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3. PRINCIPAL DESIGN CRITERIA

3.1. Purpose of Installation

The MVDS system is used for the interim storage of FSV HTGR fuel on the DOE owner controlled property at the FSV site and is operated as a stand-alone facility. The MVDS system provides storage for six segments of the HTGR fuel (1,464 fuel elements). The fuel is maintained in a sub-critical state at temperatures low enough to preclude fuel damage and protect the fuel from natural forces in order to protect the health and safety of the public. In addition, the MVDS has space to store and protect up to 37 keyed top reflector control rod elements which were originally thought to be Greater than Class C waste (Section 1.1), according to 10 CFR Part 61 (Ref. 1). These components were associated with the spent fuel per 10 CFR Part 72 (Ref. 2). It was determined that these 37 keyed top reflector control rod elements were not Greater than Class C waste, so they were removed to a LLW disposal facility and are not stored at the ISFSI. Up to six neutron source elements from the FSV also were to be stored in the MVDS, however, the neutron sources were removed from the fuel elements before they were transferred to the ISFSI. Since provisions for storage of the 37 keyed top reflector control rod elements and the six neutron source elements are an integral part of the ISFSI design, and the ISFSI has been licensed to store these elements, reference to these elements has been retained throughout the SAR (see Section 1.1.1).

3.1.1. Stored Materials

3.1.1.1. Physical Characteristics

The mechanical and structural design of the MVDS is based on the physical characteristics of the FSV fuel elements. The MVDS stores four types of fuel elements: standard fuel elements, control fuel elements, bottom control fuel elements, and neutron source elements with the neutron sources removed. All four types have the same external dimensions, but differ in: weight, number of coolant holes, reactivity holes, and neutron source holes. Descriptions of the physical characteristics of each element are shown in Table 3.1-1. The fuel elements are graphically shown in Figures 1.1-4, 1.1-5, 1.1-6, and 1.1-8. Additional details of the fuel elements are provided below.

The individual fuel elements are hexagonal in cross section with dimensions of 14.17 in. across flats by 31.22 in. high. Internal coolant channels within each element are aligned with coolant channels in elements above and below. The active fuel is contained in an array of small-diameter holes, which are parallel with the coolant channels, and occupy alternating positions in a triangular array within the graphite structure.

The fuel holes are drilled from the top face of the element to within about 0.3 in. of the bottom face. The fuel holes in all the elements are 0.500 in. diameter. The bonded rods of coated fuel particles are stacked within the holes.

The fuel holes and coolant channels are distributed on a triangular array of about 0.74 in. pitch spacing with an ideal ratio of two fuel holes for each coolant channel. Edge effects change the ratio slightly, therefore each fuel element contains 210 fuel holes and 108 coolant channels as shown in Figure 1.1-4.

The center control rod fuel element in each region is similar to the surrounding fuel elements, but contains enlarged channels for the two control rods and the reserve shutdown absorber material. The control rod channels have a 9.72 in. centerline spacing and a diameter of 4.00 in. The reserve shutdown channel has a diameter of 3.75 in. Each control rod fuel element contains 120 fuel holes and 57 coolant channels. The standard control rod fuel element is shown in Figure 1.1-5.

The bottom element in the control rod column extends below the core about 7.5 in. The fuel holes in the bottom control rod element are 22.3 in. deep so the bottom of the fuel holes of all elements at the bottom of the core are at the same elevation. The reserve shutdown absorber channel hole also is 22.3 in. deep. The bottom control rod element is shown in Figure 1.1-6.

An engagement hole at the center of each fuel element is provided for handling purposes. The bottom of the fuel handling hole has been extended in some of the regular fuel elements to accommodate a neutron source. Sources are placed in neutron source elements as shown in Figure 1.1-8.

Three graphite dowels for aligning the individual elements within a column are located on the top face of the fuel element. A normal coolant channel passes through the center of each dowel. Each dowel is threaded into the graphite structure and cemented with a carbonaceous cement material. The dowel is made from the same type of graphite as the fuel element structure and has the same extrusion orientation.

The fuel element structural (and moderator) material is conventional nuclear grade H-327 needle-coke graphite for the initial core, the first and second reloads, and half of the third reload. Half of the third reload and subsequent reloads used H-451 near-isotropic graphite.

The fuel is in the form of carbide particles, coated with a highly retentive coating, and bonded with a carbonaceous matrix into fuel rods within the fuel holes. In both the initial core fuel and the first reload cycle fuel, this matrix contained a coal tar pitch binder. In the matrix used in the second reload, the binder was changed to a petroleum derived pitch binder. The fuel rods contain homogeneous mixtures of two types of particles, called fissile and fertile. The fissile particles contain both thorium and U-235 (93.15% enriched). The fertile particles contain only thorium. The fuel particles are coated with a four-layer TRISO coating as shown in Figure 3.1-1. The inner layer is a porous pyrolytic carbon, referred to as a buffer layer. The next layer is high density isotropic pyrocarbon. A thin layer of SiC, which is highly impervious to metallic fission products, is deposited outside the inner isotropic pyrocarbon layer. The outermost layer is a strong high density isotropic pyrocarbon. The important parameters of the particles are shown in Table 3.1 3.

In addition to the fuel particles, some of the fuel elements contain a small amount of burnable poison in the form of boron carbide. The burnable poison is formed into poison rods and placed in the corner holes of the hexagonal elements.

Two startup neutron sources consisting of Cf-252 encapsulated in platinum and stainless steel were originally installed in the core. The total initial neutron generation rate was approximately 4E+09 neutrons per second. In 1981, the neutron generation had decreased to about 2.5E+08 neutrons per second due to radioactive decay of the Cf-252. A third source consisting of Cf-252 doubly encapsulated in stainless steel was added in December 1981 with an initial neutron generation rate of 1.88E+09 neutrons per second. In February 1984 a fourth source, with the same characteristics as the third source, was added. This source had an initial neutron generation rate of 1.3E+09 neutrons per second. Two more neutron source elements were installed in the core. These neutron sources were also Cf-252. These neutron sources, at the time of installation, had neutron generation rates of 4.1E+8 and 4.2E+8 neutrons per second. Both sources were placed in the top layer of the active core by replacing two standard fuel elements. These neutron source elements are modified H-327 graphite fuel elements without fuel. The location of the neutron sources within the fuel element is shown in Figure 1.1-8. None of these six neutron sources are stored at the FSV ISFSI (see Section 1.1.1).

The initial core loading contained 67 different types of fuel elements. The large number of different types was due to the variations of the block, the different fuel loadings, the positioning of the burnable poison rods and the neutron sources. Each fuel element has a permanent three digit type number engraved on the side of the hex block. This type number identifies the specific contents of the element. In addition, each element has a permanent serial number engraved on the side of the hex block. The serial number is unique for each element and can be used to trace the entire fabrication history of the components within an element.

3.1.1.2. Thermal Characteristics

The ISFSI is designed to limit the temperature of a fuel element to less than 750 degrees F. The design criteria for this limit is based on the fuel segment with the highest calculated heat generation rate at 600 days after shutdown, determined to be fuel segment 7, per Reference 3. The irradiation period of fuel segment 7 associated with this maximum heat generation rate was assumed to be 945 Effective Full Power Days (EFPD). This is equivalent to a core average burnup of 52,000 MWd/MT. The actual irradiation period of all FSV fuel segments is 230 EFPD less than the conservatively assumed EFPD for each segment, and the actual core average burnup at end-of-life was calculated to be 38,680 MWd/MT. The heat generation rate for an average segment 7 fuel block, assuming 945 EFPD, was calculated using ORIGEN-S computer code and is contained in Reference 3. The heat generation rate for a maximum fuel element was then calculated by applying an appropriate peaking factor of 1.76. The heat generation rates for a maximum and an average fuel element at 600 days after shutdown were calculated to be 150 W and 85 W, respectively. These decay heat design values are conservative since the in-service date for the ISFSI was 859 days after reactor shutdown. Calculations based on the Reference 3 methodology project that heat generation rates for a maximum and average fuel element at 859 days after shutdown, using actual burnup, were 101W and 55W, respectively.

3.1.1.3. Radiological Characteristics

The principle design criteria for acceptable radiological characteristics for an average fuel element are shown in Table 3.1-2. The radiological characteristics are based on the analysis discussed in Section 3.1.1.2 in which the fuel has been irradiated to 52,000 MWd/MT and decayed 600 days. The maximum radiation fuel source is calculated by applying a peaking factor of 1.76 to the values in Table 3.1-2. No fuel elements are considered to have a source higher than this value.

Although no unirradiated fuel is stored in the MVDS, criticality analyses are based on the most conservative enrichment of unirradiated fuel. The details of the criticality analyses are in Section 3.3.4.

The maximum design source strength of the Cf-252 neutron sources originally planned to be stored (but are not stored) in the MVDS (see Section 1.1.1) is 4.000E+05 microcuries (strength at approximately 440 days after shutdown). The actual maximum strength source would have been less than 4.000E+05 microcuries at 600 days after shutdown.

3.1.2. General Operating Functions

FSCs are arranged up to 45 to each of the six vault modules. Each FSC can store six fuel elements or twelve reflector elements, although no reflector elements are stored in the ISFSI. There is an air environment in the sealed and loaded FSCs. The decay heat is removed by the once-through buoyancy-driven ambient air flowing across the exterior of the FSCs. There is no contact between this cooling air and the fuel being stored. Long-term safety of the storage operation, therefore, is ensured by a totally passive system that is designed to withstand the most severe environmental conditions discussed in Section 3.2.

To deal with anticipated potential faults (off-normal events) and to make provision for decommissioning of the MVDS, three SSWs are provided. These storage wells are built into the MVDS structure adjacent to the vault and can be accessed through the charge face by the CHM.

Utility services required at the ISFSI facility are limited to the electrical requirements for the electric radiant space heaters, security system, security facility, administration building, fuel handling equipment during the handling operations, as well as telephone for the security facility and administration building and domestic water requirements for the administration building. The security plan is discussed in Section 9.6. Fire and explosion protection are discussed in Section 3.3.6. The electrical requirements for equipment and instrumentation are discussed in Section 3.3.3.

Table 3.1-1. Physical Characteristics of FSV Fuel Elements.

	Control Fuel Element	Fuel Element	Neutron Source Element*
Approximate Weight (lbs.)	243	285	285
Element Material	graphite hexagonal cylinder	graphite hexagonal cylinder	graphite hexagonal cylinder
Element Height (in.)	31.22	31.22	31.22
Distance Across Flat Faces (in.)	14.172	14.172	14.172
Number of Coolant Holes (both 0.5" and 0.635" dia.)	57	108	108
Number of Fuel Holes (0.5" dia.)	120	210	210
Fuel Hole Pitch (in.)	0.74	0.74	0.74
Number of Control Rod Drive Holes (4.0" dia.)	2	0	0
Number of Reserve Shutdown Holes (3.75" dia.)	1	0	0

Note: The characteristics of the Control Fuel Elements also are applicable to the Bottom Control Fuel Elements.

* No elements containing neutron sources are stored at the FSV ISFSI.

Table 3.1-2. Radiation Sources for FSV Fuel.

