado wind, and dead plus snow with ashfall loads are also shown on Table 4-4.

The safety-class (safety class 1) wind missile specified in the Design Basis Document (Bedell 1996a) (15-lb 2x4 with a horizontal velocity of 22 m/s [73.5 ft/s] and maximum height of 15 m [50 ft]) is consistent with DOE-STD-1020-94 and DOE-RL-HPS-SDC-4.1, Revisions 11 and 12. The steel barrier thickness required to prevent penetration from this missile is one sheet of 13 gauge or two sheets of 18 gauge material (Bedell 1996, Section 10B, page 26). The siding provided for the operating shelter is two sheets of 18 gauge.

The siding and structural framing for the operating shelter were evaluated for impact from the wind-generated missile in Calculation CSB-S-0010, Sheets 107 through 109 (FDI 1996c). The siding and girts (the lightest framing members) were evaluated directly and found to be adequate for the safety-class (safety class 1) missile impact. Based on the ratio of the missile mass to the effective mass of the main framing members, the effect of the missile loads on the main framing members was deemed to be insignificant. Subsequent to this analysis, the main framing members for the operating shelter were increased in size due to the imposition of the tornado loading, and therefore no further consideration of wind-generated missiles was necessary.

[This material has been moved to Section 4.3.6.3.] Operating shelter design basis loads are given in Section 4.3.4.3. A summary of loads considered in the design of the intake structure and exhaust stack is given below:

• Intake structure

Roof and structure dead load, 64 kips

Roof live load 98 kg/m^2 (20 lb/ft²)

Snow load at ground level 98 kg/m^2 (20 lb/ft²)

Extreme wind 145 km/h (90 mi/h)

Tornado wind 320 km/h (200 mi/h)

DBE seismic safety class (safety class 1) free field response spectra applied at base of supporting tower analyzed as part of the vault CSB building model

Volcanic ashfall roof ground load 117 132 kg/m² (24 27 lb/ft²),
dry uncompacted

• Exhaust stack

Structure dead load

Extreme wind 160 km/h (100 mi/h)

Tornado 320 km/h (200 mi/h)

DBE seismic safety class (safety class 1) free field response
spectra applied at base of stack.

4.3.6.5 Controls (Technical Safety Requirements). Intrusion protection features must be evaluated for flow blockage and additional seismic response loads. Specific modifications to the CSB related to future missions not yet incorporated into the design (e.g., high-level waste, security and safeguards) must be accomplished without violating the safety basis of the SNF CSB design.

4.3.7 Tube Vent and Purge Cart

4.3.7.1 Safety Function. The tube vent and purge cart provides the safety-class function of ensuring that the tube atmosphere remains nonflammable and the safety-significant function of ensuring confinement under all credible accident conditions. Nonflammable conditions are ensured by monitoring and maintaining an inert gas environment around the MCO during staging in the MCO storage tubes and by verifying that the MCO does not contain a hazardous quantity of hydrogen before the tube plug locking mechanism is unlatched in preparation for moving the MCO from staging to hot conditioning. Confinement is ensured by providing a HEPA-filtered pathway for controlled venting of gases that may have built up in the storage tubes from relief of pressure from staged MCOs. The tube vent and purge cart design precludes air ingress should the tube gas concentration exceed 4% hydrogen. The tube vent and purge cart is shown on Drawing H-2-120911, which is included in Appendix 4B. The piping and instrumentation diagram is shown on Figure 4-13.

The inert atmosphere in the tube is initially supplied from the high-pressure inert gas bottles on the cart after the air in the accessed tube is evacuated using the cart's vacuum pump. Pressurization with inert gas is controlled through a pressure regulator and relief valve that prevent overpressurization of the tube; two relief valves on the tube plug offer redundant protection. When inerting is finished, the tube pressure is slightly positive (28 kPa gauge [4 lb/in² gauge]). The schedule for venting, purging, and inerting the tubes is set so the pressure inside the tubes is maintained between about 7 kPa and 41 kPa gauge (1 lb/in² and 6 lb/in² gauge). The pressure increases to about 48 kPa gauge (7 lb/in² gauge) if hydrogen is released from one of the MCO pressure relief valves; release of hydrogen is expected from fewer than 1% of the MCOs. Because temperature variations in the vault affect the tube pressures, pressure is not a sensitive indication of hydrogen concentration. Instead, the hydrogen concentration is measured each time the cart makes a scheduled visit to a tube. If an MCO relief has occurred, the hydrogen concentration in the tube may exceed 4%. In this

event, the tube gas will be diluted to below 4% before release to the operating area and before use of the vacuum pump. Tubes used for storage of hot-conditioned MCOs are not expected to release hydrogen. Even if hydrogen is not released from an MCO, the tube needs to be reinitiated about every 6 months to make up for helium leakage through the tube seals. Gas pressure is relied on to prevent air intake.

The cart's vacuum pump is used to reduce the pressure in the tube before unlatching the plug to ensure that a sudden release from the MCO through the rupture disk could not raise the tube pressure above 48 kPa gauge (7 lb/in² gauge), which could lift the unlatched 2,404-kg (5,300-lb) tube plug, breaking the tube's confinement barrier. Drawing a vacuum on the tube verifies that the pressure differential between the tube and MCO is low enough that such an event could not occur. The weight of the unlatched plug will confine a release from the MCO relief valve, but not from the rupture disk. The rate of pressure rise for an MCO which has just been received from the CVDF and placed in a storage tube is approximately 7 kPa gauge (1.0 lb/in² gauge) per hour (Lorenz 1997), a value that bounds the rate of pressure rise inside an MCO that has been depleted of available reactants (water, hydrates, and hydrides).

4.3.7.2 System Description. The tube vent and purge cart is a utility vehicle incorporating the standards in ASME B56.8, *Safety Standard for Personnel and Burden Carriers* (ASME 1993b, including the 1994 addenda), and the requirements in Title 29, *Code of Federal Regulations*, Part 1910, "Occupational Safety and Health Standards," Section 1910.178 (29 CFR 1910). The designed life expectancy of 6 years has been assigned to each cart under full use. The rear bed of the vehicle is designed to carry all of the necessary equipment required to perform tube venting, evacuation sampling, radiation monitoring, combustible gas detection, oxygen level monitoring, and inert gas delivery. The rated load capacity is specified to be at least 1,360 kg (3,000 lb). The piping and instrumentation is depicted in Figure 4-13.

With the cart in position at the MCO tube, the tube access cover removed, and external power connected to the cart, the design flow path of gases begins with the connection and alignment of the purge cart (safety class 1 and 2) system components. The quick-disconnect fitting along with the 2 in. by 9.5 ft flexible steel hose is attached to the tube plug connection from the cart. The gas is then vented via the 2-in. flexible steel hose, through a 2-in. stainless steel pipe, branching off to a 3/4-in. ball valve, then through a 3/4-in. to 1/2-in. reducer, and on to 1/2-in. stainless steel piping. The gas flow continues on to a gas heat exchanger that reduces the temperature of the gas to a level that is within the design parameters of the gas analyzers. Gas flow continues from the heat exchanger through a 1/2-in. stainless steel pipe that divides the gas flow into four parallel paths. The first path is connected to a CAM and the second path is connected to a gas monitor. These two loops provide a means to monitor the radiation level of the gases leaving the MCO. The remaining two parallel loops provide connections for two safety-class (safety class 1) hydrogen monitors and controllers that automatically prevent use of the vacuum pump if the hydrogen concentration is 4% or greater. A 1/2-in. stainless steel pipe connects the four parallel downstream exhausts of the analyzers through a flow switch, to a 1/2-in. to 3/4-in. reducer, and then to a 3/4-in. ball valve and a connection with the original 2-in. stainless steel piping. The intake and exhaust of

this sample loop is isolated by a 2-in. ball valve that allows the full flow to bypass the sample loop after the safety of the MCO gases has been established. The 2-in. piping continues on to the first of two HEPA filters (one primary and one secondary) connected in series by a 6-in. stainless steel pipe.

The safety-significant (safety class 2) components of the tube vent and purge cart are as follows:

- Quick-disconnect fitting

Female NPT 316 stainless steel, Viton² seals, flush face/dry break type, 20.7 MPa (3,000 lb/in²) working pressure, S71-1C32-32fv

- Flexible steel hose

2-in. annular corrugated, single braid, 12.4 MPa (1,800 lb/in²) burst pressure, 304L stainless steel core and 304 stainless steel wire braid, class 150 floating flange 304 stainless steel and plain male NPT schedule 40S 304L stainless steel end connections

- 2-in. stainless steel piping

Schedule 40S seamless, 304L stainless steel, ASTM A312/A312M (ASTM 1994b) grade TP304L, beveled ends

- 3/4-in. to 1/2-in. reducer

Schedule 40S butt weld, 304L stainless steel, ASTM A403/A403M (ASTM 1994d) grade WP 304L-W

- 3/4-in. ball valve

10.3 MPa (1,500 lb/in²) threaded female NPT, three-piece body, 316 stainless steel, ASTM A351/A351M (ASTM 1994a) grade CF8M body, 316 stainless steel ball and stem, reinforced polytetrafluoroethylene seats, handle operated

- 1/2-in. stainless steel piping

Schedule 40S seamless, 304L stainless steel, ASTM A312/A312M (ASTM 1994b) grade TP304L, beveled ends

- Continuous air monitor

ANSI N42.18-1980, ANSI N320-1979, ANSI N14.1-1969, DOE/E2-1930-T5, and DOE Order 653.1A

²Viton is a trademark of E. I. du Pont de Nemours and Company.

- Gas monitor

ANSI N42.18-1980, ANSI N320-1979, ANSI N14.1-1969, DOE/E2/1930-T5, and DOE Order 653.1A

- 2-in. ball valve

10.3 MPa (1,500 lb/in²) threaded female NPT, three-piece body, 316 stainless steel, ASTM A351/A351M (ASTM 1994a) grade CF8M body, 316 stainless steel ball and stem, reinforced polytetrafluoroethylene seats, handle operated

- HEPA filters

Housing materials, ASTM A176 (ASTM 1993b) Type 304L and ANSI/ASME N509-1989 (ANSI/ASME 1989a); filter medium, MIL-F-51079 (MIL 1988) and ANSI/ASME N509-1989; gasket and seal, flat nonasbestos, oil- and ozone-resistant synthetic rubber, closed cell sponge, grade RE-43 or grade TE-43 (high-temperature), ASTM D1056 (ASTM 1991)

- 6-in. stainless steel pipe

Schedule 10S electric fusion welded 304L stainless steel, ASTM A312/A312M (ASTM 1994b) grade TP304L, beveled ends

The safety-class (safety class 1) components of the tube vent and purge cart are as follows:

- Hydrogen monitors

Capable of detecting 1% to 10% hydrogen by volume; two-part system in accordance with specification 17864B. One percent accuracy of full scale with less than 1% drift of scale in 24 hours; piping exposed to sample shall be stainless steel; Teledyne Brown Engineering Analytical Instruments Series 230 or equal.

