5 SUMMARY OF SEISMIC RESULTS

Analysis of the seismic results provides information about the overburden soil/sediment layers, bedrock surface and bedrock structure.

5.1 OVERBURDEN SOIL/SEDIMENT LAYERS

The refraction P-wave results revealed the presence of three seismic layers within the soil and sediment structure below the site to an approximate depth of 120 to 140 feet. S-wave results identified two soil/sediment zones to a depth of about 80 feet. These results indicate that a low-velocity upper soil zone, an unsaturated sediment zone and an interpreted saturated zone exist below the site. Each layer contains a limited range of seismic velocities which indicate that they are relatively homogeneous in character. As expected, these layers are somewhat horizontal and do not have significant lateral changes in their seismic velocities. No evidence exists for faulting or movement within the alluvium section.

5.2 BEDROCK CONDITIONS

Reflection results provided profiles of the bedrock surface, estimates of its depth and stratigraphy and structure within the bedrock. The bedrock surface shows a significant dip from the west portion of the site towards the eastern portion. Along Line 2, bedrock depths are estimated to range from 520 feet to over 820 feet below the proposed storage area; along Line 3, bedrock depth dips from 740 feet at Station 700 to over 1020 feet at the eastern end of the line along the access easement.

Reflectors within the bedrock revealed many strong and weak reflecting layers, many of which showed significant dip to the east. Discontinuities in the reflection profiles on both lines are interpreted as a complex fault system within the bedrock; however, no evidence exists for the continuation of these features into the lower alluvium section.

APPENDICES

APPENDIX A

DESCRIPTION OF SEISMIC METHODS

Seismic Exploration

"Seeing" with sound is a familiar concept. Bats and submarines do it and so does a blind man with a cane. In total darkness we can sense whether we are in a closed or open space by the echoes from our footsteps.

Seismic exploration, in principle, is nothing more than a mechanized version of the blind person and his cane. In place of the tapping cane we have a hammer blow on the ground, or an explosion in a shallow hole, to generate sound waves. And we "listen" with geophones, spring-mounted electric coils moving within a magnetic field, which generate electric currents in response to ground motion. Careful analysis of the motion can tell us whether it is a direct surface-borne wave, one reflected from some subsurface geologic interface, or a wave refracted along the top of an interface. Each of these waves tells us something about the subsurface.

Applications of Seismic Methods

Seismic reflection and refraction have numerous potential applications to a variety of environmental and geotechnical problems, including:

- **Depth and characterization of bedrock surface**
- **Buried channel definition**
- **Depth of water table**
- **Depth and continuity of stratigraphic interfaces**
- **Rippability determination**
- **Mapping of faults and other structural features**
- **Location of karst features**

Seismic Reflection

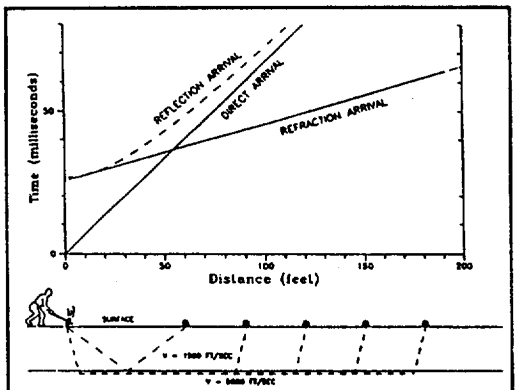
Reflections of sound waves from the subsurface arrive at the geophones some measurable time after the source pulse. If we know the speed of sound in the earth and the geometry of the wave path, we can convert that seismic travel time to depth. By measuring the arrival time at successive surface locations we can produce a profile, or cross-section of seismic travel times. A simple concept.

In practice, the speed of sound in the earth varies enormously. Dry, unconsolidated sand might carry sound waves at 800 feet per second (fps) or less. At the other extreme, unfractured granite might have a velocity in excess of 20,000 fps. And the more layers between the surface and the layer of interest, the more complicated the velocity picture. Various methods are used to estimate subsurface velocities, including refraction analysis, borehole geophysical measurements, estimates from known lithologic properties, and analysis of reflection times at increasing offsets. Generally, a combination of velocity estimation methods will give the best results.

Seismic Refraction

When a sound wave crosses an interface between layers of two different velocities, the wave is refracted. That is, the angle of the wave leaving the interface will be altered from the incident angle, depending on the relative velocities. Going from a low-velocity layer to a high-velocity layer, a wave at a particular incident angle (the "critical angle") will be refracted along the upper surface of the lower layer. As it travels, the refracted wave spawns upgoing waves in the upper layer, which impinge on the surface geophones.

Sound moves faster in the lower layer than the upper, so at some point, the wave refracted along that surface will overtake the direct wave. This refracted wave is then the first arrival at all subsequent geophones, at least until it is in turn overtaken by a deeper, faster refraction. The difference in travel time of this wave arrival between geophones depends on the velocity of the lower layer. If that layer is plane and level, the refraction arrivals form a straight line whose slope corresponds directly to that velocity. The point at which the refraction overtakes the direct arrival is known as the "critical distance", and can be used to estimate the depth to the refracting surface.



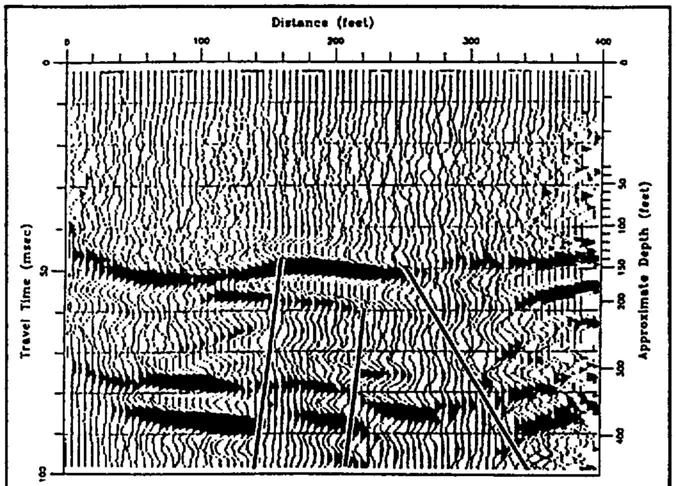
Seismic Travel Time Diagram

Field Procedures

Seismic field acquisition involves three basic elements:

- a source of acoustic energy
- seismic receivers, or geophones
- a seismograph to record the data

The choice of seismic source depends on the needs of the particular survey. For deeper work, a powerful source, such as the "Elastic Wave



Seismic Reflection Profile Showing Faulted Bedrock

Generator", a trailer-mounted accelerated weight drop, would be used. Shallow, high-resolution work demands a high-frequency source, such as the "Betsy" downhole shotgun. Geophones are also selected according to the needs of the survey: higher-frequency phones for high-resolution work, lower-frequency for deeper targets. Our Bison Instruments 8024 and 9024 seismographs both offer 24-channel recording capability, with internal data storage to enhance field productivity. The 9024 floating-point system is arguably the best engineering seismograph available today, with recording specifications better than many oil industry systems.

Typically, the geophones are placed along a line at equal intervals (3 to 5 feet for high-resolution, 10 to 20 feet for deeper work). The arrangement of source and geophones depends on the nature of the survey. For seismic reflection, the relative source and geophone positions are usually held constant, the entire 24-geophone array being moved along with the shot. (The logistical difficulties of this are eased by using a "roll switch", which selects 24 geophones from an overall spread of 48.) Refraction work requires shots at opposite ends of the spread, with additional shot locations depending on the particular needs of the job.

Data Processing

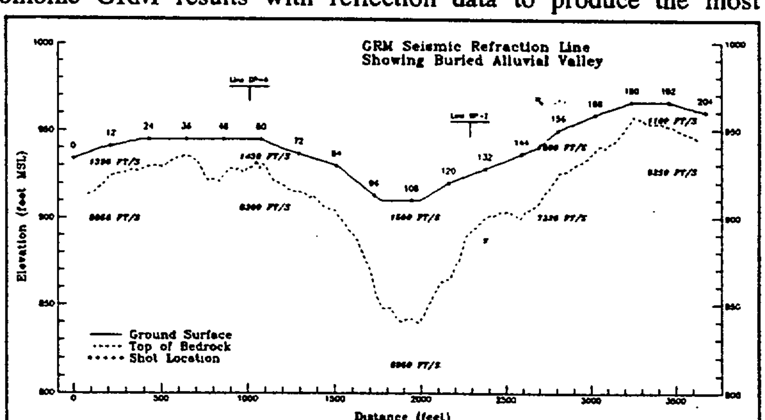
A seismic reflection section is, in principle, a series of seismic traces recorded by a geophone at the same location as the shot. Each trace must be time-corrected to allow for the source-geophone offset, the correction depending on the layer velocities. If the correction is accurate, a given reflection is moved up the trace to the position it would have were the source and receiver coincident. Using the field procedure described above, 12 individual traces, of various source-receiver offsets, will have a common midpoint. These 12 traces, after correction, are summed to produce one common depth point, or 12-fold CDP trace. The resulting summed traces are then displayed as a single seismic cross-section.