Gamma Energy (MeV)		Gamma Spectra (photons/sec)
Boundaries	Mean	600 days
4.0 - 3.5	3.75	2.11E+05
3.5 - 3.0	3.25	4.54E+08
3.0 - 2.6	2.80	1.45E+10
2.6 - 2.2	2.40	2.90E+10
2.2 - 1.8	2.00	1.44E+12
1.8 - 1.34	1.57	3.08E+12
1.34 - 0.92	1.13	7.47E+12
0.92 - 0.38	0.65	2.68E+14
0.38 - 0.22	0.30	1.72E+13
0.22 - 0.14	0.17	8.93E+08
Total		2.97E+14

Neutron Energy (MeV)		Neutron Spectra (n/s)
Boundaries	Mean	600 days
6.43 - 20.00	13.22	5.14E+03
3.00 - 6.43	4.72	6.89E+04
1.85 - 3.00	2.43	9.37E+04
1.40 - 1.85	1.63	4.40E+04
0.90 - 1.40	1.15	5.34E+04
0.40 - 0.90	0.65	5.48E+04
0.10 - 0.40	0.25	1.07E+04
Total		3.31E+05

Table 3.1-3. Important Parameters of the TRISO Coated Fuel Particles.

Parameter	Fissile		Fertile	
Th:U	3.6:1, 4.25:1		All Th	
Kernel composition	(Th:U)C2		ThC2	
	Small	Large	Small	Large
Average fuelkernel diameter(micron)	140	225	375	525
Average coating thickness:				
Buffer carbon layer(micron)	50	50	50	50
Isotropic carbon layer(micron)	20	20	20	20
SiC layer(micron)	20	20	20	20
Isotropic carbon layer(micron)	30	40	40	50
Average coated fuel diameter(micron)	30	485	635	805

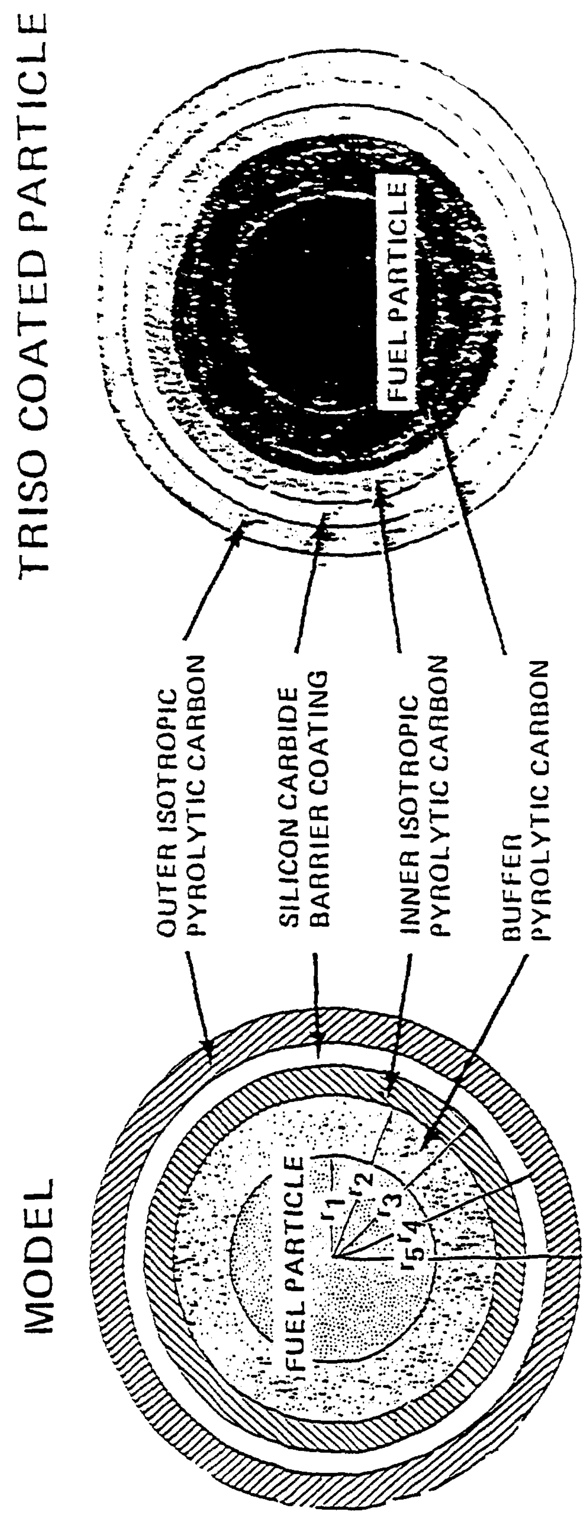

Figure 3.1-1. Model of TRISO Coated Fuel Particles and Corresponding Coated Particles.

3.2. Structural and Mechanical Safety Criteria

The design of the MVDS was based on classifying the structures, systems, and components as either important to safety, enhanced quality, or not important to safety. Items classified as important to safety fall under the FSV ISFSI Quality Assurance Program for 10 CFR Part 72 Subpart G. Complete definitions of important to safety, enhanced quality, the classification criteria, and a list of components are given in Section 3.4.

3.2.1. Tornado and Wind Loadings

3.2.1.1. Applicable Design Parameters

The ISFSI facility is located in Weld County, Colorado and is within Tornado Intensity Region I as defined by Regulatory Guide 1.76 (Ref. 4). The characteristics of a Design Basis Tornado (DBT) in Region I are as follows:

Maximum wind speed	=	360 mph
Rotational speed	=	290 mph
Translational speed	=	70 mph (maximum)
		5 mph (minimum)
Radius of maximum rotational speed	=	150 ft
Pressure drop	=	3.0 psi at a rate of 2.0 psi/second

These design criteria are identical to the criteria used in the FWEA MVDS Topical SAR (Ref. 5) and correspond to the most severe DBT. This DBT exceeds the tornado conditions documented for the area surrounding the site (See Section 2). The resulting forces on the MVDS were determined by following the procedures in NUREG-0800 (Ref. 6). The details are included in Section 3.2.1.2.

ISFSI is designed against tornado-generated missiles as defined in Section 3.5.1.4 of NUREG-0800 (Ref. 6). The spectrum of tornado-generated missiles considered is summarized in Table 3.2-1.

The civil structure is designed to resist the impact of all missiles defined in Table 3.2-1 up to 34 ft. above grade. Above this level, missiles A, B, C, and E are assumed to penetrate the structure cladding and impact on equipment within the charge hall. The assessment of these impacts is given in Section 8 of this report.

3.2.1.2. Determination of Forces on Structures

3.2.1.2.1. Wind Loads

Gust response factors corresponding to Exposure Category C have been taken from Table 8 of Reference 7 and are presented in Table 3.2-2.

Velocity pressure exposure coefficients also are given in Table 3.2-2 and have been used in conjunction with an importance factor of 1.11 for a Category III structure, from Table 5 of Reference 7, to determine velocity pressures from the expression:

$$q(z) = 0.00256K(z)\ (I \times V)^2$$

where: q(z) is the velocity pressure at height z,

K(z) is the velocity pressure exposure coefficient at height z,

I is the importance factor for a category III structure,

and

V is the Basic Wind Speed of 110 mph

Design wind pressures are calculated for the main wind force resisting systems, from the expressions in Table 4 of Reference 7, based on the appropriate pressure coefficients taken from Figures 2 and 3 and Table 9 of Reference 7.

Design wind pressures for the building main frame have been evaluated at 34 ft. and 62 ft. above grade, representing the top of the main concrete vault structure and the top of the charge hall walls respectively. Roof wind pressures were evaluated at the mean roof height of 67 ft., assuming a value of h/L of 0.43 and a roof slope of 10 degrees.

The resultant design wind pressures are given in calculation DC 1.2.6 in Appendix A4-1.

The application of design wind pressures to the structural analysis of the MVDS also is discussed in Appendix A4-1 of this report.

3.2.1.2.2. Tornado Wind Loads

The steel structure is designed to withstand forces due to maximum DBT wind speeds, assuming the cladding is to be held in place.

The design wind pressures on the building main frame for the DBT wind speed of 360 mph are given in calculation DC 1.2.1 of Appendix A4-1. The cladding is designed to withstand the maximum normal wind speed of 110 mph, but is expected to fail at tornado wind speeds exceeding 110 mph.

3.2.1.3. Tornado Generated Missile

All components and structures of the MVDS that are important to safety are designed to be protected from or to withstand the loads imposed by the DBT and its associated missiles without gross failure (see Section 8.2). Hence, the safe operation of the MVDS, in the event of a tornado strike, is assured. Structural cladding enclosing the charge hall is not designed to withstand wind loads associated with the DBT, but the secondary missiles generated are bounded by the DBT missiles.

3.2.2. Water Level (Flood) Design

The ISFSI is located between the South Platte River and St. Vrain Creek, about two miles south of the confluence of these two streams. The ISFSI is located to the east of the FSV Generating Station Storage Ponds. The grade elevation of the MVDS system is 4,781 ft. The possible sources of water that could flood onto the ISFSI facility are the South Platte River and/or the St. Vrain Creek, and the FSV Storage Ponds.

The hydrology of the ISFSI site is discussed in Section 2.4.3. Section 2.4.3 discusses the largest floods ever recorded in the South Platte River Valley in the vicinity of the ISFSI site, and compares these to the ISFSI site grade elevation. The determination is that floods of this magnitude would not damage the ISFSI. In addition to this, Section 2.4.3 presents a paragraph (taken from an estimate by the Omaha District Office of the Corps of Engineers) summarizing the effect of the Corps of Engineers estimated maximum probable flood discharge that might develop in the South Platte river basin between Chatfield reservoir and the plant site.

> "The peak discharge of the probable maximum inflow hydrograph computed for Chatfield reservoir was 548,000 cfs. The uncontrolled drainage area between Littleton and Fort Lupton is 1,556 sq. miles. It is estimated that a maximum discharge of about 500,000 cfs would occur as a result of centering a probable maximum storm over the basin between Chatfield Dam and the plant site. Hydraulic computations indicate that the stage for this discharge would be from 12 to 15 ft. above the flood plain in the vicinity of the plant."

Section 2.4.3 also states: "The elevation of the flood plain was not specified by the Omaha Office. If a flood plain elevation of 4,765 ft. is assumed, the estimated water level would be 4,777 to 4,780 ft." Thus the ISFSI facility, at grade elevation 4,781 ft, would be between zero and four feet above the high water mark of the maximum flood discharge of the South Platte River. Due to the flat topography of the area, the depth of water at the ISFSI facility would only be on the order of a few inches, and thus would not have any significant velocity or force associated with it.

An analysis has been performed to determine the bounding depth, velocity and duration of water flowing from a breach of the FSV storage ponds (Ref. 8). The topography of the ISFSI facility (Ref. 9) shows that the area around the ISFSI is a flat plain. The analysis does not take credit for the 4 ft. 6 in. wide by 1 ft. 6 in. deep canal that the water would have to flow over which would act as a stilling basin. As a result of the analysis in Reference 8, the design values for a flood are conservatively determined to be a depth of 6 feet, a velocity of 10 ft/sec, and a duration of one hour. In reality, the water from the storage ponds would flow into an essentially infinite flat plain, and thus would have negligible depth and velocity. The top of the inlet duct canopy is 11 feet above grade. Therefore even at the maximum flood height there is a clearance of 5 feet along the length of the inlet duct, giving access to the 3 ft. 6 in. wide inlet duct flow passages. This partial blockage will only result in a modest increase in fuel block and concrete temperature. Also, this flood condition is unlikely to be associated with the maximum ambient air temperature of 120 degrees F. The effects of coolant flow restrictions are described in more detail in Section 8.1.2 and Appendix A8-11.

3.2.3. Seismic Design

A response spectrum analysis has been performed which models the major civil structures along with the CHM.

The following input criteria were used:

3.2.3.1. Design Response Spectra Derivations

Free field seismic input motion has been defined by the site-independent broad banded acceleration response spectra described in NUREG/CR-0098 (Ref. 10) scaled to a zero period acceleration of 0.1g for the DBE.