The venting operation is continuous from the downstream side of the secondary HEPA filter via a 2-in. pipe and includes instrumentation to measure pressure and flow, followed by a globe valve and vent arrangement where purged gases are exhausted to the operating area. Three branch connections are attached to the 2-in. pipe between the secondary HEPA filter and the vent. The first branch connection comprises a 2-in. ball valve, pipe, and vacuum pump assembly, including a cooler, controls, and instrumentation. The second branch comprises a 2-in. ball valve and pipe, pressure relief valve, and a pressure control valve. One sub-branch connection (plug seal test connection) is attached to the 2-in. pipe between the pressure control valve and the pressure relief valve; it contains a 3/4-in. ball valve, pressure indicator, and a quick-disconnect coupling with a 1/4-in. flexible metal hose that is used during tube plug seal testing. A 3/4-in. pipe, pressure relief valve, and strainer is connected between the pressure control valve and the inert gas manifold. The inert gas manifold receives the 3/4-in. piping from the pressure control valve between two gate valves. The check valves ensure isolation between the two identical high-pressure (bottle) supply manifolds.

The 3/4-in. piping is connected from one of the check valves to a gate valve and pressure regulator where the high pressure bottle is connected. Two of these bottle manifolds with bottles ensure uninterrupted inerting gas flow during MCO and tube purging operations. The third branch connection comprises a 1/2-in. pipe with a ball valve and sample connection. During venting operations, samples can be obtained just before exhausting into the operating area downstream of the HEPA filters.

4.3.7.3 Functional Requirements. The tube vent and purge cart system provides the safety-class function of ensuring that the tube atmosphere remains nonflammable by excluding oxygen (air) and the safety-significant function of ensuring confinement under all credible accident conditions. The cart is designed for a maximum pressure of 1.0 MPa gauge (150 lb/in² gauge), maximum temperature of 93 °C (200 °F), full vacuum, and enough inert gas storage capacity to fill one tube.

During venting operations, the system is designed to analyze the gas from the MCO storage tube through a stainless steel manifold arrangement where two hydrogen analyzers, one radioactive gas monitor, and one CAM provide dynamic safety analysis of the vented gases. The temperature of the gases flowing to the analyzers is detected by a temperature element whose supporting alarm circuitry will initiate an alarm if the temperature exceeds 52 °C (125 °F), precluding possible thermal damage to the gas analyzers. Instrumentation is provided from the hydrogen analyzers that will automatically inhibit operation of the vacuum pump and initiate an alarm if a 4% or greater concentration of hydrogen is detected. A flow switch is mounted in the downstream piping from the gas analyzers that will signal a low sample gas flow if it is less than 302 cm³/s (0.64 ft³/min). The flow path of the gases is then required to pass through a primary and secondary HEPA filter assembly before being released into the operating area. Both HEPA filters are 99.97% efficient and allow only 0.3 µm or less particle penetration with a design pressure rating of full vacuum to 1.0 MPa gauge (150 lb/in²) and a design maximum temperature of 93 °C (200 °F). The normal pressure operating range of the HEPA filters is 0.7 kPa (5.0 torr) to 552 kPa gauge (80 lb/in² gauge) with a temperature of 66 °C (150 °F). A temperature element with a design temperature range of -12 °C to 93 °C (10 °F to 200 °F) and a 1.0 MPa (150 lb/in²) pressure rating is mounted in the 2-in. vent pipe downstream of the flexible metal hose that is connected to the tube plug disconnect.

After the MCO tube pressure has been reduced to atmospheric pressure and the hydrogen concentration in the vented gas stream is less than 4%, the tube vent and purge cart vacuum system will be used to draw a vacuum of 1.3 kPa (10.0 torr) on the MCO tube. The vacuum pump is used to remove any remaining suspended particles and gas inside the MCO storage tube. When the vacuum pump is operating, its cooling unit must also be operating. The MCO vent gas is routed through the primary and secondary HEPA filters before it flows into the vacuum pump and is discharged into the operating area. As the vacuum pump is an oilless pump, a low cooling flow or a spark generated from pump friction could ignite a flammable mixture of hydrogen gas. When the vacuum pump cooling flow rate falls below 7.6 L/min (2.0 gal/min), or the gas exceeds 4% hydrogen concentration, an interlock automatically shuts down the vacuum pump. When 1.3 kPa absolute (10.0 torr absolute) vacuum has been reached, the air monitoring system and the vacuum system are shut down and isolated. The normal operating pressure of the tube purging operations performed with the

cart should be approximately 28 kPa gauge (4 lb/in² gauge). The MCO storage tube space is refilled with an inert gas from the tube vent and purge cart. The inert gas flows from the inert gas cylinders installed on the cart through piping connections, pressure regulators, and hand-operated block valves to deliver gas flow in reverse direction through the HEPA filters and associated piping to the MCO storage tube. The configuration of the bottle connections allows one bottle to be in service as the other one is being changed out. The bottle pressure (2,200 lb new) is reduced by a preset pressure regulator that is set to 207 kPa gauge (30 lb/in² gauge) (one for each bottle). Flow is then directed through a common 3/4-in. supply header to a strainer. Pressure is further reduced by a 28 kPa gauge (4 lb/in² gauge) pressure regulator that sets the final pressure applied to the MCO storage tube.

4.3.7.4 System Evaluation. The hydrogen monitoring system performs the safety-class function of ensuring the tube atmosphere remains nonflammable during the time the cart is being used to draw a vacuum or to perform venting, purging, and inerting. The hydrogen monitors on the cart and the tube lines, fitting, regulator, and valves that serve the function of excluding air from the tubes need to be safety class. The remaining cart components (those not required to ensure confinement or prevent ingress of air or oxygen during tube servicing) are considered non-safety features. To ensure worker safety, personnel should leave the area of the cart if the oxygen meter alarm indicates that an oxygen-deficient condition exists.

4.3.7.5 Controls (Technical Safety Requirements). The safety-class hydrogen monitoring system must be operational before evacuating a storage tube.

4.3.8 Multicanister Overpack

See WHC-SD-SNF-SARR-005, *Multicanister Overpack Topical Report* (Lorenz 1997), for a description of MCO safety functions and functional requirements.

4.4 SAFETY-SIGNIFICANT STRUCTURES, SYSTEMS, AND COMPONENTS

The safety-significant SSCs are summarized in Table 4-78. These items are designated safety-significant (safety class 2) in accordance with approved procedures Revision 1 of WHC CM 4-46. The safety-significant SSCs for the operating deck and its associated mechanical equipment are described in Sections 4.4.1 through 4.4.2. The safety-significant (safety class 2) SSCs were designed to meet the single-failure criterion of DOE Order 6430.1A, Section 1300-3.3. Safety-significant SSCs determined to be safety class 3 according to approved procedures WHC CM 4-46 for the facility worker are included in Chapter 2-0.

Table 4-78. Safety-Significant Structures, Systems, and Components for the Canister Storage Building. (2 sheets)

Safety-significant SSC	Safety function	Functional requirements	Performance criteria (TSR applicability)
Tube vent and purge cart	Provide secondary confinement for one or two MCOs Prevent hydrogen fire Provide confinement from overpressurization of MCO	Provide confinement barrier against unfiltered particulate radionuclide releases from one or two MCOs during normal operations and from one MCO under DBA conditions Prevent fire within MCOs by provision of inert atmosphere Provide relief of pressure from hydrogen generation	To be determined Testing of HEPA filters
MHM	Provide secondary confinement for one or two MCOs Provide confinement from overpressurization of MCO	Provide confinement barrier against unfiltered particulate radionuclide releases from one or two MCOs during normal operations and from one MCO under DBA conditions Provide relief of pressure from hydrogen generation	To be determined
Portable shield gate	Provide secondary confinement for one or two MCOs Provide confinement from overpressurization of MCO	Provide confinement barrier against unfiltered particulate radionuclide releases from one or two MCOs during normal operations and from one MCO under DBA conditions	To be determined
Tube-plug Storage tube assemblies (standard storage tubes, bases, bellows, tube plugs, and tube plug HEPA filter media)	Provide confinement of MCO releases to the storage tube; prevent ingress of operating air to the tube	Provide filtered release of tube overpressure to the operating area atmosphere	Venting and purging as necessary to maintain hydrogen below the flammable limit based on pressure readings and sampling of tube atmosphere
Tube-plug HEPA filter media	Mitigate the onsite release of particulate from an MCO caused by overpressurization	The tube plug HEPA filter is capable of removing 99.97% of $> 0.35 \mu\text{m}$ particles calculated to be available for an unmitigated release from one MCO in the storage tube; designated safety significant (safety class 2) in accordance with HNF-CN-4-464 with redundancy and single failure	DOP-Testing to confirm efficiency of filter media; frequency to be developed
Plug flask	Provide secondary confinement for one or two MCOs Provide confinement from overpressurization of MCO	Provide confinement barrier against unfiltered particulate radionuclide releases from one or two MCOs during normal operations and from one MCO under DBA conditions	To be determined
Backup Emergency power system (generators, electrical distribution)	Ensure continuous power to active safety significant features during loss of offsite power. Maintain MCO leak in MHM at $< 1.0 \text{ in.}$ water gauge and 200 ft./min. by providing exhaust fans with electrical power	Provide 48-hour backup power to maintain MHM confinement features energized Single failure proof fault protection	Frequency of testing to be determined; operator action required to close breaker for non-essential loads and to MHM if first generator fails to start

Table 4-78. Safety-Significant Structures, Systems, and Components for the Canister Storage Building. (2 sheets)

Safety-significant SSC	Safety function	Functional requirements	Performance criteria (TSR applicability)
Diesel fuel supply and pumps for emergency power generators (included in backup power system)	Provide fuel for 48 hours of generator operation	Maintain fuel supply to at least one of two generators for 48 hours	Frequency of testing to be determined
Mobile service station enclosure tent containment confinement system (enclosure tent, HVAC exhaust fans, HEPA filters)	Maintain secondary confinement of MCO while in service pit with cask lid off and during servicing operations; mitigate against burst MCO when cask lid off	Maintain service station enclosure tent atmosphere at < 0.5 in. water gauge; confine particulate release from normal MCO servicing operations (upset events) and MCO overpressure	DOP-Testing of HEPA filters; functionality checks of blowers
Receiving crane	Prevent drop of MCO cask	Withstand DBE with load without tipping over	Limits on height of load above deck to prevent swing and MCO contact during sling failure
MCO service station gantry crane	Prevent drop of cask lid or shield ring/shield hatch and plate onto MCO Prevent collapse onto mobile service station enclosure	Handle 8,800-lb (heaviest load) Withstand NPHs and DBAs	To be determined
Shield hatch assembly	Confinement of particulate released from MCO rupture disk	Withstand MCO rupture disk pressure buildup in MCO service station pit Continuity of MMH confinement during MCO retrieval operations	To be developed
Service station MCO purging and inerting system	Prevent hydrogen deflagration	Vent hydrogen through HEPA filtered exhaust and refill MCO with inert gas	To be developed

WNC-CM-4-46, Safety Analysis Manual, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

DBA = design basis accident.
 DBE = design basis earthquake.
 DOP = dioctyl phthalate
 HEPA = high-efficiency particulate air (filter).
 HVAC = heating, ventilating, and air conditioning.
 MCO = multicanister overpack.
 MMH = multicanister overpack handling machine.
 SSC = structure, system, and component.
 TSR = technical safety requirement.