A seismic trace may contain as many as 4000 individual samples. With each shot generating 24 traces, a typical seismic line will contain several million samples. Geosphere processes these data with the "Eavesdropper" package, developed by the Kansas Geological Survey for 386/486 PC computers. Specialized reflection data can also be processed using common offset software developed by the Canadian Geologic Survey. Augmented by several programs developed by Geosphere, we now have a seismic reflection processing system tailored to the unique problems encountered in high-resolution seismic work. We believe this system to be unmatched in the industry.

Seismic refraction data can be interpreted in several ways. The simplest approaches assume a series of plane, dipping layers. While effective in many instances, this method is not suited to irregular or undulating layers. The Generalized Reciprocal Method (GRM) goes beyond the plane-layer assumption, producing a profile which allows for irregularities in the refracting surface. When possible, we combine GRM results with reflection data to produce the most comprehensive seismic interpretation available.

Summary

Seismic exploration is a powerful geophysical technique. The same principles which have achieved unparalleled success in the petroleum industry can also enhance environmental and hazardous waste site investigations, ground water exploration, geotechnical engineering, archaeology, and mining exploration. At Geosphere, we intend to continue providing the most effective, state-of-the art seismic exploration available.



APPENDIX B

SEISMIC REFRACTION DATA

SEISMIC REFRACTION PROCESSING DESCRIPTION
LINES 1, 2 & 3

DATA ACQUISITION PARAMETERS

Shotpoint Interval:	240 ft	Geophone Interval:	20 ft
Configuration:	on end, split spread	Traces/Record:	24 traces
Instruments:	Bison 9024	Gain Type:	AGC
Sample Rate:	0.25 msec	Data Length:	500 msec
Energy Source:	EWG 5	Field Filters:	16 to 250 Hz
Near Offset:	10, 250, 490 ft	Geophones:	30 Hz low-cut
Far Offset:	470, 710, 950 ft		

PROCESSING SEQUENCE

I. Picking of first arrival times (Interpex's Firstpix software)
A. Data displayed and expanded on computer screen
B. Picks made with electronic cursor, stored to file

II. Entry of positions and geometries
A. Manual entry of shot locations and elevations
B. Manual entry of geophone geometries, locations and elevations

III. Sort data into 48 channels per shot location
A. 24 channel first-pick files are sorted into proper 48 channel data sets

IV. Layer assignment by first arrival breaks

V. Gremix analysis using generalized reciprocal method (GRM)

VI. Plotting of Gremix layer results with seismic velocities.

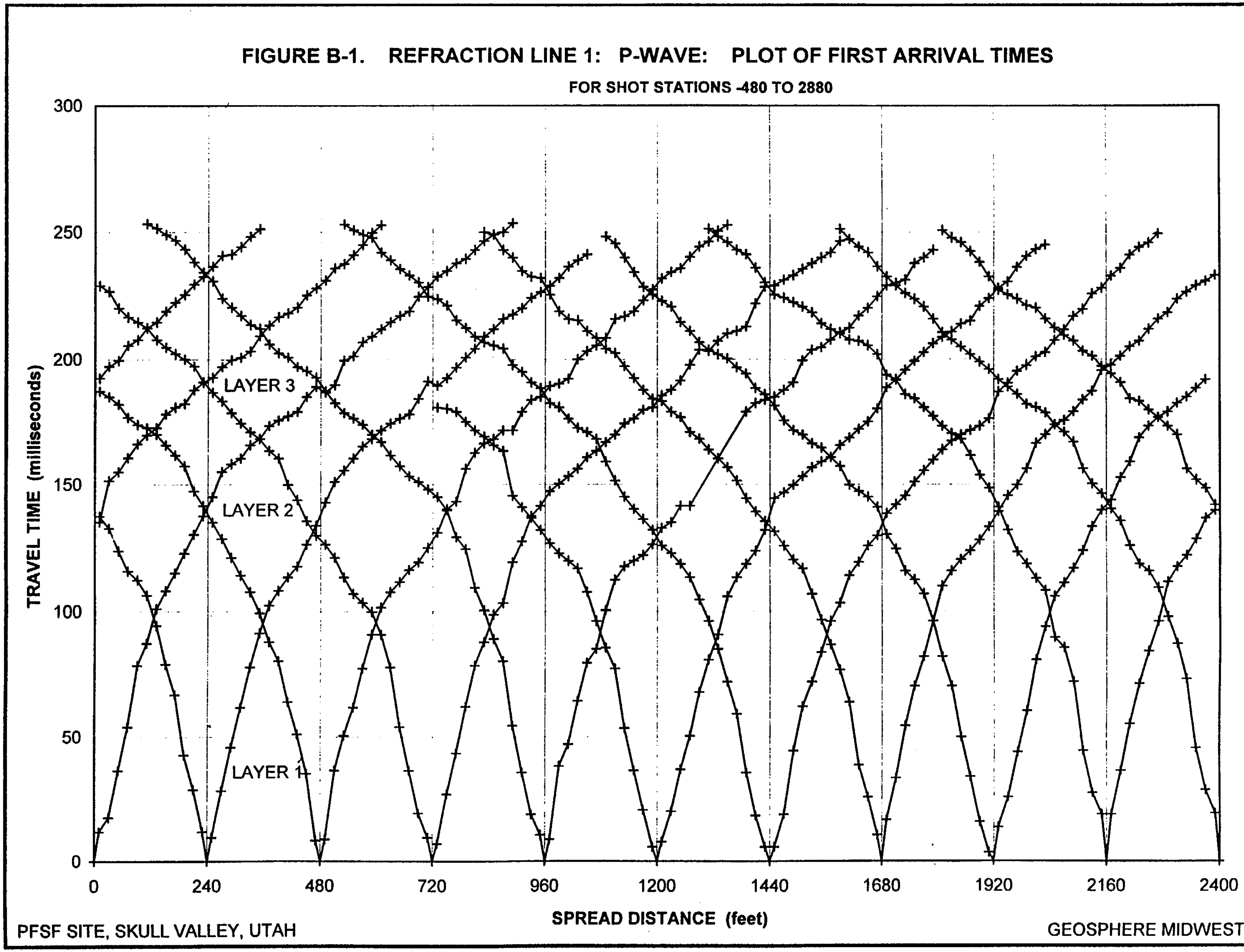
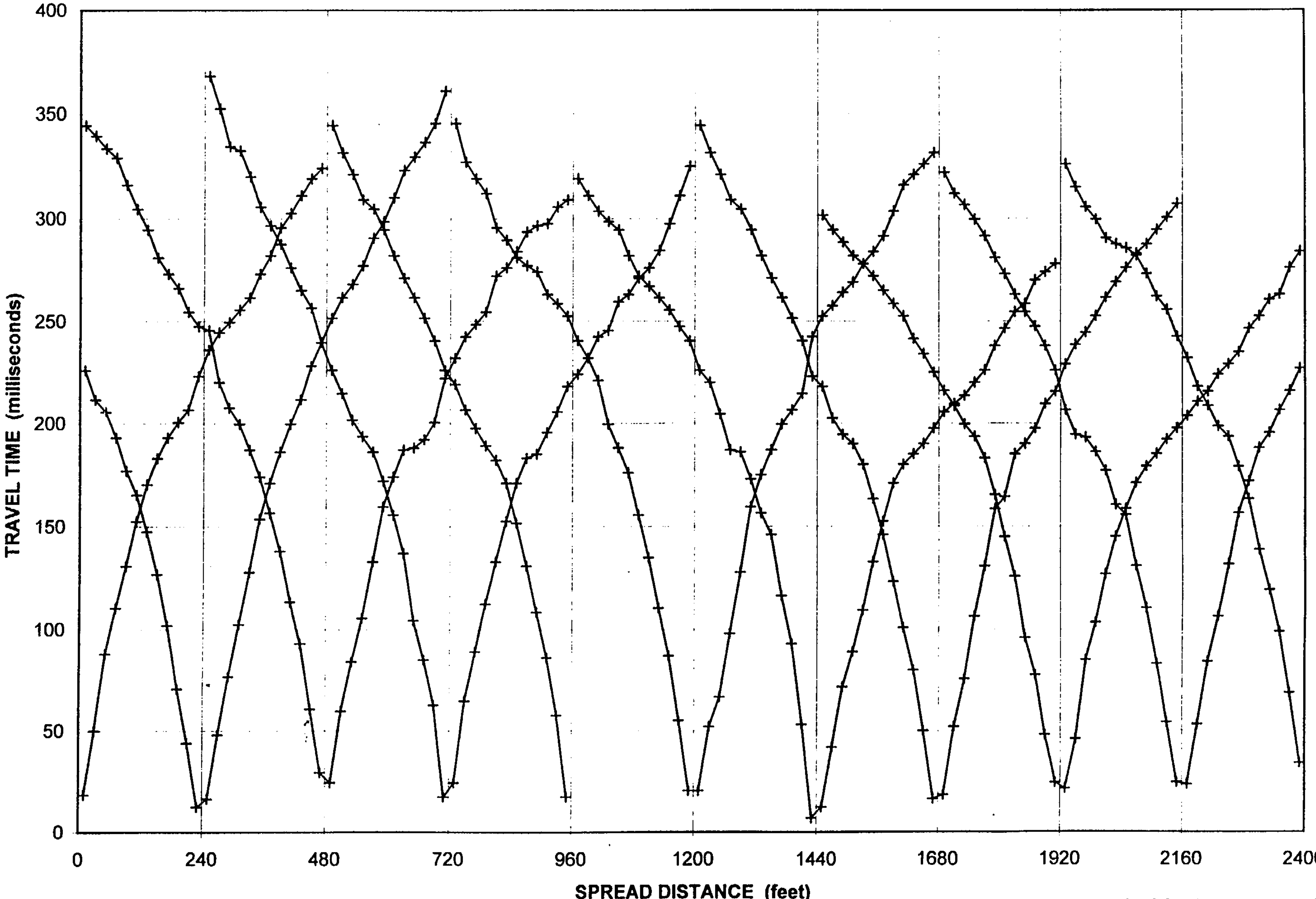