3.2.3.2. Damping

Regulatory Guide 1.61 (Ref. 11) specifies damping values of 7% for safe shutdown earthquake of bolted steel structures, 4% for welded steel structures, and 7% for reinforced concrete. However, Regulatory Guide 1.61 also states that if a structure is loaded significantly below its yield stress, then lower damping values should be used to avoid underestimating the amplitude of vibrations or dynamic stresses. Accordingly a damping value of 4% was used, for both reinforced concrete and structural steelwork.

3.2.3.3. Soil

Soil structure interaction has been included in the analysis. The maximum ground acceleration of 0.1g has been used for this specific site.

An assessment has shown that the soil is of such a consistency that liquefaction could occur during a seismic event. It was decided to replace approximately the top 12 ft. depth of soil with graded and compacted material which will eliminate the risk of liquefaction and increase the soil low strain dynamic shear modulus.

3.2.4. Snow and Ice Loading

The ISFSI is designed for a snow and ice loading of 30 pounds per square foot (psf). This value is identical to that used for the FSV site as detailed in FSV document DC-70, "Design Criteria: Structures - General," (Ref. 12).

A snow and ice load of 30 psf also envelopes the value recommended by ANSI A58.1 (Ref. 7). The flat-roof snow load is calculated in accordance with Section 7.3 of Reference 7.An exposure factor, Ce, of 0.9 has been assumed, corresponding to a windy area with little shelter. A thermal factor, Ct, of 1.2, appropriate to an unheated structure, was taken as pessimistic together with an importance factor, I, of 1.2 for a Category III structure. Since the MVDS roof slope is only 10 degrees, the roof slope factor is unity and does not affect the snow load calculation. The flat-roof snow load, pf, is found from the expression:

$$
\begin{aligned}
pf &= 0.7\ (Ce)\ (Ct)\ (I)\ (pg) \\
&= (0.7)(0.9)(1.2)(1.2)(30) \\
&= 27 \text{ lb/square feet}
\end{aligned}
$$

Drifting due to aerodynamic shade has been assessed in accordance with Clause 7.7 of Reference 7, assuming a triangular drift, as defined in Figure 12 of that reference.

The above calculations are conservative since the ground load, pg, was assumed to be 30 psf instead of the 15 psf suggested by Figure 5 of Reference 7.

3.2.5. Combined Load Criteria

The load criteria associated with the MVDS may be divided into three groups: civil structure, CHM, and MVDS crane.

3.2.5.1. Civil Structure

3.2.5.1.1. Load Factors and Combinations for Reinforced Concrete Design

The required strength U shall be at least equal to the following (Ref. 13):

Load Case	Load Combination
1.	$U = 1.4D + 1.7L + 1.7R_o$
2.	$U = 1.4D + 1.7L + 1.7W + 1.7R_o$
3.	$U = D + L + T_o + R_o + E_{db}$
4.	$U = D + L + T_o + R_o + W_t$
5.*	$U = D + L + T_o + R_o + A$
6.*	$U = D + L + T_o + R_o + F$
7.	$U = 1.05D + 1.3L + 1.05T_o + 1.3R_o$
8.	$U = 1.05D + 1.3L + 1.3W + 1.05T_o + 1.3R_o$

* Additional to ACI 349-85 (Ref. 13) but in line with ANSI/ANS 57.9 - 1984 (Ref. 14)

Where :

D = Dead load

L = Live load including snow, rain, operational, superimposed loads etc.(varied 0% to 100% as

required by ANSI ANS-57.9)

R_o = Pipe and equipment reactions - normal or shutdown (including crane loads)

W = Operating Basis Wind (OBW) Load

W_t = DBT load including tornado generated differential pressures

E_{db} = Loads due to the DBE

T_o = Internal moments and forces caused by thermal effects during normal operating or fault conditions

A = Loads due to drop of a heavy load

F = Loads due to extreme flood loading

The following additional load cases taken from ACI 307-88, shall be considered for the design of the exhaust stack:

9. Not Used

10. $U = 1.1D + 1.4\,T_o + 1.7W$

11. $U = 0.9D + 1.4\,T_o + 1.7W$

3.2.5.1.2. Load Combinations for Structural Steel Design

Structural steelwork is designed in accordance with the AISC Manual of Steel Construction (Ref. 15) and shall be based on the allowable stress design with the following load combinations for the factored strength S:

Load Case	Load Combination
1.	$S = D + L + R_o$
2.	$1.33S = D + L + R_o + W$
3.	$1.5\,S = D + L + R_o + T_o + W$
4.*	$1.6\,S = D + L + R_o + T_o + W_t$
5.	$1.6S = D + L + R_o + T_o + E_{db}$

* Load cases additional to ANSI/ANS 57.9 - 1984 (Ref. 14) but in line with ACI 349-85 (Ref. 13)

These load cases are based on ANSI ANS-57.9 but with the addition of R_o, W_t and F and with E taken as E_{db} to better agree with load cases for reinforced concrete design. All symbols are as defined in Section 3.2.5.1.1.

3.2.5.2. Container Handling Machine Raise/Lower Mechanism

Combined load criteria for the design of the CHM raise/lower mechanism equipment are given in American National Standard, "Rules for Construction of Overhead & Gantry Cranes," (Top Running Bridge, Multiple Girder), ANSI/ASME NOG-1-1983 (Ref. 16).

3.2.5.3. MVDS Crane

Combined load criteria for the design of the MVDS crane hoist equipment is given in:

CMAA 70 'Specification for Electric Overhead Traveling Cranes' Class C (Ref. 17)and ESL Spec 362F0008 (Ref. 18).

Table 3.2-1. Design Basis Tornado Generated Missiles.

(Taken from NUREG 0800 Section 3.5.1.4)

Missile	Mass (kg)	Dimensions (m)	Velocity (m/sec)
A Wood Plank	52	0.092 x 0.289 x 3.66	83
B 6" Sch. 40 Pipe	130	0.168D x 4.58	52
C 1" Steel Rod	4	0.0254D x 0.915	51
D Utility Pole	510	0.343D x 10.68	55
E 12" Sch. 40 Pipe	340	0.32D x 4.58	47
F Automobile	1810	5 x 2 x 1.3	59

Footnotes

Vertical velocities of 70% of the postulated horizontal velocities acceptable except for missile C. This missile, which is used to test barrier openings, is assumed to have the same velocity in all directions. Missiles A, B, C and E are considered at all elevations and missiles D and F at elevations up to 30 feet above grade level.

Table 3.2-2. Gust Response Factors and Velocity Pressure Exposure Coefficients for the MVDS Structural Analysis.

(Taken from ANSI A58.1 - 1982)

Height above Grade, Z (feet)	Gust Response Factors, Gz	Velocity Pressure Coefficients, Kz
0-15	1.32	0.80
20	1.29	0.87
25	1.27	0.93
30	1.26	0.98
40	1.23	1.06
50	1.21	1.13
60	1.20	1.19
70	1.19	1.24
80	1.18	1.29
90	1.17	1.34
100	1.16	1.38

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3.3. Safety Protection Systems

3.3.1. General

The MVDS is designed for safe and secure storage of the FSV HTGR irradiated fuel for up to 40 years. The structures, systems and components important to safety have been designed to maintain:

1. The spent fuel in a sub-critical configuration.
2. The integrity of the spent fuel against gross rupture during handling and storage for normal and off-normal events.
3. The capacity to shield operators and the general public from direct radiation and contamination.
4. Structures and equipment against gross collapse from operating and environmental hazards.

The equipment and structures that are required to assure that the above conditions are met are shown in Table 3.4. To ensure that item 2 is met, consideration has been given to:

1. The adequacy of air as the long-term storage gas.
2. The prediction of spent fuel storage temperatures.
3. The integrity of the total transfer system to ensure safe handling and placement of the irradiated fuel in its FSC.

3.3.2. Protection by Multiple Confinement Barriers and Systems

3.3.2.1. Confinement Barriers and Systems

The MVDS is designed to contain the radioactivity during all phases of fuel storage and unloading. This is accomplished by the multiple barriers shown in Table 3.3-1.

The direct radiation is attenuated by the bulk shielding of the civil structural components, the CHM and the transfer cask.

The primary confinement barrier for the escape of radioactivity from the spent fuel is the fuel particle TRISO coating. A description of the TRISO coating is contained in Section 3.1.1.1, Table 3.1-3, and Figure 3.1-1. Throughout storage in, and subsequent transfer from, the vault module, the FSC provides a high integrity secondary containment barrier.

The FSC is manufactured of 1/2" thick carbon steel. It is protected from atmospheric corrosion by application during manufacture of a flame sprayed coating of aluminum to the outside surfaces. The FSC is closed by a lid sealed with double metal O-ring seals that provide a high integrity arrangement designed to withstand exposure to radiation during the storage period without the need for maintenance. Provisions are incorporated for leak checking the interspace between the two O-ring seals.

3.3.2.2. Ventilation - Offgas

The spent fuel stored within the FSCs in the MVDS is cooled by a passive, self-regulating natural convection cooling system. This system induces buoyancy driven ambient air to flow across the exterior of the FSC (see Figure 3.3-1). There is no contact between this cooling air and the fuel.

The MVDS design limits the temperature of the stored spent fuel such that no fuel damage will occur under the design base conditions. The MVDS response to abnormal cooling conditions (i.e. convective air flow blockage conditions) is provided in Section 8.

3.3.2.2.1. Principle of Operation

The MVDS cooling system has been designed to provide low fuel element and FSC temperatures during long term fuel storage in the MVDS, using atmospheric air as the working fluid to cool the outside surfaces of the FSCs.

Within the FSC the three modes of heat transfer (conduction, radiation and convection) transmit the decay heat of the six fuel elements to the FSC walls. The cover gas is air. The heat from the FSCs is removed by natural convection which induces a cross-flow of ambient air from the air inlet, across the exterior of the FSCs, then out through the outlet duct.

The vault air flow rate can only be enhanced by the influence of wind on the building. This is valid for wind from any direction (see Appendix A3-1.1). This flow enhancement reduces the temperature of the FSCs and the fuel elements relative to their calm day values by an amount dependent on wind direction and velocity. No credit has been taken for the effect of vault air flow enhancement by the wind in the prediction of temperatures for this report, despite the significant reductions that will be obtained in practice. Air passing through the module is heated as it passes, in cross-flow, over the vertical FSCs containing the fuel elements. These FSCs are arranged in a regular equilateral triangular array in the shielded vault (Figure 1.1-2). The warmed air then passes up the vertical outlet duct which provides the buoyancy head that maintains the passive cooling flow over the bank of FSCs.

Heat is transferred from the fuel elements to the cooling air in the following manner:

1. Heat transfer from the fuel to the FSC is by radiation, convection and conduction. Conduction within the fuel element transfers heat radially to the outer surface of the element then heat transfer to the inner FSC surface is by all three processes.

2. Each FSC holds six fuel elements and their individual heat outputs vary, depending on their location within the reactor core and irradiation history. The average rated fuel element heat output is 85W, the average FSC heat output is 510W and the total vault module heat load for 45 FSCs is 23kW.

   Within any FSC all six fuel elements have different heat outputs but, as a consequence of the loading method, the actual heat distribution is different for all FSCs. For the vault as a whole it is assumed that the averaging effect of 45 FSCs results in no actual variation in the heat output.

3. The maximum individual peak rated fuel element heat output is 150 W and the maximum FSC heat output is 900 W. The maximum fuel element, FSC and concrete temperatures are calculated assuming this maximum rated FSC to be present at any location within a vault module which is otherwise loaded with average rated fuel.

4. Mixed/natural convection and radiation heat transfer processes can transfer heat from the FSCs into the cooling air flow and to the vault walls. The exact regime of convective heat transfer is dependent upon the air cross-flow velocity, which is affected by the total module heat load and environmental wind effects.