4.4.1 Tube Plug Filter Media

4.4.1.1 Safety Function. The tube plug HEPA filter media are required to remove particulate from a storage tube following a pressurized release from an MCO. These items are considered safety-significant. Pressurized released an unfiltered release of an MCO through the rupture disk and into the storage tube pressurizes the storage tube. Calculations in Chapter 3.0 show the unmitigated dose of a pressurized MCO release from an MCO containing 300 kg (660 lb) of particulate to exceed the WNC-CM-4-46 risk acceptance guideline for onsite dose (Sellers 1996). The filter media are required to be designed

to meet safety-significant (safety class 2) ~~(safety-significant)~~ requirements to mitigate this release.

4.4.1.2 System Description. The tube plug HEPA filter media are contained within a metal canister located upstream of the tube plug relief valves. They are depicted on Figures 4-4 and 4-5-2-5. The filter media housing is threaded to the tube plug relief valve.

4.4.1.3 Functional Requirements. The tube plug HEPA filter media are required to remove sufficient particulate to mitigate the onsite consequences of a pressurized MCO release. This is accomplished by specifying 99.97% of $> 0.3 \mu\text{m}$ removal of particulate ~~as stated in Chapter 3.0~~ and a minimum capacity of 1.3 g.

4.4.1.4 System Evaluation. The tube plug HEPA filter media are required to remove sufficient particulate to mitigate the onsite consequences of a pressurized MCO release. This is accomplished by specifying 99.97% of $> 0.3 \mu\text{m}$ removal of $\sim 1.3 \text{ g}$ (based on a respirable particulate loading of 100 mg/m^3 in the tube) of particulate as stated in Section 4.3.5.3. The tube plug HEPA filters are specified to comply with ANSI/ASME N509-1989, *Nuclear Power Plant Air Cleaning Units and Components New Construction and Modification Only* (ANSI/ASME 1989a).

4.4.1.5 Controls (Technical Safety Requirements). Frequent ~~diethyl phthalate aerosol challenge~~ testing will verify capability of HEPA filtration for the tube plug HEPA filter media. The testing of HEPA filters is specified to comply with ANSI/ASME N510-1989, *Testing of Nuclear Air-Cleaning Systems* (ANSI/ASME 1989b).

4.4.2 Multicanister Overpack Handling Machine

The material in this section is no longer current. A revised discussion of the MHM will be provided at a later date (Mahaffey 1997).

4.4.2.1 Safety Function. The MHM is used to remove an MCO from the transfer cask and place it in a storage tube. ~~The primary function of the MHM is to transport the MCO within the CSB without incident and to maintain an inerted confinement atmosphere around the MCO during these handling operations. MCO retrieval and replacement operations are similarly carried out for transfer of MCOs to and from the HCS. The tube vent and purge carts will purge the tube in order to restore the hydrogen concentration in a storage tube to below the lower explosive limit in the event of abnormal hydrogen generation from an MCO. The carts are discussed in Section 4.4.4 of this document.~~

4.4.2.2 System Description. ~~The MHM is provided with an inerting gas supply system and emergency power for its HEPA filtered secondary confinement system and radiation monitors. The architect engineer prepared specifications for the MHM equipment that require safety class interlocks designed to prevent inadvertent operations, which could cause the breach of an MCO. The principal interlocks for this function are associated with the safety class seismic restraints that inhibit trolley and gantry movement. The MHM as provided by~~

~~Foster Wheeler Environmental Corporation incorporates all the requirements of these specifications.~~

~~The shield hatch provides the interface surface for the MHM's shielded turret nose assembly at the MCO service station. The shielded turret nose assembly provides secondary confinement for the MCO during the transfer operation when the center shield plate is removed from the shield hatch assembly.~~

~~A makeup ring is inserted into the selected storage tube to raise the machine interface at the storage tube to the MHM charge face level. When the MHM is located over the tube, the lowering of the shield skirt extends the nose ring to seal on top of the makeup ring. The shield turret nose assembly provides secondary confinement for the MCO during the transfer operation when the shield plug is removed from the storage tube.~~

~~The documented shielding analyses (Kidd 1996) based on the architect-engineer's conceptual design show that the sides of the shielding enclosure need to be 28 cm (11 in.) of steel inside 10 cm (4 in.) of borated polyethylene inside an outer 2.5 cm (1 in.) of steel. This shield configuration is provided in the shield gate specification and associated drawings. It is assumed that the vendor supplied design will meet all requirements in these documents. Final confirmatory shielding analyses will be done after final design is complete. The current design approach for the MHM incorporates the functions of the shield gate and plug flask, which were the architect engineer's conceptual design, within the vendor's advanced conceptual design for the MHM.~~

~~The MHM ventilation system is designed with redundancy. The system consists of a pair of HEPA filtered exhaust fans, one of which is designated the standby unit while the other unit is in operation. The interior of the MHM cask will be at a negative pressure of 250 Pa (1.0 in. water gauge) relative to the operating area. The fan flow rate is based on a minimum induced velocity of 61 m/min (200 ft/min) to prevent back diffusion of particulate contamination in vertical and horizontal ducts and flow passages. Each system consists of an exhaust fan, HEPA filter, back draft valve, dioctyl phthalate test ports, vacuum switch, and warning light. Each exhaust system is independent of the other. Upon the loss of vacuum, the standby fan will start automatically and a red warning light will illuminate. During loss of normal power, the ventilation system will be switched to emergency power. The MHM ventilation system will be in continuous operation whenever the MHM is moved away from its parking position. The machine will be interlocked so that no task can be performed without the ventilation system being functional. Air will be drawn in via the nose of the machine and shield skirt. The infiltrating air, combining with inert gas within the MHM, will flow up over the MCO, out through a tapping in the cask above the MCO, across the rotate drag chain, through a flexible pipe to a ventilation cubicle on the trolley and will be discharged vertically upwards from a stack pipe protruding from the top of the cubicle.~~

~~4.4.2.3 Functional Requirements. An inert gas flow of 1.42 m³/min (50 ft³/min) is required to maintain a safe atmosphere within the MHM considering restricted dilution from air in leakage and projected maximum hydrogen evolution.~~

The MMH's ventilation system is based on a minimum induced velocity of 61 m/min (200 ft/min) to prevent back diffusion of particulate contamination in vertical and horizontal ducts and flow passages. The system consists of a fan, HEPA filter, back draft valve, dioctyl phthalate test ports, vacuum switch, and warning light. Each fan system will be independent of the other. One fan system will be operated while the second fan system will be used as a standby unit. Upon the loss of fan vacuum, the standby fan will start automatically and a red warning light will illuminate. During loss of normal power the ventilation system will be switched to emergency power. The MMH's ventilation system will be in continuous operation whenever the MMH is moved away from its parking position. The machine will be interlocked so that no task can be performed without the ventilation system being functional. Air will be drawn in via the nose of the machine and shield skirt, up over the MCO, out through a tapping in the cask above the MCO, across the rotate drag chain through a flexible pipe to a ventilation cubicle on the trolley and discharged vertically upwards from a stack pipe protruding from the top of the cubicle.

4.4.2.4 System Evaluation. The tube plug is engaged by the grapple of the shield plug hoist on the MMH. The grapple has electrical and mechanical interlocks that prevent its opening inadvertently. If a plug were to drop, it would not contact the tube assembly until reaching the chamfered surface, as the MMH guides it past the top flange above the bellows section. The chamfered surface may be damaged and receive minor deformation if the plug strikes it a glancing blow rather than falling cleanly into the tube. The plug will eventually rest in its seated position. The plug and tube will not fail although the seal may be unserviceable. Calculations (Fluor 1996) show that structural yielding of the components will not occur if the plug is dropped into the tube from a maximum height of approximately 3.0 m (10 ft). During tube plug removal operations, the volume of the uninerted atmosphere in the space above the tube plug mixes with the inerted volume of gas in the storage tube. The results of preliminary analyses indicate that there is no flammability hazard as long as the hydrogen concentration in the inerted storage tube atmosphere is below 6% at the time the plug is removed.

The MMH atmosphere is required to be inerted during MCO transport operations. The MMH can supply 1.42 m³/min (50 ft³/min) of inert gas to the cask body to dilute air in leakage. This supply of inert gas will be sufficient to stay below the hydrogen flammability limit of 20% air in inert gas (see Ordín [1970]). The system is sized to prevent exceeding this value with up to 0.17 m³/min (6 ft³/min) of air in leakage.

Conceptual mechanical space allocation drawings are provided in Figures 4 65 through 4 98. These depict the architect-engineer's conceptual design for miscellaneous pieces of MCO and transportation cask handling equipment. Also Depicted in Figure 4 100 is a conceptual approach to MCO secondary confinement provided by the MMH.

The estimates of trolley bridge and bridge building interface seismic loads were obtained using the representative geometry for the proposed machine design in conjunction with the response spectra from specification WHC-S-0468, Specification for Multi Canister Overpack (MCO) Handling Machine, Section 3.2.4 (WHC 1996) and ANSYS runs. The results of both trolley central and trolley offset cases are presented in Appendix 4C for the 50% design.

Static load is self weight downwards, dynamic load is seismic only and can be plus or minus. For the bridge, static minus dynamic provides the minimum load on the end truck pivot pins. Static plus dynamic provides the maximum pivot pin load for the bridge and the maximum individual wheel loads for the trolley. The results also provide "along the rail" and "right angles to the rail" loads and at the interface between the bridge and building; these are estimated to be 200 tons and 300 tons, respectively. It is estimated that these figures should be within 15% of their final values. The mathematical model used assumes that the bridge and trolley are restrained with lateral seismic restraints and rail brakes as required by specification WHC S-0468, Section 3-2.1.4d (WHC 1996). No connection has been assumed between the machine nose and the vault charge face. Refer to Appendix 4C for the latest results pertaining to the 2.7 m (9 ft) high girders.

The architect engineer used the 2.0×10^{-3} mSv/h (0.2 mrem/h) dose rate goal with a fallback to 5.0×10^{-3} mSv/h (0.5 mrem/h) as a design objective. These dose rate criteria applied to all locations in the vicinity of the MMH, including the operator station, during normal MCO handling.

The dose rate at the floor surface of the operating deck, because of both the slant angle concrete path and the gap between the MMH and deck surface, will be less than 2.0×10^{-3} mSv/h (0.2 mrem/h). The slant distance was made adequate by recommending an extended shield gate skirt that extends at least 91 cm (36 in.) beyond the edge of the floor embed. This configuration is based on the preliminary specification scoping shielding analysis (Kidd 1996). Refer to Appendix 4D for the preliminary results of the MMH cask shielding analysis.