FIGURE B-1. REFRACTION LINE 1: P-WAVE: PLOT OF FIRST ARRIVAL TIMES
FOR SHOT STATIONS -480 TO 2880
TRAVEL TIME (milliseconds)
300
250
200
150
100
50
0
LAYER 3
LAYER 2
LAYER 1
0
240
480
720
960
1200
1440
1680
1920
2160
2400
SPREAD DISTANCE (feet)
PFSF SITE, SKULL VALLEY, UTAH
GEOSPHERE MIDWEST

FIGURE B-2. REFRACTION LINE 1: S-WAVE: PLOT OF FIRST ARRIVAL TIMES

FOR SHOT STATION LOCATIONS 0000 TO 2400

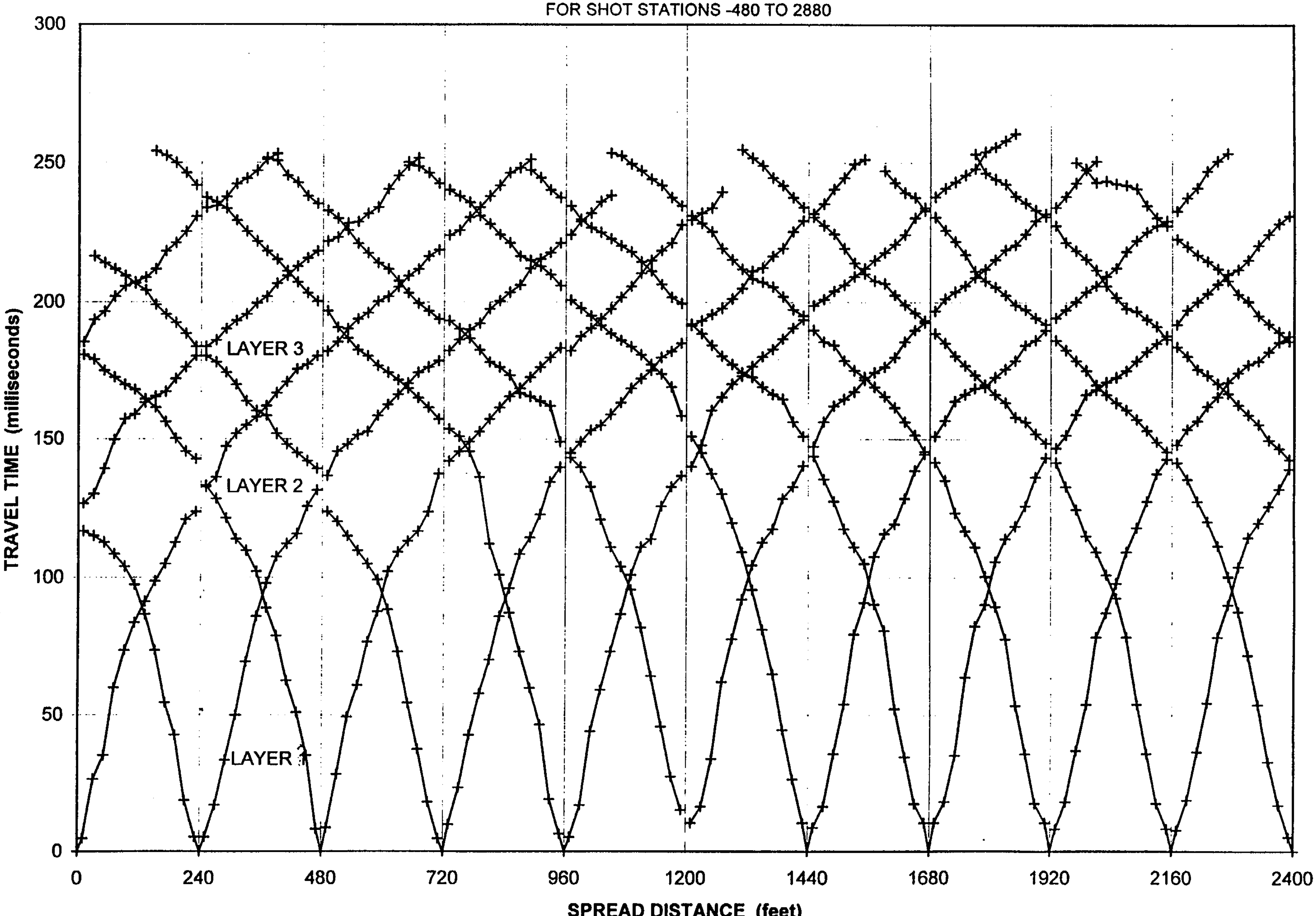


PFSF SITE, SKULL VALLEY, UTAH

GEOSPHERE MIDWEST

FIGURE B-3. REFRACTION LINE 2: P-WAVE: PLOT OF FIRST ARRIVAL TIMES

FOR SHOT STATIONS -480 TO 2880



PFSF SITE, SKULL VALLEY, UTAH

GEOSPHERE MIDWEST

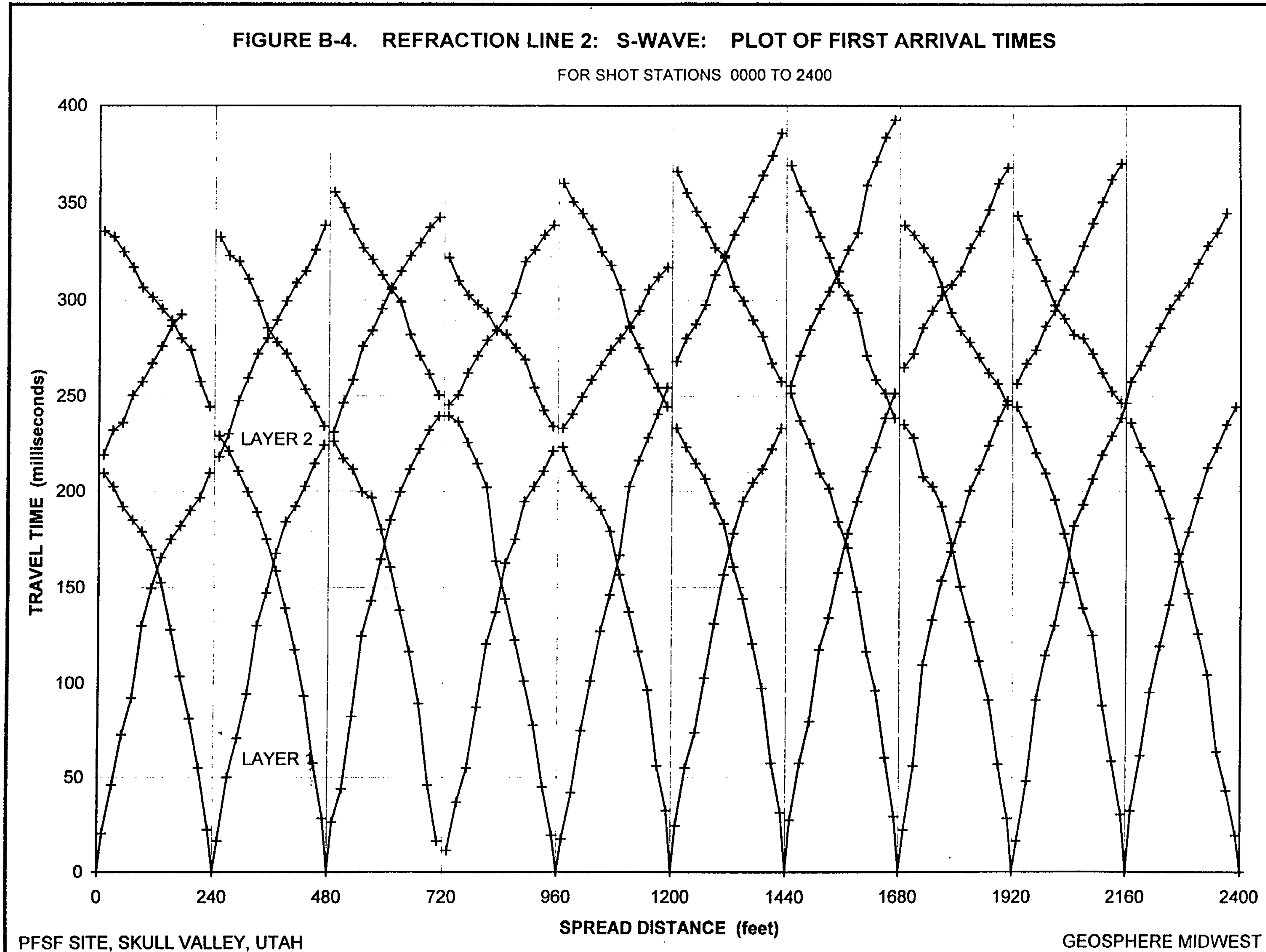
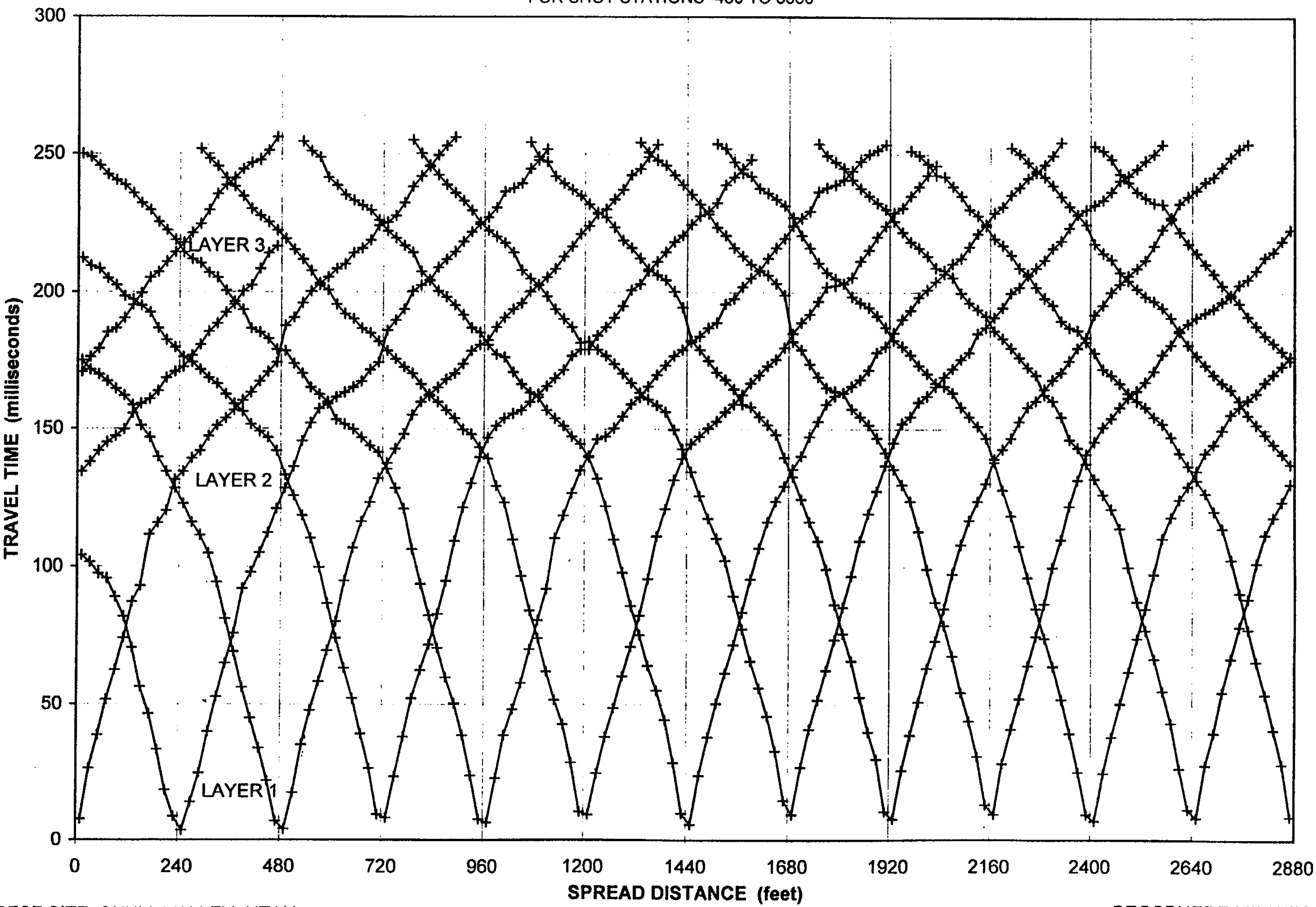