   When only a few FSCs are stored in a vault module, the mechanism can be natural/mixed convection with additional radiation transfer to neighboring FSCs and the concrete walls. Therefore, the preferred pattern for the first charge of FSCs is to place them at the outlet end of the module. This ensures that the heated air passes up the outlet duct into the atmosphere, minimizing fuel element and FSC temperatures. However, placing the initial FSC loading in a location other than the last row causes no thermal-hydraulic problems because sufficient cooling is always maintained even under calm conditions with a heat load of only one FSC.

   The buoyancy head produced in the outlet duct produces a vault flow rate which ensures that cross-flow heat transfer conditions dominate over local buoyancy effects within the tube bank whenever the store heat load exceeds approximately 0.5 kW. This condition can be exceeded by loading a single FSC into the vault. Therefore heat transfer from the FSC surfaces to the air has been assessed as a staggered tube bank heat exchanger in cross-flow, using widely available and reliable data (see Appendix A3-1.1).

   Radiation heat transfer from the FSCs to the vault walls can be a significant heat transfer mechanism, particularly from the outer FSCs in the array.

5. Atmospheric air that has been heated by the tube bank has a buoyancy potential that causes it to rise relative to air of lower temperature due to differential density effects. The MVDS has been designed to ensure that the heated air passes up the outlet duct and out into the atmosphere into which the heat is finally dissipated. The action of heated air rising up the outlet duct induces further atmospheric air into the inlet to continue the self-sustaining natural thermosyphon air cooling flow.

   The flow rate of the natural convection is affected by the decay heat output of the stored fuel and wind effects on the building. Increased heat output increases the vault module air flow rate, and wind from any direction also increases the cooling flow from inlet to outlet.

3.3.2.2.2. Ambient Temperature

MVDS thermal parameters have been evaluated at two selected ambient temperatures to demonstrate the thermal performance over the extreme temperature range.

1. Lowest ambient temperature: -32 degrees F (-36 degrees C). This is the lowest temperature considered. This was used to evaluate performance under extremely low ambient temperature conditions.

2. Maximum ambient temperature: 120 degrees F (49 degrees C). This is the maximum design temperature and provides the limiting case for thermal analysis of the MVDS.

The source of these temperature data is the Project Data File, Section 5.4 (Ref. 19).

3.3.2.2.3. Spent Fuel Elements

1. Decay Heat Output

   Decay heat output from the fuel elements stored in the MVDS has been calculated from conservative irradiation history predictions.

   The minimum decay period for fuel following reactor shutdown is 600 days giving an average fuel element heat output of 85 W and a peak output of 150 W.

2. Fuel Temperature Limits

   The maximum allowable storage temperature for an air environment is 750 degrees F (400 degrees C) and is limited by graphite oxidation. (Ref. 19, Section 3.2).

3.3.2.2.4. Loading Pattern

It is preferable that each vault module is loaded and unloaded in a specific pattern due to the following:

1. Transverse symmetry of loading across the vault module produces flow characteristics that are consistent across the width of the vault module.

2. The fuel temperatures are minimized throughout the vault module during both loading and unloading operations.

3. The specified pattern reduces the complexity of the logistical control and management of loading and unloading operations by using the location labeling shown on Figure 3.3-2.

The vault location labeling shown in Figures 3.3-2 and 3.3-3 are for loading sequence description only.

The preferred loading sequence starts at the last row of the module (row K) and follows the patterns shown on Figure 3.3-3.

Departures from the specified loading pattern will not cause any thermal problems within the vault module.

3.3.2.2.5. Concrete Temperature Limits

The maximum design steady state structural concrete temperatures are as follows (Ref. 19, Section 5.7):

Maximum bulk temperature = 135 degrees F (57 degrees C)

Maximum local temperature = 150 degrees F (66 degrees C)

Maximum crossfall temperature = 20 degrees F (11 degrees C) for a 3'6" wall thickness.

Fault condition temperatures are less than those quoted in Appendix A.4.2 of Reference 14.

3.3.2.2.6. Detailed Thermal Hydraulics of the MVDS

Full details of the MVDS Thermal-Hydraulic Analysis are given in Appendix A3-1.1.

3.3.3. Protection by Equipment and Instrumentation Selection

3.3.3.1. Equipment

The equipment important to safety is listed in Table 3.4-1. The details of this equipment are given in Section 4. The design criteria for this equipment is summarized in Section 3.6.

For off-normal operations, the additional item considered important to safety is the individual fuel element grapple.

3.3.3.2. Instrumentation

The MVDS is designed to maintain a safe and secure long-term containment and storage environment for the spent fuel using totally passive components. Therefore, no important to safety instrumentation is required for operation of the facility.

3.3.4. Nuclear Criticality Safety

This section provides a summary of the criticality safety margins inherent in the MVDS design, which ensure that a sub-critical situation exists at all times, both for storage and for fuel handling operations. The assessment covers the CHM, the SSW, and the vault module. The detailed criticality safety assessment of the MVDS is presented in Reference 20.

The criteria for criticality safety are as follows:

1. The effective multiplication factor (K_{eff}) shall not exceed the value of 0.95 with optimal density water introduced uniformly in the vault, on the outside of the FSCs.

2. The value of K_{eff} quoted will include allowances for uncertainties in the calculations, modeling geometry and the data libraries.

3.3.4.1. Control Methods of Prevention of Criticality

The configuration of the FSC tube array within the vault module ensures nuclear criticality safety under all situations. The normal fuel storage environment is dry; the fuel elements are stored in a sealed air atmosphere within the FSC and the concrete vault is dry, being protected from the maximum 6 feet flood level by a 16 ft. 4 in. inlet duct barrier wall. Flooding of the vault with water of uniform and various densities, resulting from an unspecified fault situation, also is assessed.

The criticality safety case is based on the following conservative assumptions:

1. All the FSCs contain standard fuel elements, i.e. not a mixture of standard, control and reflector elements.

2. All elements are the most reactive fuel, taken from the most heavily loaded segment (segment 9) of the reactor.

3. The upper manufacturing limit to the range of fuel element uranium loading was used: 1,347 x 1.02 = 1,374 gram of uranium per element (Ref. 21).

4. The lower manufacturing limit to the range of fuel element thorium loading was used: 11,025 x 0.97 = 10,694 gram of thorium per element (Ref. 21).

5. All fuel elements are unirradiated, i.e. no credit is taken for fuel burn-up or the presence of fission products.

6. Burnable poisons are ignored.

7. Silicon in the fuel particle coatings and other impurities are ignored.

8. The Uranium-235 content of the fuel is 93.15%.

The control methods required for the prevention of criticality are the engineered features which maintain the fuel in a defined geometry and restrict the presence of moderating materials which might otherwise increase the reactivity of the storage array. Any fuel element can be transported and stored in any location - there is no requirement to either restrict or control the fuel element inventory. There is no requirement for the presence of neutron absorbing materials for the specific purpose of ensuring subcriticality.

Fuel transfer from the transfer cask to the vault module was carried out using the CHM.

It has been shown in Reference 20 that reactivity of the FSC in the CHM is safe from criticality hazard.

In the event a loaded FSC is placed in one of the three storage wells, it will be isolated neutronically from other FSCs by the adjacent concrete structure. It has been shown in

Reference 22 that a dry, isolated, infinitely high, stack of the most reactive fuel elements is always safe from criticality hazard. The presence of metallic components which surround the fuel results in lower multiplication. External flooding of the FSC also is shown to reduce the reactivity, since it promotes the absorption of thermal neutrons in the FSC wall.

The effective multiplication factor for a full vault module under normal dry storage conditions and for a range of flooding situations is presented in Reference 20. Internal flooding of a single FSC in the center of the vault also is addressed. The vault module is designed to prevent gross water ingress. The vault has a non-return drainage system to remove water collected in the vault space. In addition, there are no installed fire protection deluge systems to cause flooding of the vault. It is, however, necessary to address those moisture levels associated with the various extreme atmospheric conditions (e.g. fog, mist and snow). Consequently the criticality analysis has considered a complete range of interstitial water densities from 0.0 to 1.0 gram/cubic centimeters.

The results of the criticality assessments are presented in Section 3.3.4.5.

3.3.4.2. Criticality Analysis Methods

The MICROX code (Ref. 23) was used to calculate P1 transport cross sections. FSV fuel particle, fuel rod, and standard element dimensions and densities were used as input, taken from the FSV fuel specification (Ref. 21). A standard concrete composition was used based on Table 5.1 of ANSI/ANS 6.4-1985 (Ref. 24).

The DTFX code (Ref. 25) was used to perform one dimensional transport theory calculations. The application of this one dimensional code for an infinite array of FSCs of infinite height gave values of K_{eff} which were pessimistic and had significant margins on the maximum allowable values.

The MCNP Monte Carlo code (Ref. 26) was used to verify the DTFX results and to provide a basis for the independent review.

The MICROX and DTFX codes are validated for the nuclear safety calculations carried out by General Atomics Inc. (GA) and all three computer codes, as well as the calculational methodologies, are consistent with GA's Nuclear Safety Evaluation Guide (Ref. 27).

The validation/verification of the MICROX and DTFX codes are given in Table 3.3-4. These results are obtained from Section 5.3.4.2 of the Demonstration Volume I of GA's License SNM-696. All calculations assumed the scattering (anisotropy) order of P1 and the angular quadrature approximation of S4. Note that the use of nine flux energy broad groups results in a consistent overprediction of reactivity. For Cases 11 and 12, i.e., the water/graphite mixtures, the conservatism varies between 0.014 and 0.052 delta k. These cases are of particular interest because the DTFX model assumes that fuel, carbon and water are homogeneously mixed and reflected (in flooded cases) with water. This means that the selected benchmark cases are fully applicable and supportive of the ISFSI nuclear safety evaluation. The experimental data is for spherical geometries, whereas the geometry of the calculational cell is cylindrical. Due to the relatively large size of the calculational cell the geometrical differences are inconsequential. Note that an increase in the number of groups results in a much better accuracy. The benchmark calculation of the TID-7028 300/1 H/U experiment (Ref. 22) was conducted to estimate the critical mass, rather than the reactivity. The calculations were on the preliminary basis, and were supplemented by the final validation work reported in SNM-696 License. Note that the systematic over prediction of reactivity by the nine group DTFX model was not factored into the ISFSI evaluation by using negative reactivity biases.

3.3.4.3. Error Contingency Criteria

The values of the effective multiplication factor calculated by the one dimensional DTFX code, for an infinite array of infinite height FSCs, has been shown by comparison with results from the MCNP code for a finite array of finite height FSCs, to include a substantial margin of conservation (Ref. 20). The maximum value of the effective multiplication factor occurs in the normal dry operating condition ($K_{eff} = 0.75$) and is significantly lower than the maximum allowable value ($K_{eff} = 0.95$) as discussed in Reference 6. A discussion of the error contingency criteria is presented in Reference 20.

3.3.4.4. Verification Analysis

All criticality calculations have been carried out by GA using calculational methodologies and the two validated computer codes (MICROS and DTFX) in a manner consistent with their Nuclear Safety Evaluation Guide (Ref. 27).

The calculations have been subject to an independent review. The result of the review is included in the Criticality Safety Report (Ref. 20).

3.3.4.5. Calculated Values of the Effective Multiplication Factor

1. The calculated values of K_{eff} for the normal dry operational conditions and for a range of hypothetical flooding situations are given. They have been assessed assuming an infinite FSC array of infinite height. Normal vault operational condition (dry): $K_{eff} = 0.7467$

2. Off normal condition, with the vault flooded with water of various uniform densities and the FSC internals dry:

H2O Content	K_{eff}
0%	0.7467
2%	0.6210
20%	0.3402
40%	0.2386
60%	0.2098
100%	0.2037

Further off normal conditions have been assessed assuming a finite array of FSCs with a finite height.