4.4.2.5 Controls (Technical Safety Requirements). TSRs for the MMH will address the MCO related confinement and inerting features of the cask, including transport time from the CVDES and MCO re-inerting in the service station. These TSRs will be developed when MCO hydrogen generation rates are better understood.

4.4.3 Backup Emergency Power System

4.4.3.1 Safety Function. The backup emergency power system is required to maintain confinement and dilution of flammable gas compositions in the MCO environment during a design basis loss of power event (loss of site power from the utility system). The CSB does not rely on the active system for mitigating a safety-class (safety class 1) event. Consequently, safety-class backup power is not required. The backup emergency-power system provides safety-significant (safety class 2) power to the MCO service station, the MMH, the service station hoist, and the in-deck 480-V power outlets used for operating the MCO vent and purge cart equipment, and to auxiliary loads associated with the emergency generator. See Table 2-1 for a complete load list. Hanford Site guidance for backup electrical systems is found in WHC SD-GN-DGS-303, *Backup Electrical Power System Definitions and Design Criteria* (Roberts 1990) WHC CM-4-46.

4.4.3.2 System Description. Two emergency generators provide power to two 480-V motor control centers located inside the CSB support building. The CSB support building is designed to protect the emergency power system against

damage from safety class 2 and safety class 1 NPHs as listed in Section 4.3.4.4. The two motor control centers are equipped with transfer switches that (1) disconnect the low voltage power and utility power system; (2) send a start signal to the generators; and (3) connect the safety class 2 and 3 loads and connected safety class 3 loads. The safety class 3 loads are the receiving crane, the main CSB operating area HVAC exhaust fans, the HVAC stack effluent air sampling system, and the uninterruptible power supply system. Safety class 2 electrical switchgear protection is provided to prevent failure of one load from causing cascading failures of other loads. The MMH is supplied with emergency power via a festoon cable. The MMH provides its own independent emergency battery power to back up the operation of the safety class 2 electrical systems (exhaust fans and monitors) on the MMH in the event of failure of the festooned cable system for 4 hours. The backup power system consists of two redundant 100-kW emergency generators powered by two separate and independent power trains. The backup power system provides the 480-V, 3-phase power used to support safety-significant (safety class 2) systems that provide defense in depth: tube vent and purge carts, diesel fuel oil pump, portable HEPA filter, service station crane hoist (used for cask lid replacement), and the HCS. Table 2-1 provides a complete load list.

Each emergency generator consists of a turbo-charged, fuel-injected, water-cooled, V-6 diesel engine; a 100-kW self-ventilated generator; a 100-kW, 480-V three-phase transfer switch; a 1,500-L (400-gal) starting air receiver; and a 100-kW resistive load bank for testing. Supporting each emergency generator is a 1,900-L (500-gal) above-ground diesel fuel storage tank, an 18.9 L/min (5.0 gal/min) positive displacement diesel fuel oil pump, and a local 190-L (50-gal) diesel fuel day tank.

The backup power system is designed to provide power to two 480-V MCCs located inside the CSB support building. The CSB support building is designed to protect the backup power system against damage from safety-significant (safety class 2) and safety-class (safety class 1) NPHs listed in Section 4.3.4.4. The two MCCs are supplied via transfer switches (NEMA AB 1) that (1) disconnect the low voltage power and utility power system; (2) send a start signal to both generators; and (3) transfer power from the normal power source to the diesel generators. Safety-significant (safety class 2) electrical switchgear protection is provided to prevent failure of one load from causing cascading failures of other loads.

Under normal circumstances, the CSB receives electrical power from the Hanford Site power grid through a dedicated 480-V transformer connected to an existing 13.8-kV power pole near the north end of the building. Power is fed from the transformer to four 480-V MCCs located inside the CSB support building. Safety-significant (safety class 2) power loads are divided between two of the four MCCs. These two MCCs, which are duplicates of each other, also are equipped with transfer switches that connect the safety-significant (safety class 2) loads to the operating emergency generator in the event of loss of normal power. Each emergency generator will feed one safety-significant (safety class 2) MCC. The current design has both the safety-significant (safety class 2) MCCs energized at all times, whether under normal power or fed by either emergency generator. Figure 4-11 shows the backup power distribution system.

The two 100-kW emergency generators are located in separate rooms inside the CSB support building, as shown on Figure 4-12. The diesel engines are designed to the standards in IEEE 446, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications* (IEEE 1987); NFPA 30, *Flammable and Combustible Liquids Code* (NFPA 1996a); NFPA 37, *Combustion Engines and Gas Turbines Stationary* (NFPA 1994); *Standard Practices for Low and Medium Speed Stationary Diesel and Gas Turbines* (DEMA 1972); and *Engine Driven Generator Sets Guideline Specifications for Emergency or Standby* (EGSA 1992). The engines are required to run on grade DF-2 diesel fuel in accordance with Federal Specification VV-F-800D, *Fuel Oil Diesel* (FS 1987). The diesel generator sets are designed to a net continuous rating of 100 kW at 0.8 power factor in accordance with IEEE 1, *Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation* (IEEE 1986); IEEE 446 (IEEE 1987); NFPA 37 (NFPA 1994); NFPA 110, *Standard for Emergency and Standby Power Systems* (NFPA 1996c); NEMA MG1, *Standards for Motors and Generators* (NEMA 1993a); ANSI C50.10, *Rotating Electric Machinery Synchronous Machines* (ANSI 1990); and ANSI C50.13, *Rotating Electrical Machinery Cylindrical Rotor Synchronous Generators* (ANSI 1989). The instrumentation and controls for the diesel generators are designed in accordance with specifications in NFPA 110 (NFPA 1996c); NEMA ICS2, *Industrial Control Devices, Controllers and Assemblies* (NEMA 1995); and UL 1059, *Terminal Blocks* (UL 1988). The electrical devices are designed in accordance with specifications in NEMA ICS2 (NEMA 1995); NEMA ICS4, *Terminal Blocks for Industrial Use* (NEMA 1993b); and UL 1059 (UL 1988).

The diesel generators are started by compressed air contained in 1,500-L (400-gal) air starter receivers. The starting air receivers are designed to contain air pressure of 758 kPa gauge (110 lb/in² gauge) in accordance with the Boiler and Pressure Vessel Code (ASME 1995a), Section VIII, Division 1, Section 13433. This pressure is sufficient to provide six starts. A startup circuit is engaged to send a start signal to the generator upon loss of normal power. The generators are capable of establishing rated power within 6.0 seconds.

Fuel for the generators is supplied in two separate fuel delivery systems, each consisting of a 1,900-L (500-gal), outside, above-ground diesel fuel storage tank, an on-tank diesel fuel oil pump, and a 190-L (50-gal) day tank located in the generator room. The diesel fuel storage tanks and piping (A53 steel) are designed to provide grade DF-2 diesel fuel (Federal Specification VV-F-800D [FS 1987]) in accordance with UL 142, *Standard for Steel Above Ground Tanks for Flammable and Combustible Liquids* (UL 1993); UL 752, *Bullet Resistant Equipment* (UL 1995); NFPA 30 (NFPA 1996a); NFPA 77, *Recommended Practice on Static Electricity* (NFPA 1996b); ASME B16.1, *Cast Iron Pipe Flanges and Flanged Fittings* (ASME 1989); ASME B16.5, *Pipe Flanges and Flanged Fittings* (ASME 1988); and ASTM A36/A36M, *Standard Specification for Carbon Structural Steel* (ASTM 1994c). The on-tank diesel fuel oil pump is a positive displacement pump designed in accordance with *Standards for Centrifugal, Rotary and Reciprocating Pump* (HI 1995), and ASTM A216/A216M, *Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding for High Temperature* (ASTM 1993d). The motor is designed to less than 1/2 hp and 480-V, three phase, in accordance with IEEE 112, *Standard Test Procedure for Polyphase Induction Motors and Generators* (IEEE 1984); IEEE 43, *Recommended Practice for Testing Insulation Resistance of Rotating Machinery*

(IEEE 1974); NEMA MG1 (NEMA 1993a); and NEMA MG13, *Frame Assignments for Alternating Current Integral-Horsepower Induction Motors* (NEMA 1984).

The day tanks provide 10 hours of fuel for the diesel generators and are designed to UL 80, *Inside Tanks for Oil-Burner Fuel* (UL 1992), NFPA 30 (NFPA 1996a), and NFPA 37 (NFPA 1994). When full, each tank has the capacity to sustain design-rated power generation for up to 48 hours. The generators serve as an alternate power source to normal power. Drawing H-2-123391 (Appendix 4E) shows the emergency generator piping and instrumentation.

An auxiliary function of the backup power supply system is to provide power to some other safety-significant loads (safety class 3) equipment, including the 15-kVA uninterruptible power supply system (DCS and radiation monitoring equipment), distribution panel 6 (radiation monitoring equipment, the security system power panel (lighting), and operating area HVAC system.

4.4.3.3 Functional Requirements.—The design-basis loss-of-power event is given as a total loss of normal power for a maximum of 48 hours in Section 3.2.2.1.3.2 of the CSB Performance Specification (Swenson 1996).—Safety class 2 emergency power is designed to the single failure proof criteria of WHC CM 4-46, Chapter 9, Appendix B. Backup power is required for safety-significant (safety class 2) equipment. Hanford Site guidance for backup electrical power is found in WHC-SD-GN-DGS-303 (Roberts 1990). The design basis loss-of-power event is given as a total loss of normal power for a maximum of 48 hours (Swenson 1996, Section 3.2.2.1.3.2).

The four-cycle, direct-injection diesel engines have turbocharging and air-starting. The diesel engine generator is water cooled by a fan-cooled radiator system. Each emergency generator is mounted on a platform that is spring isolated from the floor attachments to reduce vibration; fuel and air lines are connected with flexible couplings to minimizing vibration fatigue to piping components. The exhaust system is mounted to the building structure and incorporates flexible couplings between the diesel engine, silencer, and exhaust piping. The silencer will limit the sound level to not more than 87 decibels at a distance of 23 m (75 ft); it incorporates multiple-corrugated stainless steel expansion joints. Engine air intake filters are of the dry type, capable of removing 92% of all dirt and abrasive particles 3 μ m in size or larger. The air filters are sized to meet engine requirements up to 110% of rated load. All engine operating parameters can be monitored from a local control panel, including engine oil pressure, oil temperature, jacket water temperature, radiator coolant inlet and outlet temperature with alarm ($> 96^{\circ}\text{C}$ [205°F]), radiator coolant level, engine oil sump level, air intake pressure differential, fuel injection pressure, exhaust gas temperature, engine lube oil pressure gauge with alarm ($< 207\text{ kPa}$ [30 lb/in^2]), lube oil temperature, emergency stop status, vibration high, engine total hours, and engine speed. The engine auto shutdown features are as follows: engine coolant ($> 116^{\circ}\text{C}$ [240°F]), low low oil pressure ($< 138\text{ kPa}$ [20 lb/in^2]), load reversal, engine overspeed ($> 120\%$), and excessive vibration.