FIGURE B-4. REFRACTION LINE 2: S-WAVE: PLOT OF FIRST ARRIVAL TIMES
FOR SHOT STATIONS 0000 TO 2400
TRAVEL TIME (milliseconds)
SPREAD DISTANCE (feet)
LAYER 2
LAYER 1
0
50
100
150
200
250
300
350
400
0
240
480
720
960
1200
1440
1680
1920
2160
2400
PFSF SITE, SKULL VALLEY, UTAH
GEOSPHERE MIDWEST

FIGURE B-5. REFRACTON LINE 3: P-WAVE: PLOT OF FIRST ARRIVAL TIMES

FOR SHOT STATIONS -480 TO 3360



PFSF SITE, SKULL VALLEY, UTAH

GEOSPHERE MIDWEST

APPENDIX C

SEISMIC REFLECTION DATA

C-1: SEISMIC REFLECTION PROCESSING DESCRIPTION: LINES 2 AND 3

SEISMIC REFLECTION PROCESSING DESCRIPTION
LINES 2 & 3

DATA ACQUISITION PARAMETERS

Shotpoint Interval:	20 ft	Geophone Interval:	20 ft
Configuration:	Off-end	Traces/Record:	24 traces
Instruments:	Bison 9024	Gain Type:	AGC
Sample Rate:	0.25 msec	Data Length:	500 msec
Energy Source:	EWG 5	Field Filters:	32 to 250 Hz
Near Offset:	490 ft	Geophones:	30 Hz low-cut
Far Offset:	950 ft		

PROCESSING SEQUENCE

I. Filtering

- A. Bandpass Filtering: 45-290 Hz
- B. Fan Filtering: 5-12

II. Preprocessing

- A. Trace Editing
  - 1. Kills
  - 2. Surgical Mutes (Airwave, First Arrival, Ground Roll)
- B. CDP Sorting
- C. Elevation Correction/Datum Correction: 4460 ft

III. Velocity Analysis

- A. Exact NMO Equation Velocity Analysis
- B. Constant Velocity Stacks/Scans
- C. Refraction Results

IV. Stacking

- A. NMO Correction
- B. CDP Stacking: 12 fold
- C. AGC Scaling: 120 msec

V. Postprocessing

- A. Front End Muting
- B. Programmed Gain: +5 Db
- C. Trace Normalization

APPENDIX 2C

FINAL REPORT OF A GEOMORPHOLOGICAL SURVEY OF SURFICIAL LINEAMENTS NORTH OF HICKMAN KNOLLS,TOOELE COUNTY, UTAH

Final Report of a Geomorphological Survey of Surficial Lineaments North of Hickman Knolls, Tooele County, Utah

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Signed: ______________________

November 22, 1996

Introduction

Surficial lineaments symbolized as "faults or fractures having small or undetermined displacement" and described as "the north-south-trending Hickman Knolls fault and lineament zone" have been mapped by Sack (1993; cited below as a dataset) in an area (T5S, R8W, sections 5, 6, 7, and 8) north of Hickman Knolls that is near a potential candidate site for a surface storage facility. The work scope of this geomorphological survey is to perform an evaluation of these surficial lineaments, to establish their origin and design impact for the adjacent siting area. Technical requirements provided by SWEC list several specific questions:

> (A) Are the lineaments properly identified, i.e., are the notations on the referenced geologic map indicative of seismic faults? If yes, (1) what geologic evidence supports the existence of these lineaments as a surface expression of seismic faults, (2) are the lengths and relative location of the lineaments accurately shown on the map, (3) is there any connection between the lineaments and the presence of the Hickman Knolls in Skull Valley, (4) since bedrock appears to be several hundred feet or more below the surface in this area, are the lineaments indicative of faulting in the bedrock below, and (5) would they be considered "active" (capable) under the definition contained within 10 CFR Part 100, Appendix A?
>
> (B) If no, what is their source of origin and do they require any engineering consideration in the design of a surface storage facility?

Datasets

Observations summarized in this report are based on several sets of data. Surficial geology of the area is depicted on the *Quaternary Geologic Map of Skull Valley, Tooele County, Utah*, by Dorothy Sack (1993, Utah Geological Survey Map 150) at a scale of 1:100,000, with accompanying booklet. Topography and surface features of the area are shown on the USGS 7.5 minute series orthophotomap (topographic) of the Hickman Knolls Quadrangle, Utah—Tooele Co., which was published in 1973 at a scale of 1:24,000 and with a contour interval of 10 feet. Surface features of the area appear in three stereopairs of USGS/EROS Data Center aerial photographs, viz., frames GS-VCXL 2-2 and 2-3 (4-29-72, from which the orthophotomap was compiled), frames GS-VEFK 1-46 and 1-47 (8-8-76), and frames GS-VERD 2-16 and 2-17 (8-27-78). Information collected during a site visit (in part accompanied by SWEC engineering geologist Richard P. Gillespie) is contained in field notes dated 28 Oct 96.

Observations

Field data gathering (including a dozen hand-augered holes 2 to 6 ft deep) on October 28, 1996, was followed by office examination of aerial photographs. With little if any ambiguity, these data yield a coherent set (the following bulleted list) of constraining observations that are fundamental to the interpretation of the geomorphology of the surficial lineaments immediately north of Hickman Knolls.