1. Off normal condition, vault dry and a single centrally located FSC fully flooded (the most reactive configuration): $K_{eff} = 0.7201$

2. Off normal condition, consolidation of the FSC array into a close packed matrix in one corner of the vault (dry conditions): $K_{eff} = 0.5846$

3.3.5. Radiological Protection

The MVDS is designed to maintain both on-site and off-site doses as low as reasonably achievable (ALARA) during long term storage and decommissioning. This is effected by access control and the provision of appropriate shielding on the TCRB, CHM, and the vault.

The ISFSI is surrounded by a controlled area boundary fence to limit public access. Within this region is a fence around the MVDS structure. Adjacent to the inlet ducts is a further fenced-off area to restrict access. Personnel access to the MVDS is through the Access Control and Search Facility. There is no contamination associated with FSC handling operations during normal operating conditions.

A detailed description of the shielding design, the radiation shielding calculations, and the access controls used to provide additional radiological protection are provided in Section 7. These details together with the operational time cycles are used to assess the collective on-site and off-site doses. This assessment provides assurance that the radiological exposures of operators and the public will be maintained ALARA.

3.3.5.1. Access Control

Access to the MVDS installation is controlled in accordance with 10 CFR Part 72 (Ref. 2) and 10 CFR Part 73 (Ref. 28).

3.3.5.2. Shielding

A detailed discussion of radiation shielding calculations can be found in Section 7 of this report. Estimated exposure times for the major operations also are given in Section 7 from which the collective doses have been derived.

The design dose rates for the radiation zoning system adopted for the MVDS are shown in Table 3.3-2. The allocation of radiation zones throughout the controlled area of the facility is shown in Table 3.3-3.

In addition to these dose rate criteria, however, the design recognizes the recommendations of Regulatory Position 2 of Reg. Guide 8.8 (Ref. 29). In this way operator exposure is maintained within the limits given in 10 CFR Part 20 (Ref. 30), and the collective dose associated with the irradiated fuel storage operation is maintained at a level which is ALARA.

3.3.5.3. Radiation Monitoring

Portable radiation monitors will be used as required during the operation and maintenance of the installation.

Radiation monitoring of the MVDS controlled area boundary and charge face level will be carried out as described in Section 7.3.3.

3.3.6. Fire and Explosion Protection

Minimal amounts of combustible materials are stored within or adjacent to the FSV ISFSI MVDS. The MVDS materials of construction, primarily concrete and steel, can withstand any postulated credible fire hazard at the MVDS. Portable suppression equipment such as fire extinguishers are located within the protected area boundary of the ISFSI. Security members are trained in the use of hand-held portable fire suppression equipment.

Section 7.6.4 discusses authorization for temporary storage at the ISFSI of low-level radioactive waste awaiting disposal. Such waste would be generated during maintenance, surveillance, defueling or decommissioning operations related to spent fuel storage. It is expected to consist primarily of dry active waste such as rags or paper wipes, and anti-contamination clothing (coveralls, caps, hoods, gloves, shoe covers, etc.). This waste would be packaged in 55 gallon steel drums and temporarily staged at the ISFSI while awaiting shipment. It is considered that there will not be more than about 15 drums of low-level waste stored at the ISFSI at any given time, totaling less than 100 cubic feet. Although the steel drum packaging should prevent ignition and combustion of the waste, the potential dose effects from the postulated combustion of the low-level radioactive waste are discussed in Section 8.2.4.

The ISFSI administration building meets all local fire codes and applicable National Fire Protection Association (NFPA) guidelines.

The MVDS contains no volatile materials or gases, therefore no credible internal explosion is postulated. The design basis for explosions away from the MVDS is bounded by the DBT described in Section 3.2.1 for overpressures resulting from oil and natural gas production and collection activities and infrastructure.

The effects of fires and explosions associated with oil/natural gas facilities in the vicinity of the MVDS are assessed in Reference 31. The bounding case involving an explosion in Reference 31 conservatively postulated the release of 91,700 scf of natural gas in 2 minutes from a worst case rupture of the 4 inch collection pipeline 540 feet north of the MVDS (depicted as HSG-02 on Figure 2.2-1). The nearest approach of a flammable concentration of the natural gas plume to the ISFSI from this accident, assuming conservative meteorological conditions and buoyancy of the natural gas, was computed to be 343 feet from the MVDS at a height of 200 feet above ground. It was hypothesized that all of the natural gas in the plume that was in a flammable concentration was detonated at its closest point of approach to the MVDS, although detonation of an unconfined cloud of natural gas in air is not considered credible. The resultant peak side-on overpressure at the MVDS structure was computed to be 0.74 psi, using the TNT energy equivalent method. Reference 31 determined that this overpressure is well below that which would be produced by a DBT, and this postulated accident would not threaten the structural integrity of the MVDS structure.

In Reference 31, the closest 6 inch pipeline was analyzed in the same manner as the bounding (4 inch) case. This case conservatively postulated the release of 83,300 scf of natural gas in 1 minute from a worst case rupture of the 6 inch collection pipeline 2000 feet west of the MVDS (also depicted as HSG-02 on Figure 2.2-1). The nearest approach of a flammable concentration of the natural gas plume to the ISFSI from this accident, assuming the same conditions as the bounding case, was computed to be 1770 feet from the MVDS. The detonation assumptions and calculation methods from the bounding case were applied to the 6 inch case. The resultant peak side-on overpressure at the MVDS structure was computed to be 0.12 psi which is well below the value computed for the bounding case.

In Reference 32, PSCo requested NRC review and approval of the installation of nine new oil/natural gas wells and associated natural gas pipelines within one-half mile of the ISFSI. Analyses were performed which determined that the effects of postulated rupture of the existing 4 inch pipeline routed within 540 ft. of the ISFSI, described above, would bound effects associated with the proposed new oil/natural gas wells and associated pipelines. The closest proposed new natural gas collection pipeline (depicted as DES-01 on Figure 2.2-1), which also is 4 inch diameter, will be located a distance of at least 800 ft. from the ISFSI. The closest production facilities (three-phase oil/gas/water separator and oil storage tanks) are also located approximately 800 feet from the ISFSI and are also discussed in Reference 32. The NRC approved installation of the proposed wells and pipelines within one-half mile of the ISFSI described in References 31 and 32, as evidenced by an amendment to the ISFSI license, issued in Reference 33.

As discussed in Section 2.2.1, PSCo decided to repower the FSV plant, located approximately 1,500 ft. south of the ISFSI, with combustion turbines and heat recovery steam generators. The natural gas combustion turbines and heat recovery steam generators are located on the east side of the FSV decommissioned nuclear reactor building, approximately 1,200 ft. south of the ISFSI. Natural gas is piped to the FSV power plant by means of a 12 inch diameter pipeline (depicted as FSV-02 on Figure 2.2-1) from the metering station near the intersection of Weld County Roads 19 1/2 and 34, approximately 5,700 ft. south-southwest of the ISFSI. The 12 inch supply pipeline does not approach closer than 1,400 ft. to the ISFSI. The metering station is supplied by a 24 inch diameter pipeline (depicted as FSV-01 on Figure 2.2-1) from the north at the Cheyenne, Wyoming hub. The closest point of approach of the 24 inch main supply pipeline is approximately 4,300 ft. west of the ISFSI.

PSCo submitted to the NRC a description of plans for repowering the FSV plant, along with analyses of potential effects of postulated natural gas pipeline ruptures on the ISFSI (Ref. 34). PSCo installed a valve with an automatic isolation feature over one-half mile from the ISFSI based on the commitment to the NRC in Reference 35. This valve and its control system were designed to isolate the 12 inch service line in the event of a low pressure condition, such as would result from rupture of the 12 inch service line. The analyses of the effects of natural gas pipeline ruptures on the ISFSI, summarized below, do not take credit for this automatic isolation capability.

The analyses described in Reference 34 considered four separate postulated pipeline rupture scenarios as follows:

Case 1: A rupture of the 12 inch service line at its closest point of approach to the ISFSI, conservatively assumed to be 1,400 ft. south of the ISFSI.

Case 2a: Double-ended rupture of the 24 inch main supply line at the metering station where the 12 inch service line connects to it, conservatively assumed to be 5,280 ft. south-southwest of the ISFSI.

Case 2b: Double-ended rupture of the 24 inch main supply line at the closest point of approach of the 24 inch pipeline to the ISFSI, 4,300 ft. west of the ISFSI.

Case 3: Detonation of natural gas within the turbine building, assumed to be located at a point 1,737 ft. southwest of the ISFSI. It was assumed that a pipeline rupture occurred near the turbine building and the turbine building ventilation system pulled natural gas into the building, filling the building with a stoichiometric concentration of natural gas which then ignited and detonated.

The above pipeline rupture scenarios assumed conservatively high natural gas release rates and evaluated different wind speeds to obtain worst case meteorological conditions to produce a large plume close to the ISFSI, maximizing the effects of postulated plume explosion. The analyses determined that under no condition could a flammable concentration of natural gas reach or enter into the ISFSI. While evidence indicates that an unconfined natural gas vapor cloud will conflagrate and not detonate, it was hypothesized that plume ignition resulted in a detonation for all cases (not just Case 3, where the gas is confined), resulting in conservatively high overpressures at the ISFSI. Amplification of the overpressures by reflection of the pressure wave off the ground was factored in for Cases 1, 2a and 2b above, in which elevated detonations were postulated.

The following table identifies the overpressures and impulses (pressure integrated with time) computed for the different scenarios:

Overpressure	(psi)	Impulse (psi-millisecond.)
Case 1:	3.3	252
Case 2a:	1.0	228
Case 2b:	1.3	267
Case 3:	0.7	47

The results of these analyses show that a rupture of the 12 inch service line at its closest point of approach could create the highest overpressure at the ISFSI. Because this overpressure exceeds the value for the DBT, detailed structural analyses were performed to assess the response of various portions of the ISFSI structure to the overpressures and impulses generated by the detonations. It was determined that the metal cladding of the ISFSI could be substantially damaged by Case 1, and suffer light to moderate damage for the other cases. However, the cladding does not perform a nuclear safety function, but serves as a weather enclosure for worker comfort. The important-to-safety concrete walls and chimney of the ISFSI and the charge face structure would suffer only superficial damage, and would continue to carry out their safety functions of protecting the FSCs from damage, maintaining the FSCs in a subcritical array, providing for natural convection cooling, and providing adequate radiation shielding. Thus it was determined that nuclear safety at the ISFSI would not be compromised even in the event of a worst case natural gas pipeline rupture scenario.

The NRC approved PSCo's proposed natural gas pipeline installation plans, as evidenced by an amendment to the ISFSI license issued in Reference 33, concluding that the installation of natural gas pipelines and repower facilities is acceptable and does not pose a threat to nuclear safety at the ISFSI.

In 2007 Xcel Energy, the successor company to PSCo, advised DOE-ID of its plan to add two additional combustion turbines adjacent to the three existing units, as well as a new 12 inch service line parallel to the existing service line. A qualitative comparison of the new service line with the hazard analysis of bounding Case 1 indicated the Case 1 analysis bounded the new service line (Ref. 42).