The site elevation for the engine installation is 215.8 m (708 ft) above sea level. Normal barometric pressure should be approximately 99 kPa absolute (14.3 lb/in^2 absolute). The expected temperature range of the engine operating area is 16°C to 40°C (60°F to 104°F). The expected range of relative humidity is 6% to 100% (noncontrolled). The continuous rating

capacity of this engine generator installation is 100 kW at 0.8 power factor, supplying 480-V, 3-phase power at 60 Hz. The engine-generator unit is required to attain rated speed and voltage within 10 seconds and be able to start loading within 15 seconds of the start signal. To ensure instantaneous starting when a start signal is received, a coolant warming system has been installed. The engine temperature is kept at an optimum level ($> 13^{\circ}\text{C}$ [55°F]) by an electric immersion heater and circulation water pump. Engine oil is also circulated to enhance quicker starts. Both engine oil and coolant keep warm systems automatically shut down upon engine start.

The generators furnished with this system are expected to provide electrical power at not less than 0.8 power factor. They are synchronous, AC, brushless-excited, revolving field, and air-cooled. The generators are directly driven from the engine crankshaft. The voltage regulator is of solid-state design with adjustments for setting output voltage from the potentiometer at the control panel. The voltage regulator is capable of maintaining voltage regulation within 0.5% from no-load to full load. The generator set is provided with local controls and indications such as three position phase-to-phase and phase-to-neutral, kW load meter, six position volt meter phase-to-phase and phase-to-neutral, frequency meter, load reversal alarm, and load control hand switch. A resistive load bank is installed next to the radiator such that cooling air is circulated through the load bank by the engine-driven cooling fan. The generator is a complete system with all necessary controls to manually exercise the backup power source. The bank has a temperature sensor in the load exhaust that automatically disconnects the load bank in the event of an over temperature. The load bank is rated for 100 kW at 480 V, three phase, three wire, 60 Hz, 1.0 power factor, with selectable load resolution of 50 kW, (2) steps of 50 kW each. The load bank has an interface with the automatic transfer switch to disconnect the load when normal power is lost or the generator is connected to the facility load.

Both of the diesel generators are started by compressed air contained in 1,500-L (400-gal) air start receivers. The starting air receivers are designed to contain air pressure of 758 kPa gauge (110 lb/in² gauge). The sized capacity is sufficient to provide six starts of each diesel generator. The coincident design pressure and temperature is 1,724 kPa gauge (250 lb/in² gauge) and 66°C (150°F). No alarms or active control devices are incorporated with this design.

The automatic transfer switch is physically installed as an integral part of the normal power supply system with the primary purpose of starting its associated emergency power generation system and transferring power to those areas where normal power is lost. The switch configuration is such that the transfer to emergency power will be initiated upon reduction of normal power to 70% of nominal voltage and transfer to normal power when the normal source restores to 90% of nominal. Voltage testing of the automatic start signal from the transfer switch is accomplished by actuation of the normal power source failure switch.

The day tanks are double walled and constructed of steel. Each tank has a capacity of 190 L (50 gal) and is vertically-oriented. One overflow line exiting the top of the tank returns excess diesel fuel back to the storage tank. A level controller is installed in the top of the day tank that controls the fuel level in the day tank by operating the fuel transfer pump

that is located on top of the 1,900-L (500-gal) fuel oil storage tank. The transfer pump will deliver a minimum of 19 L/min (5 gal/min) to the fuel oil day tank with a discharge pressure of 345 kPa (50 lb/in²). Changing fuel levels in the day tanks will generate the following actions; LOW-LOW level alarm (27 L to 34 L [7.0 to 9.0 gal]), LOW level alarm (53 L to 61 L [14.0 to 16.0 gal]), transfer pump auto start (72 L to 80 L [19.0 to 21.0 gal]), transfer pump auto stop (136 L to 144 L [36.0 to 38.0 gal]), HIGH level alarm (148 L to 155 L [39.0 to 41.0 gal]), and HIGH-HIGH level alarm (170 L to 178 L [45.0 to 47.0 gal]).

The diesel fuel storage tanks that are located outside of the CSB have a nominal capacity of 1,900 L (500 gal) each and are constructed of steel with a rectangular configuration. The venting system for the tanks incorporates a normal vent 5 cm by 2.4 m long (2 in. by 8 ft long), fitted with an environmental cap. Another vent, designated as an emergency vent, only opens when the pressure inside the tank reaches 17.2 kPa (2.5 lb/in²). The internal construction incorporates a double shell design with a polystyrene foam membrane in the interstitial space. If fuel leaks into this area, the foam will dissolve and the leak detection probe will cause the alarm to activate. One alarm is associated with the fuel level in the diesel fuel storage tanks, and it will generate a response when fuel is at the indicated level, LOW level alarm (zero to 95 L [0.0 to 25.0 gal]). Tank level indications are located at the tank and in the control room; alarms are only acknowledged in the control room and are part of the DCS system. Both of the diesel fuel storage tanks are manually refilled via hose connections from a tanker truck.

4.4.3.4 System Evaluation. A failure modes and effects analysis was prepared for each safety-significant (safety class 2) electrical component of the emergency generator system to verify that the single-failure and redundancy criteria of WHC-SD-GN-DGS-303 (Roberts 1990) WHC-CM-4-46 were met by the design and that undetectable failures could not affect the system's safety functions (Zimmerman 1996). The failure of each component of the system was evaluated, including consideration of how that component might fail and the effect of each failure on the safety functions of the system load and CSB facility.

Each electrical power system is protected by safety-significant (safety class 2) fire barriers and fire suppression systems. The emergency power system includes fire stops, seals, and fire-resistant conduit. The electrical room is constructed with fire barriers, detectors, and fire sprinklers. Consequently loss of both backup emergency power systems caused by failure of the fire suppression system is not considered credible. The outside diesel fuel supply tanks are electrically grounded and protected by the Site fire department. Each diesel generator room is protected by a fire water sprinkler system.

File 106.151, *Failure Modes and Effects Analysis: Emergency Power System* (Zimmerman 1996), established that the design met all of the single component failure and redundancy criteria in WHC-SD-GN-DGS-303 (Roberts 1990) WHC-CM-4-46. The design includes single-failure-proof automatic transfer switches to shed non-safety class equipment. There is no need for additional equipment for automatic shedding of safety class 3 power from the two motor control centers that are supplied by the emergency generators.

4.4.3.5 Controls (Technical Safety Requirements). The design of the emergency generators is such that upon a loss of offsite power signal, the generator (EG 1A) connected to the MCC motor control center bus powering the MHM festoon cable receives the start signal. After two starting attempts, the start signal is sent to EG 1B. The operator shall close the tie breaker switch between MCC 33 207 and MCC 33 208 after emergency generator EG 1B comes on line to power the MHM's festoon cable. The TSRs for the emergency generators must deal with operability and availability issues revolving around periodic surveillance. These TSRs will be developed and included in the final SAR.

4.4.4 Tube Vent and Purge Carts

4.4.4.1 Safety Function. Storage tube vent and purge carts provide confinement when connected to the storage tube plug. The tube vent and purge carts provide a means to periodically evacuate the storage tubes of hydrogen and to sample the gas stream for concentrations of radioactivity. This precludes the buildup of hydrogen above the 4% lower flammability limit. See Figure 4-13. The carts contain HEPA filtration equipment to remove particulate released into the tube and drawn into the cart to preclude its release to the operating area.

4.4.4.2 System Description. The tube vent and purge carts are designed to monitor the gas concentration in the tube, pressure purge the tube with inert gas while maintaining confinement (gases are vented through HEPA filters), and draw a vacuum on the tube. The tube purging systems piping and instrumentation diagram is shown in Figure 4-13. The mechanical assembly drawing (H-2-120911) is found in Appendix 4B.

The cart connects to the tube plug by means of a 5-cm (2-in.) flexible metal hose. The cart-mounted equipment consists of a 1.4 standard m³/min (50 standard ft³/min) vacuum pump operated by a 5.4 horsepower, 480 V, 3-phase motor. The vacuum pump draws tube air through two in-series HEPA filters. The metallic filter medium is rated for 79 °C (175 °F), a flow rate of 0.6 standard m³/min (20 standard ft³/min) at a pressure drop of 0.2 kPa (1 in. water gauge). Storage tube gas is monitored by means of a 1.9-cm (3/4-in.) line from the 5-cm (2-in.) piping header through a 70 Btu/h heat exchanger, an in-line CAM, gas monitor, and hydrogen monitor. A 1.9-cm (3/4-in.) manifold feeds inert gas to the 5-cm (2-in.) cart header at 35 kPa gauge (5 lb/in² gauge) from two 17,237 kPa gauge (2,500 lb/in² gauge) cart-mounted gas bottles connected to a series of pressure regulators.

The inert atmosphere is initially supplied from high-pressure inert gas bottles on the cart after the air in the accessed tube is evacuated using a vacuum pump. Pressurization with inert gas is controlled through a pressure regulator and relief valve that prevent overpressurization of the tube; two more relief valves on the tube plug offer redundant protection. The carts are will be equipped with a vacuum pump capable of drawing the storage tube to 1.3 kPa (10 torr) at the maximum tube gas temperature of 80 °C (175 °F). They can will have the capability to detect airborne radioactivity and dangerous hydrogen concentrations in a sample tube.

The equipment on the cart will include a safety-class (safety class 1) hydrogen lower-explosive-limit monitor (thermal conductivity type) with an accuracy of 2% of span and a range of zero to 10% by volume, a non-safety class radioactive gas analyzer to measure airborne tritium concentration in an ion chamber, and a continuous air monitor non-safety class CAM that is sensitive to beta-gamma in a low radiation field and contains an alpha detector. The non-safety class vacuum pumps are prevented from operating if the hydrogen concentration reaches 4% by volume. A mixture of 6% hydrogen in inert gas is safe (not flammable) mixed with any proportion of air (Ordin 1970). The cart equipment will include diethyl-phthalate-testable, redundant, in-line, safety-significant HEPA primary and secondary filters for removing particulate from the gas taken from the storage tube.

The carts are battery powered for motion. The equipment is powered through cables inserted into electrical outlets in the deck. The tube vent and purge carts are operated using valves that are located on the cart. The operator has to make and break connections to the tube plug. The tube plug is designed to provide shielding, confine radioactive particulate, and minimize hydrogen fire hazards.