- A total of at least twenty surficial lineaments, about half of which are quite distinct and about half of which are much fainter, are parallel or subparallel to each other (not *en echelon*) and occur within a limited area of roughly one square mile.
- The surficial lineaments have an individual length of no more than 1.2 miles; similarly, the lineament group has a maximum length of 1.2 miles.
- Within that length, the generally NNE-SSW trends of the surficial lineaments display as much as 45° of sweeping curvature (convex to the NW).
- The surficial lineaments seem to radiate southward from a relatively small area (near the center of T5S, R8W, section 5), where many of them tend to be tangent to each other.
- The small area from which the surficial lineaments seem to radiate is adjacent to a major alluvial fan-fed stream (now ephemeral) that has its headwaters in Indian Hickman Canyon, at the 11,000-ft level of the Stansbury Mountains.
- The surficial lineaments are <u>not</u> one-sided scarps—they are two-sided ridges that range in height from about 1 to 9 ft and in width from about 10 to 100 ft.
- The ridges have hummocky (probably wind-modified) crests, but nevertheless are distinctly accordant in elevation (4485 ± 10 ft a.s.l.), both along a single ridge and from ridge to ridge.

- To the north and to the southwest, the ridges appear to be vertically accordant with—and planimetrically tangent to—a zone of strong Lake Bonneville shoreline development.
- The ridges are composed of relatively clean sand to depths of at least 6 ft (the maximum depth of hand augering on October 28), although at least one ridge also contains some fine gravel.
- All of the sandy ridges are partially overlain by (are older than) Lake Bonneville deep-water sediments (white marl and reworked white marl).
- There is no evidence on the ground that lineaments of any sort project southward into or onto the bedrock of Hickman Knolls. (The sedimentary bedrock of Hickman Knolls has weakly expressed homoclinal bedding that strikes generally north and dips about 20° east, giving rise to very low, north-trending hogback ridges that are completely unrelated to the lineaments.)

Conclusions

The above constraining observations lead to two inescapable conclusions that are definitive with respect to the nature of the linear features (and definitive with respect to the main concern on page 2 of this report).

(1) The surficial lineaments north of Hickman Knolls are almost certainly not "faults or fractures having small or undetermined displacement," as mapped from aerial photographs by Dorothy Sack, but rather they are sandy beach ridges deposited by southward longshore transport of sediments from a local sandy delta (Indian Hickman Canyon paleodrainage) in the Stansbury shoreline coastal zone, which was active about 20,000 radiocarbon years (about 23,000 calendar years) ago, during the transgression of Lake Bonneville.

(2) The sandy beach ridges (surficial lineaments) north of Hickman Knolls provide no basis for inferring anything about the paleoseismicity of the proposed surface storage facility site—except that (a) the ridges themselves are not of tectonic origin and (b) the ridges show no discernible evidence of having been disturbed by faulting since they were first deposited by lacustrine processes about 20,000 radiocarbon years (about 23,000 calendar years) ago.

APPENDIX 2D

DETERMINISTIC EARTHQUAKE GROUND MOTIONS ANALYSIS

GEOMATRIX

FINAL REPORT

DETERMINISTIC EARTHQUAKE GROUND MOTIONS ANALYSIS

PRIVATE FUEL STORAGE FACILITY SKULL VALLEY, UTAH

Prepared for:

Stone & Webster Engineering Corporation
CS-028233 J.O. NO. 0599601-005

Prepared by:

Geomatrix Consultants, Inc.
and
William Lettis & Associates, Inc.

March 1997

GMX #3801.1 (REV. 0)

GEOMATRIX

SWEC #0599601-005
GMX #3801-1 (REV. 0)

DETERMINISTIC EARTHQUAKE GROUND MOTIONS ANALYSIS

PRIVATE FUEL STORAGE FACILITY, SKULL VALLEY, UTAH

Prepared for:

Stone & Webster Engineering Corporation

Prepared by:	Robert R. Youngs	Date:	3/10/97
Reviewed by:	Kathryn L. Hanson	Date:	3/10/97
Approved by:	Kevin J. Coppersmith	Date	3/10/97

QA Category I

Geomatrix Consultants, Inc.
San Francisco, CA

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GEOMATRIX

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DETERMINISTIC EARTHQUAKE GROUND MOTIONS ANALYSIS PRIVATE FUEL STORAGE FACILITY SKULL VALLEY, UTAH P.O. NO. CS-028233, J.O. NO. 05996.01

1.0 INTRODUCTION

This report summarizes a deterministic earthquake ground motion analysis conducted for the proposed Private Fuel Storage Facility (PFSF) in Skull Valley, Utah. This study was conducted for Stone & Webster Engineering Corporation under contract P.O. No. CS-028233, J.O. No. 05996.01. This report incorporates and supersedes the preliminary results given in our Phase 1 report entitled: "Phase 1 Results, Geological and Seismic Consulting Services, Site Seismic Evaluation, Private Fuel Storage Facility."

In the Phase 1 Report, four topics were identified that, in our opinion, needed to be addressed to provide a more defensible assessment of deterministic ground motions (section entitled "Finalizing this Assessment"). All four of these topics were addressed prior to our finalization of this analysis: (1) the lineaments north of Hickman Knolls were evaluated by Prof. Donald Currey (University of Utah) and assessed to be related to lacustrine (lake) depositional processes; (2) geotechnical boreholes and seismic reflection profiles were acquired that provide an interpretation of the depth to bedrock; (3) new published attenuation relationships for normal faulting have been incorporated into this assessment, and (4) geophysical studies were conducted to develop an interpretation of the shear-wave velocity structure beneath the site. With the gathering of this additional information, we are able to develop more confident assessments of ground motions.

The purpose of this study is to develop a deterministic ground motion assessment that can be used for the design of the PFSF. The deterministic methodology has considerable precedent for nuclear power plant design. It provides a conservative estimate because it is based on a series of conservative assumptions: the *maximum* earthquake is assumed to occur on all seismic sources; the maximum earthquake is assumed to occur at the *closest approach* of the source to the site; and the ground motions are evaluated at the *84th percentile* of the ground motion attenuation relationships. The deterministic methodology followed in this study is identical to that followed in the western U.S. for nuclear power plant studies consistent with Appendix A to 10 CFR Part 100. Because the Skull Valley site lies within a tectonic environment characterized by relatively low seismic activity and long recurrence intervals between large earthquakes, the deterministic methodology provides a very conservative estimate of ground motions.

This report consists of the following: Section 2 summarizes the seismotectonic setting, Section 3 presents the regional potential seismogenic sources, Section 4 presents the characterization of seismic sources and the ground motion assessment. Section 5 presents a summary of this analysis and our conclusions.

2.0 SEISMOTECTONIC SETTING

The Skull Valley PFSF site is located in the central part of the western Cordillera of the United States, an approximately 1300-km-wide region of elevated, mountainous topography that extends from central California on the west to the Great Plains on the east. Orogenic activity within the Cordillera dates back to the Paleozoic, and generally reflects a long history of crustal shortening that continued through the late Cretaceous-early Tertiary Laramide orogeny (Oldow and others, 1989). Mid-Tertiary to Quaternary tectonism within the Cordillera, however, is characterized by crustal extension and is distributed over many hundreds of kilometers east of the transcurrent Pacific/North American plate boundary in California.

2.1 Seismotectonic Provinces

Previous workers have subdivided the western Cordillera into distinct provinces based on physiographic characteristics, volcanic activity, the presence and activity of late Cenozoic faults, and patterns of seismicity. Provinces that lie within 320 km of the PFSF site include the Basin and Range province, the Wasatch Frontal Zone province, the Snake River Plain province, and the Colorado Plateau province (Figure 2-1). We discuss each of these provinces below.

The Skull Valley PFSF site is located within the Basin and Range province. The province is an approximately 400 to 800 km wide region of active crustal extension and distributed normal faulting that is bounded on the west by the Sierra Nevada mountain range in eastern California, and bounded on the east by the Wasatch Frontal Zone province in Utah (Figure 2-1). The Basin and Range province is named for the characteristic topography associated with the development of fault-bounded, tilted structural blocks, which define subparallel, north-trending ranges and intervening internally drained basins. Large-scale crustal extension in the Basin and Range province in Utah began approximately 20 to 21 million years ago (Rowley and others, 1978) and continues to the present. Mountain ranges are several tens of kilometers long and locally attain crustal elevations of approximately 3 km. The floors of the adjacent valleys commonly lie at elevations of approximately 1.2 to 1.5 km. Late Cenozoic and Quaternary normal faults in the Basin and Range typically lie along the bases of the ranges and dip beneath the valleys. The Wasatch fault is considered the eastern boundary of the

Basin and Range province, and given its westward dip, the associated seismicity is in the Basin and Range province. The Basin and Range province has been the source of numerous moderate and large magnitude historical earthquakes, including the 1983 Borah Peak earthquake (M_S 7.3) in Idaho; the 1954 Dixie Valley (**M** 6.9); 1954 Fairview Peak (**M** 7.3); and 1915 Pleasant Valley (**M** 7.8) earthquakes in central Nevada (Rogers and others, 1991); and the 1934 Hansel Valley earthquake (**M** 6.6) near the northern end of the Great Salt Lake in Utah (Smith and Arabasz, 1991). In general, historical and contemporary seismicity is concentrated along the eastern and western margins of the Basin and Range province, with the exception of the Central Nevada Seismic Belt (de Polo and others, 1989).