The effects of fires on the MVDS are analyzed in Reference 36. That analysis considers fires from oil/gas wells, pipelines, a 9,000 gallon storage tank, small aircraft (such as crop dusters), and diesel fuel tanks. The bounding case involving a fire is that of the transport trailer tow vehicle fuel tanks catching fire in the TCRB. Such a fire will not create a significant hazard to the MVDS concrete structure or important to safety equipment. A barrier was installed in the TCRB before unloading FSCs to the MVDS during fuel loading operations with the FSV-1 transfer cask (see Section 4.3). This barrier assured that the transport trailer tow vehicle's fuel tanks remained outside the MVDS. ISFSI defueling operations will utilize the TN-FSV transfer casks instead of the FSV-1 casks, as described in Section 4.3. The trailers that transport the TN-FSV casks are much longer than those used with the FSV-1 casks, and approximately 4 feet longer than the TCRB. The length of the TN-FSV cask trailers positively prevents entry of the tow vehicle's fuel tanks into the TCRB.

No credible design basis mechanism could be identified that could cause a graphite fire (graphite oxidation) of the spent fuel elements to occur. The FSCs are carbon steel with double metal O-ring seals. The storage environment is a confined volume of air.

3.3.6.1. Aircraft Hazards

As described in Section 2.2.3, there are two federal low altitude airways that pass overhead within a 5 mile radius of the ISFSI site. Victor 575, which goes northwest from DIA toward Laramie, Wyoming, passes within approximately 4.8 miles southwest of the ISFSI; and Victor 220, which is directed southwest from Greeley, Colorado, passes within approximately 4.1 miles to the northwest of the ISFSI (Ref. 37). There also is a high altitude jet route passing within a 5 mile radius of the ISFSI, designated J-13, directed north from DIA towards Cheyenne, Wyoming. The ISFSI is located approximately 21 miles north and 9 miles west of the nearest DIA runway. A conservative assessment of the annual probability of an aircraft impacting the ISFSI MVDS was made based on the following information using the guidelines in NUREG 0800, Chapter 3.5.1.6 (Ref. 5):

1. The traffic volume at the Stapleton International Airport for the years 1986 through 1994 (Ref. 38) was as follows:

Year	Yearly Total Operations	Average Daily Operations
1986	524,247	1,436
1987	520,836	1,427
1988	503,185	1,379
1989	463,797	1,271
1990	484,040	1,326
1991	488,254	1,338
1992	506,706	1,388
1993	552,422	1,513
1994	530,839	1,454

Flight operations at Stapleton International Airport ceased at the end of February, 1995, with the opening of DIA. For the first six months after its opening on February 28, 1995, DIA had a total of 245,538 flight operations, an average of 1,334 operations per day. The Federal Aviation Administration (FAA) at DIA indicated that flight paths of aircraft departing DIA vary constantly depending on the departing and arriving runways in operation. Arrival flight paths are more consistent, and the ISFSI is located outside the area where arriving aircraft normally begin their final descent below 6,000 feet above ground level into DIA. Aircraft arriving and departing DIA will normally be at least 6,000 feet above ground level in the vicinity of the ISFSI (Ref. 39). In response to PSCo's request for information, FAA personnel at DIA estimated that 66,000 flights per year pass through the airspace above a horizontal circle on the ground, centered at the ISFSI, with a radius of 5 nautical miles (Ref. 40). This estimate includes flights operating out of airports other than DIA, such as Loveland/Fort Collins, Greeley and Jefferson County.

A traffic volume near the FSV site of 240 flights per day (15%) based on a DIA daily traffic volume of 1,600 operations was conservatively assumed. Relative to the major population centers throughout the continental United States, the majority of the DIA operations would involve east-west destinations rather than north/south over the ISFSI site. This volume includes general aviation (including crop dusting and spray aircraft), air carrier and military.

2. The enroute accident rate was assumed to be 4E-10 per mile (Ref. 5). This value is conservative (for the data presented in Ref. 5) since the ISFSI site is greater than 10 miles from the end of DIA's runways.

3. Although the legal width of Federal VOR airways is 9.2 statute miles, the effective width of the Federal airways is 7 miles at the ISFSI site. Federal Aviation Regulations (14 CFR 91.123(a)) require aircraft operating under IFR to fly along the centerline of the Federal airway. The regulations (14 CFR 171) permit a maximum error of ± 6 degrees in the aircraft equipment used to determine the location of the airway. Since the ISFSI site is within 30 miles from 5 VOR transmitters, the effective width of the airway at the ISFSI site would be 7 miles.

4. An impact angle of 45 degrees to the MVDS was assumed. This angle will result in calculating the largest effective target area. The effective area of the MVDS would be the (MVDS base area) + (MVDS elevation area x cot 45 degrees) = .0005 square miles. An effective target area of .002 square miles, which includes the area within the ISFSI fence, was conservatively assumed.

5. The annual probability of flight accident (PFA) of an aircraft traveling on an airway or initial approach segment impacting on the ISFSI MVDS is given by Ref. 5:

   where: PFA = CNA/W

   C = Probability of aircraft accident per mile of flight = 4E-10 per mile

   N = Number of aircraft/year traveling on airway = 87,600

   A = Effective area of plant = 0.002 square miles

   W = Effective width of airway in miles = 7 miles

   PFA = 1.0 E-08 per year

NUREG-0800, Section 3.5.1.6, Acceptance Criteria states that "aircraft accidents which could lead to radiological consequences in excess of the exposure guidelines of 10 CFR Part 100 with a probability of occurrence greater than about 1E-7 per year should be considered in the design..."

It is conservatively concluded that the risk of an aircraft impacting upon the ISFSI MVDS and causing radiological consequences exceeding 10 CFR Part 100 guidelines is below 1E-7 per year. Such accidents are therefore not considered design basis events, and design for aircraft impact or ensuing fire hazard is not necessary.

3.3.7. Materials Handling and Storage

3.3.7.1. Spent Fuel Handling and Storage

The handling of spent fuel is conducted with the fuel fully contained by its FSC and shielded within the transfer cask or CHM. Criticality safety during all phases of handling and storage is discussed in Section 3.3.4, where it is shown that sub-criticality is maintained.

The maximum temperature of the fuel will not endanger its integrity.

3.3.7.2. Radioactive Waste Treatment

Radioactive waste, both of solid or liquid form, are minimal with the MVDS design. Further information is provided in Section 6.

Table 3.3-1. Radioactivity Confinement Barriers and Systems for the MVDS.

Radioactive Source: FSV HTGR spent fuel.

Confinement Barriers and Systems: Fuel TRISO coating. In addition the following are available:

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1. Residence in the vault module storage position: FSC.

2. During transfer of the FSC between the vault module storage position in the MVDS and the cask: FSC and CHM.

Table 3.3-2. Radiation Zone Designations.

ZONE NO.	ZONE DESCRIPTION	MAXIMUM DOSE RATE (mrem/hr)
I.	Unrestricted area - continuous access	< 0.20
II.	Unrestricted area - occupational access	< 2.0
III.	Restricted area - periodic access	< 5
IV.	Restricted area - controlled access	< 20
V.	Radiation area - controlled infrequent access	< 100
VI.	High radiation area not normally accessible	> 100

Table 3.3-3. Allocation of Radiation Zones for MVDS.

PLANT AREA	RADIATION ZONE DESIGNATION	(MREM/HR)
Controlled Area Boundary (Outer Fence)	II	(< 2.0)
ISFSI Fence	IV	(< 20.0)
Administration Building	II	(< 2.0)
TCRB	IV	(< 20.0)
Charge Hall	III	(< 5.0)
Around CHM with full FSC loaded	V	(< 100.0)
Exclusion around inlet duct	V	(< 100.0)

Table 3.3-4. Calculated Multiplication Factors for Uranium, Water, and Graphite Spheres.

CASE	REFERENCE	H/U	C/U	REFLECTED?	2GR	5GR	9GR	12GR	18GR	22GR
1	*	0	0	YES	1.060	1.130	1.034	1.057	1.051	--
2	*	20	0	YES	1.194	1.077	1.027	1.009	--	--
3	*	126	0	YES	--	--	1.039	--	--	--
4	*	500	0	YES	1.160	1.056	1.038	1.019	1.014	--
5	*	573	0	YES	--	--	1.030	1.011	1.005	1.004
6	*	573	0	NO	--	--	1.022	--	--	--
7	*	1000	0	YES	--	--	1.023	1.005	--	--
8	**	0	316	YES	--	1.025	1.022	--	--	--
9	**	0	1271	NO	1.049	1.038	1.032	1.022	--	--
10	**	0	5091	NO	--	--	1.009	--	--	--
11	**	335	316	YES	1.156	1.062	1.052	1.022	--	--
12	**	1348	1271	YES	--	--	1.014	1.006	--	--

* W.R. Stratton, "Critical dimensions of Uranium - Graphite - Water Spheres, Cylinders, and Slabs," LAMS-2944, LANL, 1962.

** H.C. Paxton, "Critical Dimension of systems Containing U-235, Pu-239, and U-233," TID-7028, LANL/ORNL, 1964.

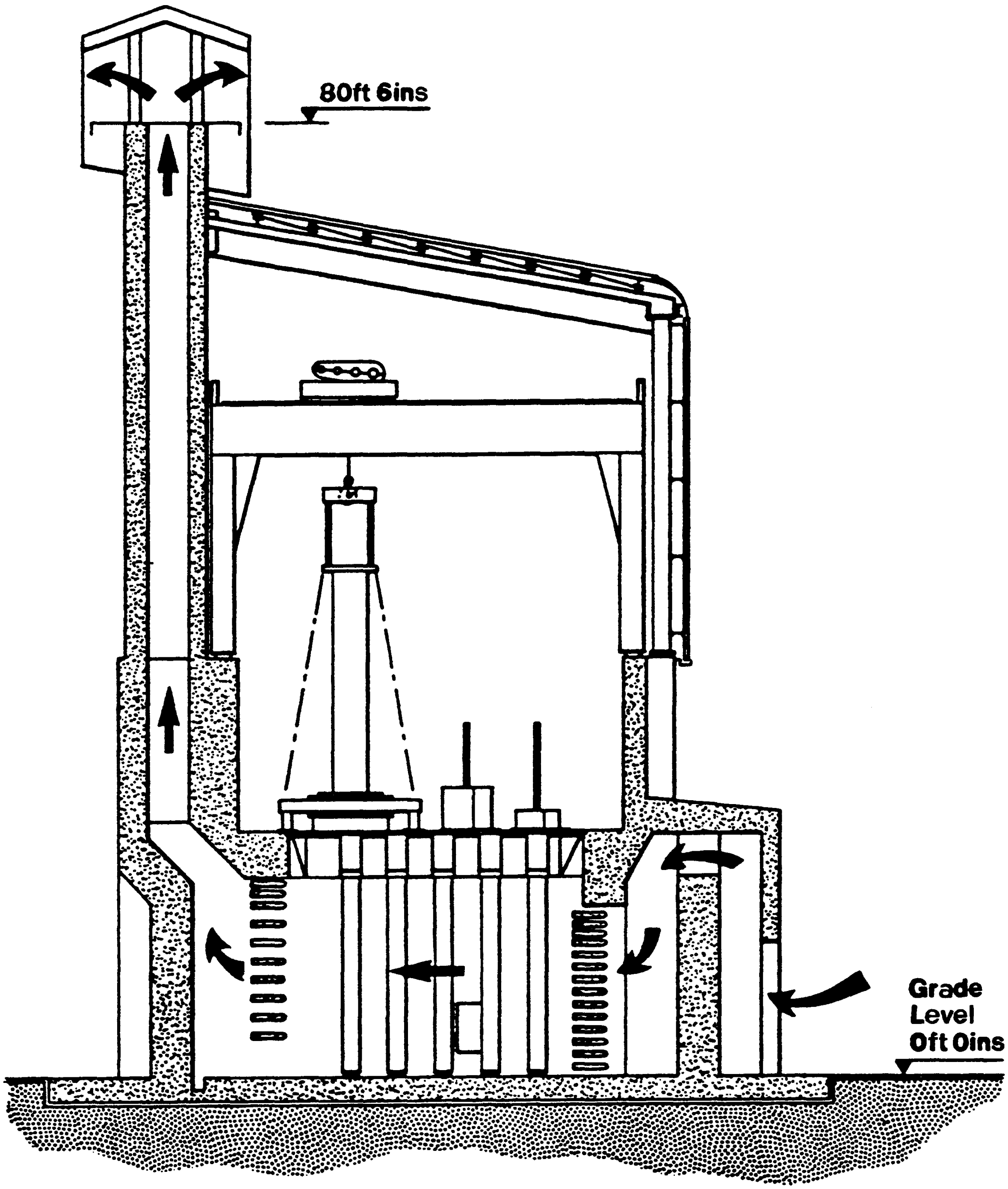

Figure 3.3-1. MVDS Cooling Flow.