4.4.4.3 Functional Requirements. The tube vent and purge carts are used to maintain and replenish the inert gas atmosphere in the storage tubes. The carts facilitate controlled venting of gases that may have built up in the storage tubes from relief of pressure from the staged MCs (there is a 1.0 MPa gauge [150 lb/in² gauge] rupture disk and a pressure relief valve set at or below the rupture disk pressure. Gases from the tube are monitored and vented to the operating area through HEPA filters on the cart. An automatic safety-class interlock system on the cart ensures that the vacuum pump is not operable unless the tube gas is at less than 4% hydrogen. Periodic tube venting also keeps the pressure from rising high enough to activate the relief valves in the tube plug. The cart interfaces with a connection on each tube plug that allows monitoring and purging of the tube atmosphere without interfering with the sealing surfaces of the plug. The tube vent and purge carts evacuate and refill a storage tube to a slightly positive pressure immediately preceding tube plug removal. Equipment on the storage tube vent and purge carts can detect airborne radioactivity and hydrogen concentrations and provide HEPA filtration of the sampled volume before release to the operating area atmosphere. The equipment can will be capable of drawing the 79 °C (175 °F) (maximum gas temperature) storage tube atmosphere to 1.3 kPa (10 torr). The cart equipment will draw an 80 °C (175 °F) sample, passes it through the monitors listed above, and vents it to the operating area through two stages of HEPA filters. Connections to the storage tube are made using quick-disconnect fittings atop the storage tube plug. A towable hoist is provided to remove the center access plate in the storage tube plug cover. Figure 4-1310 represents a diagram of piping, instruments, and equipment required by the tube vent and purge carts to service the storage tubes.

4.4.4.4 System Evaluation. Failure of the confinement and inerting features of the cart during a DBA could result in release of radioactivity if the DBA could result in radionuclides being released from the MCs. Offsite consequences may occur if cart failure after a DBA results in a detonable concentration of hydrogen.

When inerting is finished, the tube pressure is slightly positive (28 kPa gauge [4 lb/in² gauge]). Hydrogen relieving through the MCO relief valve increases the tube pressure to about 48 kPa gauge (7 lb/in² gauge) if the MCO is one of the fewer than 1% expected to relieve. The schedule for venting, purging, and inerting the tubes is determined from initial operating experience and outdoor temperature. The interval between scheduled visits is set so the pressure inside the tubes is maintained between 7 kPa and 41 kPa gauge (1 lb/in² and 6 lb/in² gauge). Because temperature variations in the vault affect the tube pressures, pressure is not a sensitive indication of hydrogen concentration. Instead, the hydrogen concentration is measured each time the cart makes a scheduled visit to a tube. If an MCO relief has occurred, the hydrogen concentration will exceed 4%; in this event, the tube gas will be diluted to below 4% before release to the operating area and before using the vacuum pump.

If during the evacuation of a storage tube containing an MCO at just below the rupture disk set pressure, the rupture disk's pressure is reached, then the MCO will vent unfiltered particulate into the storage tube. This release is will be captured by the tube vent and purge cart's larger-than-tube-plug HEPA filter.

As stated in Section 2.5.2, the frequency of storage tube purging is affected by the amount of sludge in an MCO because of the accompanying hydrogen gas generation. Recent preliminary studies of hydrogen gas generation in an MCO (Lorenz 1997, Bergsman 1996) indicate that pressurization of an sealed MCO (as would be received from the CVDFs) depends on the quantity of water in the MCO, its temperature, and the time elapsed since sealing. For a worst-case sealed MCO containing 142-160 kg (313-353 lb) of sludge and 10% 6% water by weight, the 1.0 MPa (150 lb/in²) MCO design pressure is reached within 30-5 hours (Lorenz 1997). The CSB design basis is the nominal case, which is expected to be a maximum of 1.8 kg (4 lb) of water present in an MCO. From this, 0.45 kg (1 lb) per MCO was determined to be a conservative estimate of the average free water present and was used to determine the number of tube vent and purge carts required. Eighteen purges are required to remove 0.45 kg (1 lb) of water. Several carts may be required in order to meet the contemplated schedule when vault 1 MCO capacity is reached. One cart is reserved as a spare during normal operations.

The worst-case MCO is estimated to reach a pressure of 1.0 MPa gauge (150 lb/in² gauge) after approximately 30 hours in staging and to continue venting hydrogen at a high rate for approximately 10 hours, at which time the reactants will be depleted and the hydrogen generation will drop off towards zero (Lorenz 1997, Figure 4-33). Consequently, the tube and tube plugs are designed to confine releases of radioactive contaminated gas and to protect against hydrogen combustion hazards. The expected gas pressure for the nominal MCO during staging is less than 1.0 MPa gauge (150 lb/in² gauge) (Duncan 1996) because the reaction is limited by the quantity of water available to produce hydrogen. The maximum expected quantity of water in an MCO is 1.1 kg (2.4 lb), corresponding to the bound water associated with 160 kg (353 lb) of corrosion product sludge (6% water by mass). The nominal MCO will generate hydrogen at a slower rate, reaching 276 kPa gauge (40 lb/in² gauge) after 40 hours (Lorenz 1997, Figure 4-34). The high nominal case MCO (155 kg [342 lb], 6% water, 80,000 cm² [12,400 in²] of reactive surface area) is predicted to reach 379 kPa absolute (55 lb/in² absolute) after 90 hours.

4.4.4.5 Controls (Technical Safety Requirements). The cart's HEPA filters must be operational before connecting to a tube plug. TSRs dealing with frequency of testing will be developed and included in the final SAR. The tube vent and purge carts provide the means to maintain the TSRs for hydrogen generation and inerted atmosphere requirements for the vented MCOs. These TSRs will be developed after hydrogen evolution values are obtained.

4.4.5 Receiving Crane

4.4.5.1 Safety Function. The receiving crane design provides for safe handling of transport casks loaded with MCOs without exceeding the normal condition of transport time. MCO overpressure could result in an unfiltered release of particulate that, unmitigated, exceeds the risk acceptance guidelines for exposures to onsite personnel.

4.4.5.2 System Description. The receiving crane is a 60-ton capacity equal-leg gantry crane with two wire-rope hoists supported on a top-running trolley. The receiving crane gantry span is 8.4 m (27 ft, 6 in.), and it can travel 50 m (164 ft) in the east-west direction. The receiving crane includes a 10-ton auxiliary hoist, a shielded operator station, remote operating equipment (including a powered rotating hook and local control), and miscellaneous long-handled tools. The receiving crane is used to off-load MCO transport casks from their vertical position on the transport vehicle and to place them into the service station where the MCO is prepared for transfer to a storage tube. After the MCO has been extracted from the transport cask in the service station, the receiving crane is used to place a new (empty) MCO into the cask and to remove the transport cask and return it to the transport trailer. The transport trailer is loaded and unloaded while it is located in the truck vestibule. The truck vestibule is an extension of the CSB that provides an air-locked transition area for the transport semi-trailer and receiving crane to off-load the MCO cask.

The receiving crane is equipped with a shielded operating station located on the outboard side of the north gantry leg. This station is necessary to implement ALARA considerations. Crane control is available either from the operating station or by radio. The receiving crane is expected to receive a total integrated dose of 4.0×10^4 Rad over its 40-year design life. The shielded operating station is specified to be a minimum 8.9-cm- (3.5-in.-) thick carbon steel with viewing windows at least 30 cm by 15 cm (12 in. by 6 in.) in size.

The receiving crane system is designed, fabricated, manufactured, inspected and tested in accordance with the requirements of NUREG-0564, Single Failure Proof Cranes for Nuclear Power Plants (NRC 1979); CMAA Specification No. 70, Specifications for Top Running Bridge and Gantry Type Multiple Girder Electric Overhead Traveling Cranes (CMAA 1994); ASME B30.20, Below the Hook Lifting Devices (ASME 1993a); and ASME NOG-1-1995 (ASME 1995c), Type I with the exception of NOG-5420(a) (reeving is in accordance with CMAA Specification No. 70 [CMAA 1994]), and NOG-5428.1 (a single hook is used rather than a double hook). As described in Section 2.8.1.1, the receiving crane is provided with backup power as a defense in depth feature.

4.4.5.3 Functional Requirements. The crane operates over the service station, which may contain an MCO and a service enclosure that provides secondary confinement. Loss of secondary confinement could result in a safety-significant release. The crane features that prevent dropping loads or components onto the MCO are designated safety significant (safety class 2). DOE Order 6430.1A, Section 1320-5, requires systems and equipment that "ensure safe loading, removal, and handling" of SNF to be designed as "safety class items." The receiving crane does not handle unconfined SNF nor carry loads over unconfined SNF. Therefore, the features of the receiving crane that prevent crane collapse, dropped loads, or falling components from breaching the MCO are designed to safety-significant (safety class 2) criteria.

Not all crane components need be operational after the seismic event. If a suspended transport cask remained inaccessible for sufficient time, then overheating of and/or hydrogen buildup in the contained MCO could result in a release of radionuclides to the interior of the transport cask. The cask is designed to prevent damage to the MCO and to prevent the release of radioactive material if a drop were to occur.

4.4.5.4 System Evaluation. Failure of receiving crane components during normal operations or a DBA could result in a drop of the transport cask containing an MCO. Such a drop or crane failure (tipping over) could severely damage the transport vehicle, the reinforced concrete floor, or the service station structure. The MCO pressure relief devices could fail in such an event. The release would be confined by the cask immediately after the drop. The service station enclosure would confine the material during recovery operations.

The receiving crane is designed to safety-class (safety class 1) criteria to provide protection against a DBE. The receiving crane is considered decoupled from the runway rails (e.g., no mechanical rail clamps). Lateral displacement is restrained by the wheel flanges and longitudinal displacement is restrained by the crane wheel brakes during a seismic occurrence. The receiving crane is stable against overturning during a seismic occurrence with a safety factor of 1.1, in accordance with ASME NOG-1-1995 (ASME 1995c). Results of the stability analysis performed by the manufacturer of the receiving crane indicate that the minimum safety factor against overturning for the extreme environmental load conditions is 1.64 about the x axis (transverse horizontal), and 1.1 about the z axis (transverse longitudinal) (ACECO 1997). Static and dynamic analyses of the receiving crane have been performed to verify that the receiving crane will not tip over or collapse during a seismic event (ACECO 1997). The receiving crane is stable against overturning during a DBE with a safety factor of 1.1 (ACECO 1997), in accordance with ASME NOG-1-1995 (ASME 1995c).

WMC-SD-SNF-FHA-002, *Phase 2 Preliminary Fire Hazard Analysis for the Canister Storage Building* (Sadanaga 1996), determined that a fire, in the load-in/load-out area or elsewhere, will not result in the loss of safe handling of the cask-MCO by the receiving crane (Sadanaga 1996). The receiving crane is not allowed to collide with the MHM crane. This is accomplished by two sets of two collision prevention limit switches that interrupt power should either crane trip its first limit switch.

4.4.5.5 Controls (Technical Safety Requirements). A limit will be established on the number of MCOs inside the receiving/servicing bay at one time. Limits will be established on the height of the load above the deck.

4.4.6 Service Station — Ventilation Enclosure

4.4.6.1 Safety Function. The service station enclosure maintains a negative pressure with respect to the surrounding atmosphere for confinement of releases.

4.4.6.2 System Description. The service station enclosure and portable HEPA filter are located in the MCO receiving and servicing area of the CSB. A small gantry-type crane and hoist is provided within the enclosure as well (see Section 4.4.5).