The Wasatch Frontal Zone province is a transitional zone between the actively extending Basin and Range province and the tectonically quiescent Colorado Plateau province in northern Utah (Figure 2-1; Jacobs Engineering and others, 1988). The western margin of the province lies about 85 km east of the PFSF site. The Wasatch frontal zone is distinguished from the Basin and Range province by a higher level of background seismicity, and generally higher deformation rates. The major active fault along the western margin of this province is the Wasatch fault zone, an approximately 370 km long, west-dipping normal fault system that has been the source of repeated large magnitude Holocene surface-faulting earthquakes (Machette and others, 1991). The Wasatch Frontal Zone province is part of the central and southern reaches of the Intermountain Seismic Belt, a north-trending zone of active seismicity that extends from southern Nevada and northern Arizona to northwestern Montana (Smith and Arabasz, 1991). The Intermountain Seismic Belt is approximately 100 to 200 km wide, has a generally curvilinear trend along its length, and is characterized by moderate to high levels of shallow crustal seismicity (i.e., hypocentral depths of 20 km or less). Analyses of earthquake focal mechanisms show that seismogenic deformation in the Intermountain Seismic Belt accommodates approximately east-west-directed crustal extension (Eddington and others, 1987; Smith and Arabasz, 1991).

The western margin of the Colorado Plateau province lies approximately 150 km east of the PFSF site (Figure 2-1). In contrast to the Basin and Range province, which locally has accommodated 30% to 100% of horizontal crustal extension during Tertiary time (Christiansen and Yeats, 1992; Wernicke, 1992), the Colorado Plateau is a relatively stable crustal block that has undergone negligible deformation (Christiansen and Yeats, 1992). The

Colorado Plateau also is distinguished from the Wasatch Frontal Zone province to the west by very low levels of background seismicity. Most of the historical seismicity in the Colorado Plateau province has occurred near the Uncompahgre uplift (Sullivan and others, 1980), which lies approximately 475 km east-southeast of the PFSF site.

The Snake River Plain province forms the northern boundary of the site region, approximately 250 km north of the PFSF site (Figure 2-1). In contrast to the rugged topography of the Basin and Range and the Wasatch Frontal Zone provinces to the south, the Snake River Plain is an area of low relief. The province is approximately 600 km long, 70 to 100 km wide, and has an arcuate, concave-northward shape (Malde, 1991). Workers have divided the Snake River Plain province into western and eastern parts based on distinctive patterns of sedimentation, faulting, and late Cenozoic volcanism. The eastern Snake River Plain, which passes through the northern part of the PFSF region, is a bimodal volcanic province characterized by extensive rhyolitic volcanic rocks overlain by basaltic lava flows (Malde, 1991). The rhyolite and basalt are interpreted to mark the presence of a thermal plume, or "hot spot", in the mantle that presently is centered beneath Yellowstone National Park in northwestern Wyoming. Seismicity is concentrated along the southern, northern and eastern margins of the Snake River Plain province, although this seismicity may be associated with Basin and Range-type extension rather than processes within the Snake River Plain. Within eastern Idaho and western Wyoming, most seismicity in this province is associated with the northern continuation of the Intermountain Seismic Belt (Smith and Arabasz, 1991).

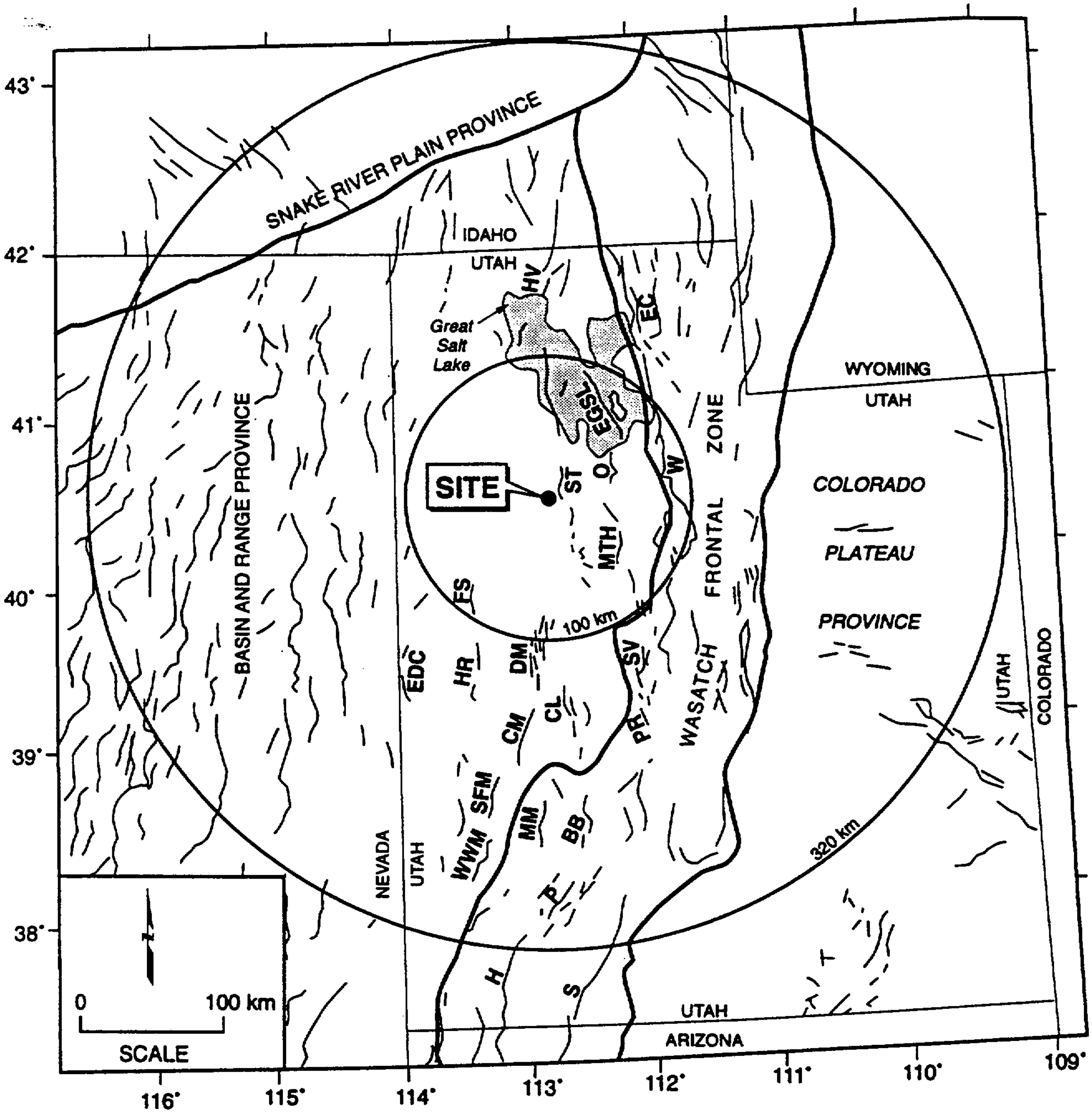
2.2 Tensile Stresses and Active Crustal Extension in the Site Region

The study region lies within the Cordilleran extensional stress province, which is defined by Zoback and Zoback (1989) to be part of the Rocky Mountain/Intermontane plate-tectonic province. The Cordilleran extensional stress province is approximately 1,700 km wide and is bounded by the Sierra Nevada range in California to the west, and by the Great Plains on the east. Based on earthquake focal mechanisms, the orientation of Quaternary volcanic features, and borehole breakout data, Zoback and Zoback (1989) interpret that the state of stress within this province is characterized by approximately east-west-trending maximum tensile principal stress. The Colorado Plateau also is included in this stress province, although the orientation of the maximum tensile principal stress within the Plateau is inferred to be north-

northeast/south-southwest and thus is anomalous in comparison to regional trends elsewhere in the province (Wong and Humphrey, 1989; Zoback and Zoback, 1989).

The Cordilleran extensional stress province differs from areas of generally compressive horizontal stress to the east and west by its high topography (1.5 to 2.0 km average elevation) and higher average heat flow (Zoback and Zoback, 1989). These characteristic features are significant for assessing the origin of the regional tensile stress and the resulting deformation. Jones and others (1996) propose that the horizontal tensile stress that drives active extension in the western United States arises from gravitational body forces acting on the buoyant, topographically high Cordilleran lithosphere. Simple physical analyses show that variations in the density structure and buoyancy of the lithosphere produce variations in the average lithostatic pressure at depth (Molnar and Lyon-Caen, 1988; England and Jackson, 1989). Because the lithosphere has the mechanical properties of a viscous fluid when viewed at the province scale and over long periods of time (England and Jackson, 1989), the lateral gradients in average lithostatic pressure (also known as the buoyancy force) may cause the lithosphere to flow or spread in order to minimize the pressure differences at depth. The rate of flow for a given magnitude of buoyancy force depends on the average strength of the lithosphere (Jones and others, 1996).

Using models for the tensile strength of the lithosphere, Jones and others (1996) showed that the gravitationally derived buoyancy forces in the Cordilleran extensional stress province are sufficient to drive extension (i.e., "spreading") in the Basin and Range and Wasatch Frontal Zone provinces at a strain rate of approximately 10^{-16} sec^{-1}, which is comparable to the average extension rate in these regions measured by seismologic and geodetic techniques (Eddington and others, 1987; Dixon and others, 1995). For example, the integrated extension rate across the Basin and Range between the Colorado Plateau and the Sierra Nevada is approximately 1 cm/yr, which corresponds to an average strain rate of 10^{-16} sec^{-1}. Because the extension is driven by gravitational forces, the tectonic stresses are present regionally, and thus can be assumed to affect the site area. Areas of the Cordilleran extensional stress province that are not deforming at geologically significant rates, such as the Colorado Plateau and southern Rocky Mountains, represent regions where the lithosphere is stronger and able to support the gravitationally derived tensile forces without significant spreading (Jones and others, 1996). This interpretation suggests that the forces that drive crustal extension in the study region arise from the local structure and geophysical characteristics of the lithosphere, rather than from the influence of the Pacific/North American plate boundary located more than 1,000 km to the west.