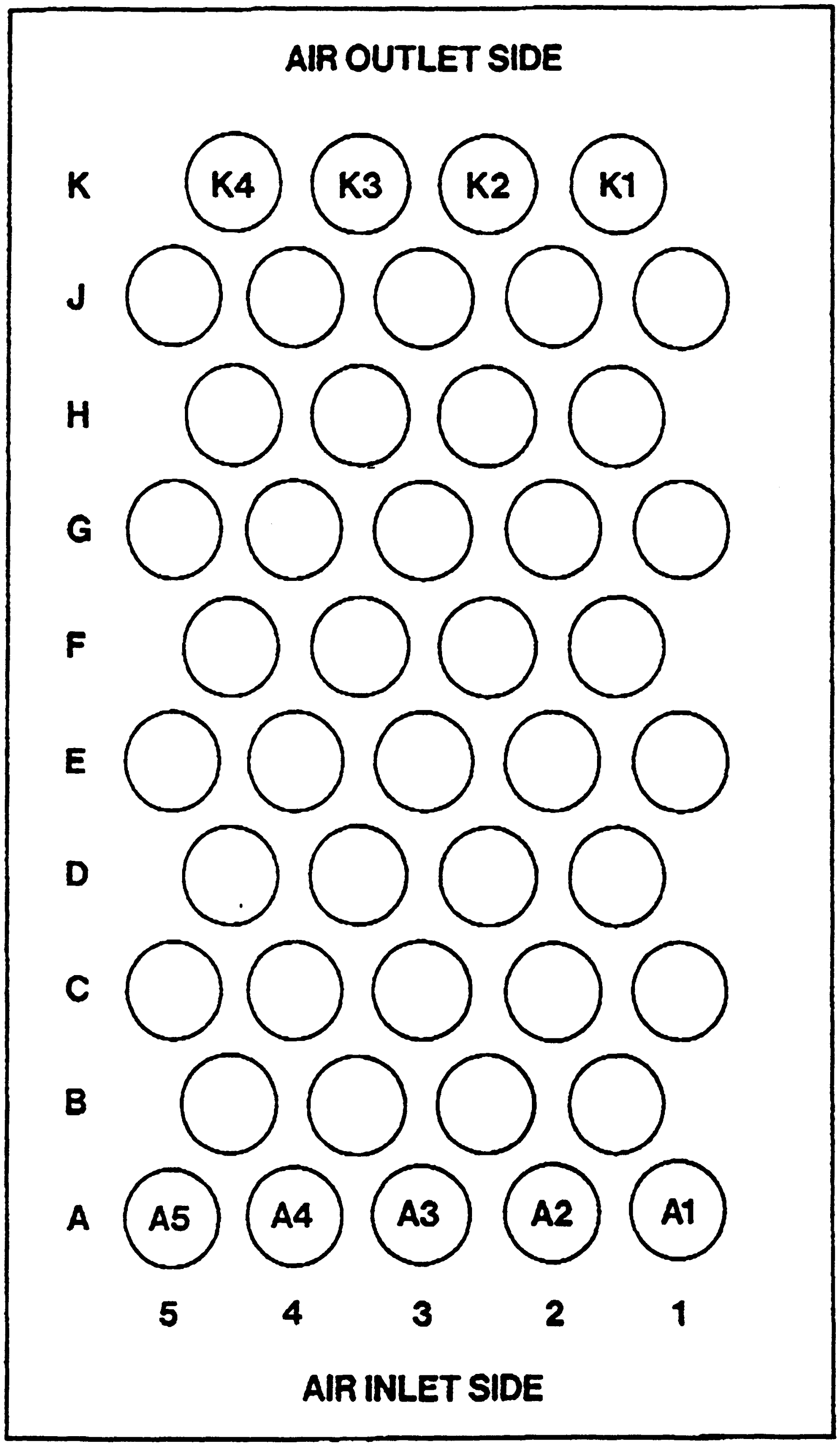

Figure 3.3-2. Vault Module Storage Locations.

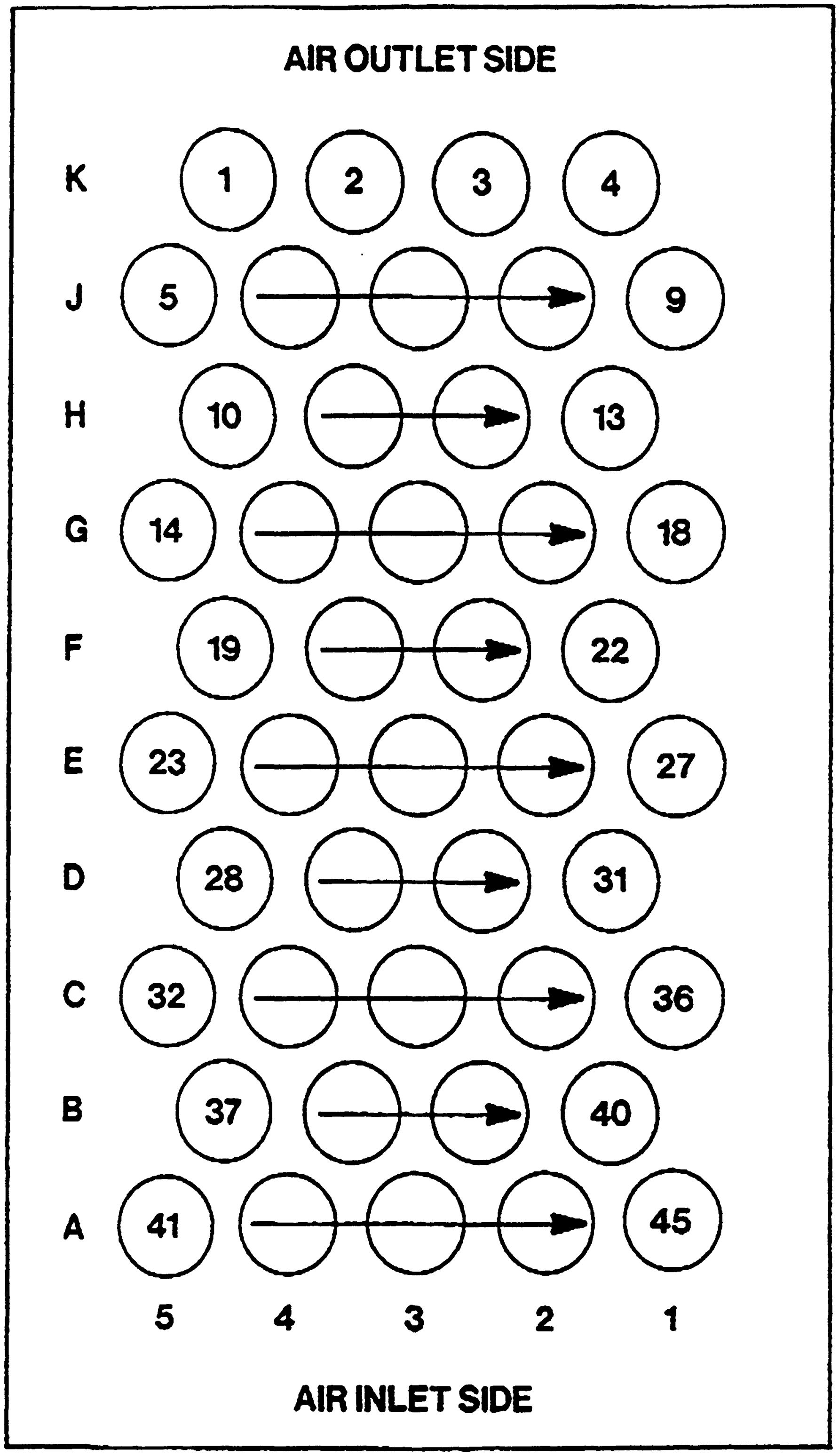

Figure 3.3-3. Vault Module Loading Pattern

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3.4. Classification of Structures, Systems, and Components

Classification of components as important to safety or enhanced quality was based on the specific need for component function under accident conditions, or other operational considerations.

3.4.1. Important to Safety

The definition of important to safety in 10 CFR Part 72 (Ref. 2) is:

"Structures, systems and components important to safety means those features of the ISFSI whose function is:

1. To maintain the conditions required to store spent fuel or high level radioactive waste safely,
2. To prevent damage to the spent fuel or high level radioactive waste container during handling and storage, or
3. To 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."

3.4.1.1. Classification Criteria

The classification criteria used during design for compliance with the 10 CFR Part 72 definition was:

“An ISFSI structure, system, or component shall be classified as important to safety if:

1. It forms a primary or secondary containment boundary, or
2. It controls or prevents criticality, or
3. It is used to prevent radioactive releases (gaseous and particulate) resulting in an exposure at the owner controlled boundary in excess of 5 rem (per 10 CFR 72.106) for any design basis accident.”

The classification criteria met the 10 CFR Part 72 definition for structures, systems, and components considered as important to safety for the following reasons.

1. A structure, system, or component which forms a primary containment boundary encompasses all three functions of the definition. Primary and secondary containment allow safe storage of spent fuel since the primary function is to prevent the release of radioactive gases and particles. It also acts as a barrier against fuel damage during handling and storage. In addition, it provides a method for handling the spent fuel without creating an undue risk to the health and safety of the public.

2. A structure, system, or component which prevents criticality allows spent fuel to be handled and stored safely. Items in this category prevent the establishment of a configuration which would sustain a nuclear chain reaction. By preventing criticality, the spent fuel can be packaged, stored, handled and retrieved safely without exposing the public to an undue risk to their health and safety.

3. A structure, system, or component which prevents radioactive releases in excess of 5 rem (design basis accident) at the owner controlled boundary allows the ISFSI design to meet the requirements of 10 CFR 72.106. Items in this category help to provide reasonable assurance that the spent fuel can be handled and stored safely without causing an undue risk to the health and safety of the public.

Therefore, the criteria established for the ISFSI design to meet the definition of important to safety provide a reasonable assurance that spent fuel will be packaged, received, handled, stored, and retrieved safely at the ISFSI without posing an undue risk to the health and safety of the public in accordance with 10 CFR Part 72.

DOE-ID will use these classification criteria to classify structures, systems, and components involved with any future design modifications.

3.4.1.2. Listing of Structures and Components

The FSV ISFSI components classified as important to safety are listed in Table 3.4-1. These items were selected based on the criteria in Section 3.4.1.1 as follows:

1. FSCs and Standby Storage Wells (provides the secondary containment boundary for the spent fuel).

2. Raise/Lower Mechanism and FSC Grapple assemblies of the Fuel CHM (prevents damage to the FSC during handling operations).

3. CLUP and FSC Support Stools (prevents and controls criticality and radioactive releases).

4. The structural steel of the Charge Face Structure (the charge face structure maintains the FSCs in a non-critical array and therefore prevents criticality).

DOE-ID will apply its QA Program, described in Section 11, to these important to safety items.