The enclosure is 5.5 m wide by 7.3 m long by 2.7 m high (18 ft wide by 24 ft long by 9 ft high). The enclosure must conform to the CSB deck's design limits for live and dead loads. The enclosure's windows are 20-gauge fire retardant plastic that is certified to release less than 100 ppm of leachable chlorides. The enclosure also includes electric lighting capable of a minimum of 753 lx (70 footcandles). The enclosure is designed to maintain a negative pressure with respect to the surrounding atmosphere for confinement of releases of particulate in the event that an MCO pressure relief valve or rupture disk were to activate. It is also designed to accommodate a negative pressure of 0.125 kPa (0.5-in. water gauge).

The enclosure contains the following auxiliary equipment:

- A 1.5 m by 1.5 m (5 ft by 5 ft) anteroom that contains two 0.6-m (24-in.) diameter sleeves and two windows located in an exterior wall
- Two doors, one along a side wall and the other between the work area and anteroom; each door includes a window in the upper half of the door
- A portable HEPA-filtered ventilation system provides active confinement.

The portable ventilation system is located on the north side of the enclosure. This ventilation system consists of a prefilter, a stainless steel HEPA filter, and two redundant 1.5-hp exhaust fans. Differential pressure indicators show the pressure drop across each filter section. The portable ventilation system provides a negative air pressure in the enclosure relative to the operating area. The exhaust from the portable ventilation system is monitored for radionuclides before it is released into the operating area air stream.

4.4.6.3 Functional Requirements. The service station enclosure provides confinement for the MCO service station. Safety-significant releases from the MCO pressure relief systems could occur during servicing. The service station enclosure is required to withstand activation of the MCO pressure relief systems.

4.4.6.4 System Evaluation. The effects of a 1.0-MPa (150 lb/in²) MCO rupture disk relieving inside the ventilation enclosure have been evaluated (FDI 1996c, Calculation CSB-PR-0011). The results indicate that the peak pressure inside the enclosure reaches 0.2 kPa gauge (0.03 lb/in² gauge). This does not exceed the enclosure's negative pressure. Thus the release is confined through the HEPA-filtered ventilation in the enclosure.

4.4.6.5 Controls (Technical Safety Requirements). The service station's HEPA-filtered ventilation enclosure is operating and maintaining a negative pressure of 125 Pa (0.5 in. water gauge) at 28.3 m³/min (1,000 ft³/min) before the cask lid is removed.

4.4.7 Service Station — Shield Hatch Assembly and Shield Ring

4.4.7.1 Safety Function. The service station's shield hatch assembly is required to limit radiation exposure while the MCO is being removed from the transportation cask in the service station pit. The internal surfaces of the shield hatch assembly provide a confinement function whenever the assembly is in place over an MCO in the service station pit. The service station enclosure provides confinement for operations that must take place in the service station prior to placement of the shield hatch assembly.

The shield ring is used if servicing of the MCO is required. The shield ring fits the cask body in place of the regular cask lid and prevents streaming radiation from exiting the cask. Any time the MCO cask cover is removed, there will be high radiation shine (approximately 100 mrem/h) above the MCO. Exposure must be limited in accordance with the applicable radiation work permit.

4.4.7.2 System Description. The shield hatch assembly provides shielding and confinement of the MCO while the MHM is being moved into place and while the MCO is being lifted into the MHM. There are two parts to the shield hatch assembly: the center shield plate and the primary shield ring.

The shield hatch assembly is moved into place over the service station and lowered to floor level using the service station gantry and hoist. This operation takes place after the cask has been lowered into the service station and the enclosure has been moved into place. The shield hatch assembly forms a part of the secondary confinement surface for the exposed MCO during the time that the enclosure is moved out of the way and the MHM is moving into place to retrieve the MCO.

A shield ring (not to be confused with the primary shield ring portion of the shield hatch assembly) is also provided for use during an abnormal circumstance that may require MCO servicing in the service station pit. If servicing (pressure purging and reinerting) is required, this shield ring is placed over the cask-MCO in place of the cask lid. The shield ring protects workers from radiation that streams between the MCO and interior cask walls. After servicing is completed, the shield ring is removed and the shield hatch assembly is put back into place over the MCO.

4.4.7.3 Functional Requirements. The shield hatch assembly prevents radiation exposure to workers and provides sealing to the MHM while the MCO is

being removed from the cask into the MHM. It also forms a part of the secondary confinement for the exposed MCO during the time that the enclosure is moved out of the way and the MHM is moving into place to retrieve the MCO. Preliminary calculations of an MCO pressure control valve relieving at 834 kPa gauge (121 lb/in² gauge) and resetting at 683 kPa gauge (99 lb/in² gauge) result in an MCO cask pit pressure of 14 kPa gauge (2 lb/in² gauge).

The shield ring prevents radiation streaming from between the MCO and interior cask walls when the cask lid is removed and MCO servicing is required (an off-normal event).

4.4.7.4 System Evaluation. The service station motorized gantry and hoist are designed to prevent dropping the shield hatch assembly or shield ring. The shield hatch assembly is designed to mate with the MHM. The seal between the MHM and the shield hatch assembly is part of the confinement system. An adequate seal is also required between the shield hatch assembly and the pit-deck surface to minimize air leakage that will flow towards the MHM HEPA filters. The MHM interlocks prevent lifting the MCO unless the MHM is properly positioned with confinement established over the shield hatch assembly. The shield hatch assembly primary shield plate is capable of withstanding 17 kPa gauge (2.4 lb/in² gauge) pressure before lifting. Confinement of MCO relieved gas is provided.

The shield ring provides radiation shielding during pressure purging of the MCO; it is not part of the confinement barrier.

4.4.7.5 Controls (Technical Safety Requirements). Administrative procedures will be in place to ensure that the shield hatch is in place before the MHM is brought to the load-in/load-out area and that the shield ring is in place before the MCO is prepared for staging. TSRs dealing with seal integrity will be developed and included in the final SAR.

4.4.8 Multicanister Overpack Servicing System

4.4.8.1 Safety Function. The function of the MCO servicing system is to purge excessive amounts of hydrogen from off-normal MCOs and replenish them with inert gas. Servicing an off-normal MCO reduces the hydrogen level (and associated hazard) to the same level the MCO had when it was closed at the CVDF. Off-normal MCO purging and inerting operations must not create a flammable atmosphere inside the MCO or the cask. This is accomplished by purging the off-normal MCO of hydrogen using a closed (air-free) system to pressurize the MCO with inert gas. No servicing of normal MCOs arriving from the CVDF will be required. (Normal MCOs are those that arrive at the CSB without complications and within the allowable time window.) Any time the cask cover is removed, radiation streaming from the space between the MCO and the cask wall can occur. Placement of the shield hatch assembly and the shield ring, discussed previously, will shield personnel from this radiation.

4.4.8.2 System Description. The MCO servicing system consists of an inert gas supply, a primary canister HEPA filter, flexible steel hose, sample station, a secondary HEPA filter, piping, valving, and control system interfaces.

The MCO servicing system is designed to return off-normal MCOs to safe condition by removing excessive amounts of hydrogen and replacing the high-hydrogen MCO atmosphere with inert gas. This is accomplished by repeatedly venting and pressure purging any MCO that has been determined to be in an abnormally pressurized condition, caused by either a delayed arrival or by an excessive pressurization during shipment from the K Basins. The MCO is vented and purged while still inside the open cask and located inside the service station pit. The piping and instrumentation is depicted on Drawing H-2-123393 (Appendix E). All servicing actions take place inside the confinement of the service station enclosure (see Section 4.4.6).

The operator accesses the MCO to be serviced via the service station shield hatch assembly and the shield ring. As mentioned above, these components are used to provide the operator with protection from the radiation streaming coming from the inner space between the MCO and the cask.

The designed flow path for servicing system operations begins with aligning the system for venting (confinement of vented gases from the off-normal MCO is controlled to safety-significant [safety class 2] criteria). The quick-disconnect fitting attached to the 3.8-cm (1.5-in.) wand is connected to the appropriate fitting (filtered through MCO HEPA filters) on the MCO. The gas is then vented through a canister HEPA filter and flexible steel 3.8-cm (1.5-in.) piping via quick-disconnect fittings attached to both ends of the HEPA filter. Provisions are included to measure the MCO gas pressure (Section 4.3.8). The MCO gas is vented through 3.8-cm (1.5-in.) piping, a 3.8-cm (1.5-in.) ball valve, 3.8-cm (1.5-in.) temperature element, 3.8-cm to 7.6-cm (1.5-in. to 3-in.) reducer, 3.8-cm to 7.6-cm (1.5-in. to 3-in.) piping, a secondary HEPA filter, operating area exhaust unit, and then routed through the exhaust stack. The purpose of the venting portion of the servicing system is to safely vent the initial pressure from the MCO as it arrives from the CVDF.

The safety-significant (safety class 2) components of the MCO servicing system are as follows:

- Quick-disconnect fitting

Female NPT 316 stainless steel, Viton seals, flush face/dry break Type, 20.7 MPa (3,000 lb/in²) working pressure

- 3.8-cm (1.5-in.) wand

Schedule 40S seamless, 304L stainless steel, ASTM A312/A312M (ASTM 1994b) grade TP304L, beveled ends

- Canister HEPA filter

Housing and filter, stainless steel type 316L, ASTM A240 (ASTM 1993a); filter to remove challenge agent particles greater than 0.3 μ m with 99.97% efficiency, ASHRAE 52.1 (ASHRAE 1992) and SAE J726 (SAE 1993), fire resistant, MIL-F-51068 (MIL 1988); gasket and seal, flat, nonasbestos-type, fire resistant, MIL-F-51068 (MIL 1988) and UL 585

- Flexible steel 3.8-cm (1.5-in. piping)

Flexible metal hose, annular corrugated, single braid, 304L stainless steel core and 304 stainless steel wire braid, class 150 floating flange, 304 stainless steel, and plain male NPT schedule 40S 304L stainless steel end connections, 2.9 m (9.5 ft) total length

- Quick-disconnect (wand)

Male/female NPT 316 stainless steel, Viton seals, flush face/dry break type, 20.7 MPa (3,000 lb/in²) working pressure

- 3.8-cm (1.5-in.) piping

Schedule 40S seamless, 304L stainless steel, ASTM A312/A312M (ASTM 1994b) grade TP304L, beveled ends

- 3.8-cm (1.5-in.) temperature

Copper/platinum 316S sheathed thermocouple, 10 °C to 204 °C (50 °F to 400 °F), element 1.0 MPa gauge (150 lb/in² gauge), ANSI/ASME B1.20.1 (ANSI/ASME 1993)

- 3.8-cm (1.5-in.) reducer

Schedule 10S butt weld, 304L stainless steel, ASTM A403/A403M (ASTM 1994d) grade WP 304L-W

- 3.8-cm (1.5-in.) valve

Class 150 raised face flanged, full port two-piece body, 316 stainless steel ASTM A351/A351M (ASTM 1994a) grade CF8M body, 316 stainless steel ball and stem, handle operated

- 7.6-cm piping

Schedule 10S electric fusion weld, 304L stainless steel, ASTM A312/A312M (ASTM 1994b) grade TP304L, beveled ends

- Secondary HEPA filter

Housing, ASTM A176 (ASTM 1993b) Type 304L and ANSI/ASME N509-1989 (ANSI/ASME 1989a); filter, MIL-F-51079 (MIL 1988) and ANSI/ASME N509-1989; gasket and seal, flat, nonasbestos-type, oil- and ozone-resistant synthetic rubber, closed cell sponge, grade RE-43 or grade TE-43 (high temperature), ASTM D1056 (ASTM 1991).