Basin and Range Province Faults

CL	Clear Lake
CM	Cricket Mountains
DM	Drum Mountains
EGSL	East Great Salt Lake
FS	Fish Springs
HR	House Range
HV	Hansel Valley
MTH	Mercur-Topliff Hill
O	Oquirrh
SFM	San Francisco Mountains
ST	Stansbury
EDC	East Deep Creek
WWM	Wah Wah Mountains

Wasatch Frontal Zone Faults

BB	Beaver Basin
EC	East Cache
H	Hurricane
MM	Mineral Mountains
P	Paragonah
PR	Pavant Range
S	Sevier
SV	Scipio Valley
W	Wasatch

Figure 2-1. Regional seismotectonic provinces, showing major known late Quaternary faults within 320 km of the site.

3.0 REGIONAL POTENTIAL SEISMOGENIC SOURCES

3.1 Potential Fault Sources Between 100 and 320 km of the Skull Valley Site

As noted above, the PFSF site region includes parts of the Basin and Range, Wasatch Frontal Zone, Colorado Plateau and Snake River Plain provinces (Figure 2-1). Each of these provinces contains faults that are potential seismic sources, although at distances of greater than 100 km it is unlikely that any of these potential sources would produce significant ground motions at the PFSF site.

The Basin and Range province contains many normal faults along the margins of north-trending uplifts. In eastern Nevada, many of these faults are potential capable sources, although most have not been previously characterized and none has had historic surface rupture (Rogers and others, 1991). In western Utah, Hecker (1993) shows several north-trending faults that exhibit evidence of late Pleistocene or Holocene activity. These include the East Deep Creek and House Range faults, which are southwest of the PFSF site (Plate 1). The House Range faults are aligned with the Fish Springs fault, which is described below in Section 3.2. South of the PFSF site, a series of north- to northwest-trending faults exhibit evidence of late Quaternary activity. These include the Wah Wah Mountains, San Francisco Mountains, Cricket Mountains, and Drum Mountains faults. The latter of these is within 100 km of the PFSF site and is described in Section 3.2. In northern Utah, Hecker (1993) summarizes the Hansel Valley fault, which experienced surface rupture during the M_W 6.6 Hansel Valley earthquake in 1934 (Doser, 1989). McCalpin and others (1992) suggest that earthquakes comparable in size to the 1934 event may have occurred during times of shallow or no lakes in the Hansel Valley, whereas larger events may have occurred during times when deep lakes occupied the basin. All of the faults in the Basin and Range province between 100 and 320 km from the PFSF site are shorter and(or) probably have lower slip rates than some of the faults within 100 km of the site, and thus are unlikely to produce higher ground motions than nearby sources.

The Wasatch Frontal Zone also contains many faults that exhibit evidence of repeated Holocene and(or) late Pleistocene activity. In northern Utah, this province is dominated by the East Cache and Wasatch fault zones (Plate 1). The East Cache fault zone consists of three segments, with the central segment exhibiting Holocene movement and the northern and southern segments exhibiting middle to late Pleistocene and late Pleistocene movement, respectively (McCalpin and Forman, 1991). Youngs and others (1987) calculated a maximum earthquake magnitude of 7.25 for the East Cache fault zone. The Wasatch fault is the primary structural feature in central Utah, and consists of nine segments that exhibit either Holocene or late Pleistocene activity (Hecker, 1993). Northeast of the PFSF site, these segments include the Clarkston Mountain, Collingston, Brigham City, and Weber segments (Machette and others, 1992). Hecker (1993) suggests that the Brigham City segment is overdue for a surface-rupturing earthquake on the basis of recurrence intervals and the elapsed time since the most-recent rupture. East of the PFSF site (and within 100 km of the site), the Wasatch fault consists of the Holocene Salt Lake City, Provo, and Nephi segments, which are described below in Section 3.2. Southeast of the PFSF site, the Holocene Levan and late Pleistocene Fayette segments (Machette and others, 1992; Hecker, 1993) are more than 100 km from the PFSF site. The Levan segment is separated from the Nephi segment by a 15-km-long gap in Holocene faulting, and the Fayette segment is less well expressed than other segments of the Wasatch fault.

South of the Wasatch fault, extension in the Wasatch Frontal Zone probably is accommodated by movement on a series of north-trending faults, including the Scipio Valley, Pavant Range, Beaver Basin, Mineral Mountains, and Paragonah faults. These faults exhibit evidence of Holocene or late Pleistocene movement. In the Wasatch Frontal Zone in southern Utah, major faults include the Hurricane and Sevier faults, both of which have had late Pleistocene movement with recurrence intervals of about 5,000 years for earthquakes of M7 or greater, and have slip rates of 0.3 to 0.5 mm/yr (Hecker, 1993).

Based on the fault compilation by Hecker (1993), the Colorado Plateau province within 320 km of the PFSF site contains no faults that exhibit prominent evidence of Holocene or late Pleistocene displacement related to tectonic activity. There are a few west- to northwest-trending faults that exhibit evidence of Quaternary movement, although these are associated with salt dissolution within the Paradox Basin and are more than 250 km from the site. Considering the distances from the PFSF site to the Colorado Plateau or Snake River Plain provinces, it is unlikely that strong ground motions from a source within either of these provinces would be significant at the site. Based on the number of faults having Holocene or late Pleistocene activity in the Basin and Range and Wasatch Frontal Zone provinces, it is likely that ground motion hazards would be dominated by sources within either of these latter provinces.

3.2 Potential Fault Sources Within 100 km of the Skull Valley Site

Capable and potentially capable sources within 100 km of the PFSF site are listed in Table 3-1, and are discussed below. Plate 1 also shows the location and activity of these potential sources.

3.2.1 Stansbury Fault

The north-trending Stansbury fault forms the border between the western margin of the Stansbury Mountains and the eastern margin of Skull Valley (Plate 1). At its closest location, the fault is 9.5 km from the PFSF site. The Stansbury fault dips to the west, and has had down-to-the-west displacement of late Quaternary alluvium derived from the Stansbury Mountains. Previous investigations show that the fault has had late Quaternary displacement along approximately 40 to 45 km (Hecker, 1993; Helm, 1995). The Stansbury fault as defined by previous workers extends from the northern end of the Stansbury Mountains at the village of Timpie, to Johnson Pass near the village of Willow Springs. Helm (1995) notes that the fault consists of two distinct sections, separated by a west-trending cross fault coincident with Pass Canyon and the southern margin of Salt Mountain. The 20-km-long section of the fault north of Pass Canyon consists of several strands and has a complex pattern of synthetic and antithetic faults. Helm (1995) notes that displacement along the northern section of the fault is partitioned among several strands. The 25-km-long southern section of the fault, in contrast, is comparatively simple, with most of the displacement occurring on a single, distinct strand. Helm (1995) shows that these two sections also are associated with differences in range-crest elevation, plan-view geometry, scarp heights, and drainage-basin asymmetry. In addition, regional gravity data suggests that the basin-fill deposits in Skull Valley are thickest adjacent to the highest parts of the Stansbury Mountains thus supporting Helm's (1995) proposed sections of the Stansbury fault. She postulates that the fault sections are rupture segments that may or may not rupture independently.

South of Johnson Pass, Hecker (1993) also includes a fault trace along the western margin of the Onaqui Mountains mapped by Moore and Sorensen (1979) as part of the Stansbury fault. Sack (1993) also mapped this trace and referred to it as the Onaqui fault zone. This fault extends from Johnson Pass south to a major canyon termed The Delle, a distance of about 9 km. West of The Delle, a bedrock salient extends westward from the base of the Onaqui Mountains, and is crossed by numerous north-trending, discontinuous fault strands (Moore and Sorensen, 1979). South of this salient, the range front is sinuous, and Moore and Sorensen (1979) do not map a fault along the range margin. Sack (1993), however, shows a west-down fault along the southern 3 km of the western Onaqui Mountains front. The range-crest elevations south of Johnson Pass support the presence of at least one additional fault section between Johnson Pass and Lookout Pass.

There is some uncertainty concerning the timing of the most-recent earthquake on the Stansbury fault, although all workers agree that there has been late Quaternary movement. On the basis of fault-scarp morphology, Barnhard and Dodge (1988) and Helm (1995) suggest that the most recent movement on the Stansbury fault occurred prior to the Lake Bonneville highstand (about 15,000 years ago). In contrast, on the basis of stream nickpoints located a short distance upstream of the scarps, Everitt and Kaliser (1980) concluded that the most recent movement on the fault occurred during the Holocene. Barnhard and Dodge (1988) addressed this possibility by visiting two stream channels with prominent nickpoints, and concluded that resistant bedrock influenced upstream migration of the nickpoints, and thus that the fault has not had Holocene displacement. Field mapping by Sack (1993) also suggests the possibility that there has been surface rupture along the fault since the Bonneville highstand. Via analysis of aerial photography, she identified several northwest-trending *en echelon* fault scarps that offset the Bonneville shoreline located about 10 km northeast of Hickman Knolls. In addition, Barnhard and Dodge (1988), and Helm (1995) map a series of *en echelon* fault scarps topographically lower than the Bonneville shoreline. It is unclear why these workers conclude that the most-recent earthquake pre-dates the Bonneville highstand while at the same time acknowledge the presence of these fault scarps. Our field reconnaissance of the scarp at Indian Hickman Canyon, directly east of the PFSF site, supports the interpretation that the Stansbury fault scarp displaces late Quaternary alluvial-fan deposits and has had multiple late Quaternary surface ruptures. We conclude that the Stansbury fault has had recurrent movement during the middle to late Pleistocene, and perhaps has ruptured since the Bonneville highstand.