The following two items discuss the structures and components which were not classified as important to safety, but fell under the enhanced quality program during design and construction. The enhanced quality items do not form a primary or secondary containment boundary, prevent or control criticality, or prevent radioactive releases, however, the function they perform is considered important to the operation of the ISFSI and they received a level of quality commensurate with their important function.

1. The structural concrete of the MVDS building was designed to withstand the forces from a seismic event and a DBT. This structural concrete was designed to

ACI 349-85 (Ref. 13) and constructed to ACI 318-83 (Ref. 41). The enhanced quality program implemented the QA requirements specified in these ACI codes. The MVDS structural concrete was considered enhanced quality since it does provide radiation and missile shielding and is capable of withstanding a seismic event. However, it does not form a primary or secondary containment boundary, prevent or control criticality, or prevent radioactive releases.

2. The concrete fill inside the Charge Face Structure was designed and constructed under the enhanced quality program since it performs the bulk of radiation shielding for operations personnel. It should be noted that the concrete fill does not aid the structural steel sections of the Charge Face Structure in preventing criticality.

The enhanced quality program that was in effect during the ISFSI design, construction and initial fuel loading, which was included in PSCo's FSV 10 CFR Part 50 Appendix B QA program, was applicable to certain aspects of the physical security and fire protection systems. Neither the security nor the fire protection systems are important to safety, therefore any modifications to these systems after license transfer will be under the DOE-ID Quality Assurance Program.

Table 3.4-1. FSV ISFSI Components Classified as Important to Safety.

Important to Safety Items
Fuel Storage Containers
Fuel Storage Container Support Stools
Standby Storage Wells
Container Handling Machine Raise/Lower Mechanism
Container Handling Machine Fuel Storage Container Grapple
Charge Face Structure Structural Steel
Cask Load/Unload Port
Structural Concrete of the MVDS Building (Enhanced Quality Item)
Concrete Fill inside the Charge Face Structure (Enhanced Quality Item)

3.5. Decommissioning Considerations

Details of conceptual plans for decommissioning the FSV ISFSI are contained in DOE-ID's FSV ISFSI Decommissioning Plan provided as an enclosure to the FSV ISFSI License Renewal Application. This decommissioning plan describes the proposed program (approaches, elements, and cost estimates) for decommissioning the FSV ISFSI.

The tentative selection of decommissioning alternatives is based on providing decontamination and removal of radioactivity from the site and dismantling the modular vault structure. DECON is the preferred decommissioning alternative. The program includes fuel removal, detailed decommissioning plan preparation (engineering and planning, filing an updated decommissioning plan with the NRC, and site preparation), decommissioning operations and license termination, and site restoration.

The FSV ISFSI Decommissioning Plan contains cost estimates for decommissioning the FSV ISFSI. The DOE Office of Environmental Management has included the FSV ISFSI decommissioning program in its overall cost estimate for the Environmental Management Program at the INL. Based on these estimates, there is reasonable assurance that decommissioning funds will be provided.

Decommissioning of the MVDS can be performed in a manner consistent with that for decommissioning other INL nuclear facilities, including spent nuclear fuel facilities. The FSCs can be retrieved from the MVDS and transferred to a federal facility.

All components of the MVDS are manufactured of materials similar to those found at existing plants (e.g., reinforced concrete, carbon steel, and stainless steel). These components can, therefore, be decommissioned by the same methods in place to handle those materials at the INL. Any of the components that may be contaminated can be cleaned and/or disposed of using the decommissioning technologies available at the time of decommissioning.

The MVDS is a dry containment system that effectively confines all contamination within the FSCs. When the FSCs are removed from the MVDS, the freestanding MVDS can be manually decontaminated for any radioactive material, dismantled, and removed from the site.

Records that support decommissioning will be treated as QA records. The FSV ISFSI Decommissioning Plan identifies the types of records that will be maintained to facilitate the ISFSI decommissioning.

3.6. Summary of MVDS System Design Criteria

3.6.1. Reference Spent Fuel Characteristics

1. Quantity: Up to 1,482 HTGR fuel elements (six segments), up to six neutron source elements and 37 keyed top reflector elements. (See Section 1.1.1 for actual inventory.)

2. Decay Heat: 150 W per element (maximum)

   85 W per element (average).

3. Maximum Burnup: 52,000 MWd/MT

Physical and radiological characteristics of the spent fuel are given in Table 3.1-1 and 3.1-2.

3.6.2. Components Functions

1. FSC: provides a sealed containment envelope for the spent fuel.

2. CHM: provides for the shielded and contained transfer of the FSCs between the transfer cask and the MVDS, vault module storage positions.

3. MVDS: provides shielding, passive decay heat removal, structural and seismic support and environmental protection for the FSCs.

4. MVDS Crane: provides the means of handling the transfer cask, CHM, and other equipment in the MVDS.

3.6.3. Environmental Conditions

<u>Seismic</u>

1. Ground Motion Spectra

   In accordance with NUREG/CR-0098 (Ref. 10).

2. Ground Acceleration

   DBE ground acceleration of 0.1g.

3. Damping

In accordance with NRC Regulatory Guide 1.61 (Ref. 11).

Flooding

Six feet above grade elevation.

Tornado

1. The design tornado in accordance with Regulatory Guide 1.76 Region 1 (Ref. 4) and tornado missile in accordance with NUREG 0800, Section 3.5.1.4 (Ref. 6).

2. The steel enclosure cladding to withstand a maximum wind speed of 110 mph as specified in ANSI 58.1 (Ref. 7).

3. The steel structure to withstand forces due to design tornado in accordance with Regulatory Guide 1.76, Region 1, assuming cladding in place.

Temperature

Ambient air temperature extremes are: maximum 120 degrees F, minimum minus 32 degrees F.

Snow Loading

Maximum snow load of 30 psf.

3.6.4. Safety Protection

1. The worst case condition for fuel temperatures was encountered while the fuel was contained in the transfer cask. The maximum calculated temperatures, assuming peak rated fuel, are 316 degrees F at the fuel element centerline and 264 degrees F at the FSC. These temperatures are well below the design temperatures of 750 degrees F (fuel) and 300 degrees F (FSC).

2. Fuel confinement - Multiple Barrier Concept.

3. Criticality control is by the vault storage configuration ($K_{eff} < 0.75$).

4. Off-gasses - During normal operation there is no release of "off-gasses." In the off-normal operation of changing over fuel elements from one FSC to another, any FSC gas pressure is released and filtered before the FSC is opened. If purging is required any gasses released will be HEPA filtered and monitored during the release.

3.7. References

1. 10 CFR Part 61, "Licensing Requirements For Land Disposal of Radioactive Waste."

2. 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste."

3. Engineering Evaluation, "Fort St. Vrain Decay Heat Analysis for Spent Fuel," Rev. A, June 20, 1990.

4. "Design Basis Tornado For Nuclear Power Plants," USNRC Regulatory Guide 1.76 - 1974.

5. Foster Wheeler Energy Application, Inc. Topical Report for the Modular Vault Dry Store (MVDS) for Irradiated Nuclear Fuel, Revision 1, November 12, 1987.

6. NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, LWR Edition, July, 1981.

7. ANSI A58.1 - 1982 "Minimum Design Loads for Buildings and Other Structures."

8. Engineering Evaluation, "ISFSI Flood Analysis (From the FSV Storage Ponds)," EE-DEC-0028, Rev. A, March 16, 1990.

9. FSV document Dwg. 172-1.8, "Fort St. Vrain 1979 Aerial Map and Contours," Sht. 5, Rev. A.

10. NUREG/CR-0098, "Development of Criteria For Seismic Review of Selected Nuclear Power Plants."

11. "Damping Values For Seismic Design of Nuclear Power Plants," USNRC Regulatory Guide 1.61 - 1973.

12. FSV document DC-70 "Design Criteria: Structures - General," Issue F.

13. ACI 349-85, "Code Requirements for Nuclear Safety Related Concrete Structures."

14. ANSI/ANS 57.9 - 1984, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)."

15. AISC Manual of Steel Construction: Allowable Stress Design, Ninth Edition, 1989.

16. ANSI/ASME NOG-1-1983 "Rules for Construction of Overhead and Gantry Cranes."

17. CMAA 70 "Specification for Electric Overhead Traveling Cranes," - 1988.

18. GEC Alsthom Energy Systems Ltd. Technical Specification, MVDS Crane, No. 362 F 0008.

19. GEC Alsthom Energy Systems Ltd. Technical Specification, Modular Vault Dry Storage Project Data File, No. 362 F 0001, Issue D.

20. Rucker, R., "Nuclear Safety of FSV ISFSI," General Atomics Technologies Inc. Report Number 910055.

21. GA Technologies Inc., Document No. GA-10600, FSV Fuel Specification, Issue BP, February 28, 1985.

22. Summary of Nuclear Criticality Safety for the FSV HTGR Fuel, G.A. Document, GAMD-10493, April 1971.

23. Walti, P., and Kock, P., MICROX - A two region flux spectrum code for the efficient calculation of group cross sections, Gulf-GA-A10827, April 14, 1972.

24. ANSI/ANS 6.4-85, "Guidelines on Nuclear Analysis and Design of Concrete Radiation Shielding for Nuclear Power Plants."

25. Archibald, R., Lathrop, K.D., and Mathews, D., 1DFX-A revised version of the IDF (DTF-IV) Sn transport theory code, Gulf-GA-B10820, September 27, 1971.

26. MCNP - A general Monte Carlo Code for neutron and photon transport, Version 3A, LA-7396-M, Revision 2, September 1986.

27. Nuclear Safety Evaluation Guide, January 1988, by General Atomics Nuclear Safety Staff.

28. 10 CFR Part 73, "Physical Protection and Plants and Materials,"

29. "Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Reasonably Achievable," USNRC Regulatory Guide 8.8, Rev. 3, June 1978.

30. 10 CFR Part 20, "Standards For Protection Against Radiation."

31. PSCo letter dated July 2, 1991 (P-91202), Crawford to Ruffin (NRC), Subject: "Fort St. Vrain Independent Spent Fuel Storage Installation; Potential Effects of Nearby Natural Gas Wells and Pipelines."

32. PSCo letter dated August 24, 1994 (P-94073), Crawford to Sturz (NRC), Subject: "Request Issuance of License Amendment to Permit Installation of New Oil/Natural Gas Wells and Pipelines Within One-Half Mile of the Fort St. Vrain ISFSI."

33. NRC letter dated August 2, 1995 (G-95126), Travers (NRC) to Crawford, Subject: “Amendment No. 1 to License SNM-2504.”

34. PSCo letter dated July 21, 1994 (P-94061), Warembourg to Sturz (NRC), Subject: “Fort St. Vrain Repowering Natural Gas Hazards Analysis.”

35. PSCo letter dated July 12, 1995 (P-95072), Fisher to Sturz, Subject: “Fort St. Vrain Repowering, Amendment to ISFSI Materials License to Permit Installation of Natural Gas Pipelines.”

36. Engineering Evaluation, "Independent Spent Fuel Storage Installation Fire Hazards Analysis," EE-FP-0019, Rev. BA, August 23, 1990.

37. VFR Terminal Area Chart, Denver, 43rd Edition, February 2, 1995.

38. Total Operations Report, 1986 through 1989, DOT/Federal Avaition Administration, Airport Traffic Control Tower, Stapleton International airport.

39. Federal Aviation Administration Letter dated June 8, 1994, Parrent to Yoder (PSCo), Subject: “Air Traffic Overflying Fort St. Vrain with the New Denver International Airport.”

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41. ACI-318-83, Revised in 1986, "Building Code Requirements for Reinforced Concrete."

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3.8. Appendix A3-1.1

Proprietary