Equipment provided for the venting operation downstream of the secondary HEPA filter includes 7.6-cm (3-in.) piping, a 7.6-cm by 3.8-cm (3-in. by 1.5-in.) reducer, a sampling connection with a 1.3-cm (0.5-in.) ball valve, a 3.8-cm (1.5-in.) flow orifice, and an inert gas dilution control system. The sampling connection will provide a means of pulling a sample from the initial MCO flow stream and is designed for the potentially hot temperature of the gas

coming from the off-normal MCO. Inert gas addition to the MCO off-gas stream is controlled via a pressure controller combined with the flow orifice to promote mixing and dilution before venting the potentially high-hydrogen gases to the operating area exhaust stack.

The designed flow path for the MCO servicing system ends with aligning the system for the purging operation. Purging is performed by providing pressurized inert gas directly to the MCO. A combination of special-connection hardware specific to the inert gas and operation of the MCO servicing system at atmospheric pressure and above precludes the possibility of inadvertently adding air to the MCO. Upon completion of venting and purging operations, the MCO is filled with low pressure inert gas. Hydrogen monitoring can be performed using the tube vent and purge cart if deemed necessary. However, knowledge of initial off-normal MCO pressure and inert gas backfill pressure from CVDF records allows accurate projection of final hydrogen concentration following repeated vent-pressurize cycles without actual hydrogen concentration measurement. Before the MCO can be removed from the service station by the MHM for transport to an MCO storage tube, the quick-disconnect fitting attached to the 3.8-cm (1.5-in.) wand is disconnected from the appropriate fitting on the MCO.

4.4.8.3 Functional Requirements. The MCO servicing system is designed for a maximum pressure of 1.0 MPa gauge (150 lb/in² gauge) and maximum temperature of 204 °C (400 °F) (Bedell 1996). The maximum anticipated pressure coming from the MCO is 1.0 MPa gauge (150 lb/in²) based on the rupture disk burst (0.8 MPa gauge [120 lb/in² gauge] based on the pressure control valve release pressure), and the maximum anticipated temperature is 204 °C (400 °F) for the worst-case MCO (Bazinet 1996a). The actual expected off-normal MCO gas pressure and temperature should be significantly lower, based on the MCO pressure control valve pressure and the average anticipated normal MCO gas temperature.

During venting operations, the MCO is depressurized to atmospheric pressure. The emitted off-gas is vented to the stack through a filtered pathway, first passing through a sintered metal canister type-HEPA filter and finally through a secondary nonmetal HEPA filter. Both HEPA filters are 99.97% efficient and allow only 0.3 µm or smaller particle penetration with a design pressure range of full vacuum to 1.0 MPa gauge (150 lb/in² gauge) and a design maximum temperature of 204 °C (400 °F). The normal operating range of the HEPA filters for pressure is 0.7 kPa to 552 kPa gauge (5.0 torr to 80 lb/in² gauge) with a maximum temperature of 66 °C (150 °F). A 3.8-cm (1.5-in.) temperature element with a design temperature range of 10 °C to 204 °C (50 °F to 400 °F) and a design maximum pressure of 1.0 MPa gauge (150 lb/in² gauge) is used in the flow path to monitor and record the MCO gas temperature as it depressurizes. The design pressure for the vent piping is in accordance with ASME B16.5 (ASME 1988). The design temperature range is -33 °C to 204 °C (-27 °F to 400 °F). The MCO servicing system components are designed to seismic ground acceleration of 0.21 g, which is appropriate for safety-significant (safety class 2) items (FDI 1996c, Calculation CSB-P-0001).

The inert gas system also plays a role in diluting the MCO exhaust gas to prevent a flammable gas mixture from reaching the exhaust stack. This is accomplished by using a flow orifice and an inert gas pressure control system to ensure enough inert gas is mixed with the gas venting from the off-normal

MCO to prevent a flammable concentration of hydrogen from entering the operating area exhaust system and exhaust stack. This system is also used to assist the vent system in providing an atmospheric pressure vent path (zero kPa gauge [0.0 lb/in² gauge]) and inert gas purge (552 kPa gauge [80 lb/in² gauge]). The venting and purging operations are repeated until the residual atmosphere in the MCO is below flammability limits. Two redundant inert gas storage banks supply the inert gas required to purge the off-normal MCO to safe hydrogen concentration levels and are also used to supply inert gas to mix and dilute gases as they are vented. Servicing of the off-normal MCO containing the maximum credible amount of hydrogen requires up to 35 vent and pressurize cycles to ensure that the residual concentration of hydrogen in the serviced MCO is not hazardous (F01 1996c, Calculation CSB-PR-0013). After purging operations are complete, the MCO will be purged and inerted one final time to 35 kPa gauge (5.0 lb/in² gauge) for interim storage.

4.4.8.4 System Evaluation. The MCO servicing system is designed as a closed system that operates at atmospheric pressure and above. Special connections unique to the inert gas selected prevent inadvertent attachment of the wrong gas (oxygen or air) thus precluding the possibility of hydrogen deflagration resulting from use of the MCO servicing system. All system components that connect to the off-normal MCO and filter released gases are designed to 1.0 MPa gauge (150 lb/in² gauge) and 204 °C (400 °F). Failure of the rupture disk and admission of air into the MCO causing hydrogen deflagration are both beyond design basis events in the service station (see Section 3.0). The maximum credible accident for this system is the overpressurization of an MCO, which has safety-significant (safety class 2) consequences. During venting operations, the MCO is depressurized to atmospheric pressure. The venting operation downstream of the secondary HEPA filter is a (safety class 3) consequence activity. The delivery of inert gas to the MCO is a (safety class 3) function. The inert gas system also plays a role in diluting the MCO exhaust gas with inert gas to prevent a flammable gas mixture from reaching the exhaust stack.

This system is used to place off-normal MCOs (expected to total four or five MCOs) into known baseline status before placement into storage tubes. The expected number of off-normal MCOs should be further refined based on CVDF operating experience and evolving spent fuel characterization data. Based on current probabilistic evaluations, it has been determined that less than 1% of the MCOs are expected to become overpressurized and require servicing (see Section 3.0). This estimate is subject to revision based on ongoing fuel characterization studies. The MCO servicing system is not required to be operational after all MCOs are received at the CSB and have been hot conditioned.

The system must provide inert gas at a high enough pressure to overcome the pressure drop of the piping and MCO HEPA filters. The system piping includes HEPA filters to capture particles that might pass through the MCO HEPA filters, which are not testable. The MCOs have a pressure relief valve that may also malfunction and is not testable. The fire hazards associated with hydrogen release have been addressed in the design. Several options to mitigate hydrogen hazard were evaluated and it was determined that an orifice should be installed within the MCO relief pathway to limit the escaping hydrogen to a flow rate of 2.5 standard m³/min (90 standard ft³/min). The hydrogen flame size potentially resulting from flow of hydrogen does not

constitute an unacceptable fire risk (Sadanaga 1996). However, the hydrogen flame resulting from a burst rupture disk would result in an unacceptable fire hazard accompanied by increased likelihood of particulate release.

Personnel protection from radiation during off-normal MCO servicing operations is provided by the shield hatch assembly, the shield ring, and required protective clothing including face masks.

4.4.8.5 Controls (Technical Safety Requirements). These TSRs will be developed and provided in the final SAR.

4.4.8 Canister Storage Building Support Building

4.4.8.1 Safety Function. The CSB support building houses support systems and utilities for CSB operations that include provision of safety significant (safety class 2) backup power. The CSB support building is classified as non-safety class (safety class 3); however, it is designed so that its failure will not result in failure of the CSB operating area shelter or the safety-class (safety class 1) deck. Therefore, the CSB support building is designed for safety class (safety class 1) DBE and tornado wind loads. The HVAC stack is also designed for tornado wind and safety class (safety class 1) earthquake loads. The support building protects the following safety support systems: emergency generators, instrument and plant air, liquid waste collection, compressed air, and fire protection.

4.4.8.2 System Description. The support building is a single-story steel-framed structure approximately 45.7 m long, 16.2 m wide, and 4.0 m high (150 ft long, 53 ft wide, and 16 ft high) located to the north of the CSB vaults and operating area shelter. The foundations and superstructure are structurally isolated from the CSB vaults and operating shelter. The building houses safety significant and non-safety class (safety class 2 and 3) equipment for electrical, HVAC, continuous air effluent monitoring, facility operations monitoring, and change rooms. A 0.7 m diameter, 22.9 m high (28 in. diameter, 75 ft high) steel HVAC exhaust stack, supported at grade, penetrates through the building roof. The structural system consists of roof beams spanning the east-west direction and supported by girders and columns spaced typically at 8.3 m (27 ft, 1 in.) on center. Seismic and tornado lateral force resistance is achieved by girder-column frame interaction in the north-south direction and through a vertical bracing system along the north and south walls. The building is brace framed in the east-west direction. The foundations for the building and equipment are spread footings located below the frost depth (Calculation CSB S-0019). Support building plan and elevation drawings, H-2-119320 and H-2-119321, are included in Appendix 4A. Piping and instrumentation diagrams for the safety support systems are in Appendix 4E.

4.4.8.3 Functional Requirements. The support building must provide adequate protection of safety significant and non-safety class (safety class 2 and 3) equipment therein from loss of function. It must also be designed to withstand damage from the DBE, tornado winds, or other NPI events such as ashfall that could result in concurrent failure of the CSB operating area shelter. The support building must not be damaged by the DBE or other events

so that safety class (safety class 1) items under the operating area shelter (i.e., the vault deck) can maintain their safety functions.

4.4.B.4. System Evaluation. The support building is designed to be resistant to safety class (safety class 1) DBE and tornado winds. The structure has been designed for all applicable loads and load combinations as defined in Section 10.5 of the Design Basis Document (Bedell 1996) for safety classes 1 and 3. The loads include normal loads, severe and extreme environmental loads, natural phenomena loads, and any DBAs identified by safety analysis. Loads considered for the Support Building are summarized in Section 4.3.4.4.

4.4.B.5. Controls (Technical Safety Requirements). No TSAs have been identified for this building.

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Figure 4-1. Air Temperature Profile.

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APPENDIX 1A

STRUCTURAL FEATURES OF THE COLUMBIA BASIN