Helm (1995) summarizes available scarp-height data along the fault, and shows that the scarps range in height from 3.9 to 49.5 m. Barnhard and Dodge (1988), Hecker (1993), and Helm (1995) all state that scarp heights are greater in older alluvial deposits than in younger deposits along the length of the fault, indicating recurrent movement during the Quaternary (within the past 1.6 million years). Krinitzsky (1989) states that the single-event displacement is 2.4 to 3.9 m, based on data given by Barnhard and Dodge (1988). However, Barnhard and Dodge (1988) note the presence of a 20-m-wide graben along most of the fault trace, and thus reported scarp measurements may overestimate the net tectonic displacement. Barnhard and Dodge (1988) and Helm (1995) caution against using scarp height and surface deformation data to estimate net tectonic displacement.

Slip rates are good indicators of relative fault activity over long time periods, and are critical to the assessment of seismic source characteristics. Unfortunately, there are no published data on the late Quaternary slip rate of the Stansbury fault. Helm (1995) estimates that there has been about 850 m of vertical separation of a basalt flow that is about 12.4 million years old, and calculates a long-term slip rate of 0.07 ± 0.02 mm/yr. This amount of displacement is from the northern section of the fault, north of Pass Canyon, and thus may be slightly lower than the post-12.4 Ma displacement along the southern section. In addition, the Stansbury fault likely dips moderately to the west, and therefore the net slip rate on the fault is probably slightly higher than the vertical separation rate. Other Basin and Range faults that lie west of the Wasatch fault have Quaternary slip rates in the range of 0.1 to 0.2 mm/yr. We use this range to characterize the slip rate for the Stansbury fault. Based on these data, we conclude that the Stansbury fault is a capable tectonic source.

3.2.2 East Cedar Mountains Fault

As part of a hydrologic reconnaissance of Skull Valley, Hood and Waddell (1968) inferred the presence of a fault with east-down displacement along the eastern margin of the Cedar Mountains, herein informally termed the East Cedar Mountains fault (Plate 1). This inferred fault extends from a point due east of Hastings Pass and about 7 km southwest of the village of Delle (along Highway 80), south along the eastern margin of the Cedar Mountains to the southern end of the range at the town of Dugway. At its closest location, the fault is 9 km from the PFSF site. As shown by Hood and Waddell (1968), the fault contains a northern, 33-km-long section that strikes about N10°E, and a southern, 27-km-long section that strikes about N45°W. The total fault length as shown by Hood and Waddell (1968) is 60 km.

Later workers, concentrating on the presence of fault scarps present in alluvial deposits in the region, did not acknowledge the existence of this fault (Everitt and Kaliser, 1980; Barnhard and Dodge, 1988; Hecker, 1993). However, Arabasz and others (1989) included suspected Pleistocene fault scarps along the northeastern flank of the Cedar Mountains, north of the fault mapped by Hood and Waddell (1968), in their compilation of seismic sources in the region. These possible faults were based on photolineaments that had been identified, but not field checked, by Barnhard and Dodge (1988). Hecker (1993) designates these inferred faults as "Quaternary (?)" and shows them as a 10 km-long zone of short (<2 km) discontinuous fault scarps that are 2 to 3 km east of the range front. Considering these possible fault traces as part of the East Cedar Mountains fault, the fault extends from the northern end of the Cedar Mountains at Interstate 80, to the southern end of the range at the town of Dugway. This interpretation of the fault yields a total fault length of 72 km, with a 45-km-long northern section and a 27-km-long southern section.

The entire length of the East Cedar Mountains fault is within the area covered by the late Pleistocene Lake Bonneville, based on the location of the Bonneville and Provo shorelines mapped by Currey and others (1983), Barnhard and Dodge (1988), and Sack (1993). The possible fault traces at the northern end of the range mapped by Barnhard and Dodge (1988) are located basinward of the 10,000- to 11,000-year-old Gilbert shoreline shown by Sack (1993). This would suggest possible fault movement within the past 11 ka. However, detailed mapping of surficial deposits throughout Skull Valley by Sack (1993) does not show the presence of the possible fault identified by Barnhard and Dodge (1988). It is likely that the features identified by Barnhard and Dodge (1988) are not related to surface faulting.

In addition, Sack (1993) identified a 1.5-km-long, northeast-facing scarp along the eastern margin of the Cedar Mountains, approximately 9 km southwest of Hickman Knolls. This scarp also is basinward of the Provo (<15 ka) shoreline and, if related to surface faulting, would suggest a surface-rupture earthquake within the past approximately 15,000 years.

However, our aerial reconnaissance and preliminary aerial photographic analysis conducted during this study showed no evidence of surface displacement at the location of the scarps noted by Sack (1993), nor anywhere else along the eastern Cedar Mountains range front between Rydalch Canyon and Dugway. Based on examination of aerial photography conducted for this study, the scarps identified by Sack (1993) are at the same elevation as sinuous lake shoreline features to the southwest. Therefore, we interpret that the features mapped by Sack (1993) are shoreline scarps.

Thus, we conclude that there is no definitive evidence of post-Bonneville displacement along the East Cedar Mountains fault, as implied by mapping by Everitt and Kaliser (1980), Barnhard and Dodge (1988), and Hecker (1993). However, with the available data, we cannot preclude the possibility of middle or late Pleistocene displacement (between 500 and 15 ka). Based on the available data, therefore, we conclude that the East Cedar Mountains fault is a potentially capable tectonic source.

3.2.3 West Cedar Mountains Fault

Aerial reconnaissance conducted for this study on September 2, 1996 suggests the presence of a fault along the western margin of the southern Cedar Mountains west of White Rock. At its closest approach, the west Cedar Mountains fault is 19 km from the PFSF site. The fault was mapped by Moore and Sorenson (1979) as an east-vergent thrust fault within Pennsylvanian bedrock. The 8.5-km-long fault is identified based on a southwest-facing bedrock scarp, alignment of topographic saddles, and linear alignment of flowing springs. These features maybe related to the juxtaposition of different rock types along the fault. Because the activity of this inferred fault is unknown, we assume that the west Cedar Mountains fault is a potentially capable fault.

3.2.4 Clover Fault Zone

The Clover fault is a northwest-trending, east-dipping normal fault that borders the northeast flank of the Onaqui Mountains along the western margin of Rush Valley (Bucknam, 1977; Everitt and Kaliser, 1980; Hecker, 1993). This fault zone also is referred to as the North Onaqui East Marginal fault (Everitt and Kaliser, 1980; Krinitzsky, 1989). At its closest approach, the Clover fault zone is 27 km from the PFSF site. Scarps in late Pleistocene to

Holocene(?) alluvium indicate a minimum fault length of 4 to 7 km. The scarps have been modified by agricultural activities and, therefore, cannot be used to estimate the age of faulting. The graded profiles of streams that cross the fault suggest that the most recent faulting occurred more than several thousand years ago (Barnhard and Dodge, 1988). Arabasz and others (1989) assign an age of >15.5 ka to the timing of the last movement on this fault. Scarps heights of 1.1 to 1.2 m, and a single event displacement of 0.6 m, are reported for the Clover fault (Barnhard and Dodge, 1988; Krinitzsky, 1989).

The total length of the Clover fault is uncertain. The fault is one of a series of short discontinuous zones of Quaternary faulting along the western margins of the Tooele and Rush Valleys. To the north, a short (1.3-km-long), east-facing fault scarp in older alluvium near East Hickman Canyon is mapped by Solomon (1993). To the south, prominent Quaternary fault scarps are mapped along the Sheeprock fault (Plate 1). The short lengths of these fault scarps suggest that the earthquakes that produced these scarps were at or near the threshold magnitude of surface rupture (i.e., M 6 to 6.5) and that the length of subsurface rupture may have exceeded the length of surface faulting. Based on the presence of scarps across late Pleistocene and Holocene (?) deposits, we conclude that the Clover fault zone is a capable tectonic source.

3.2.5 Mid-Valley Horst Faults

The Mid-Valley Horst faults border an uplifted structural block within the middle of Rush Valley referred to as the "mid-valley horst" (Everitt and Kaliser, 1980) or the "St. John Station Alluvial Fill faults" (Arabasz and others, 1989). At their closest approach, these faults are 32 km from the PFSF site (Plate 1). The low scarps (0.6 m) and short length (5.6 km and 3.0 km, respectively) along the both the western and eastern margins of the mid-valley horst (Everitt and Kaliser, 1980) suggest that the magnitude of the most recent surface-faulting event was at or near the threshold of surface faulting. Subsurface investigations revealed the presence of additional faults concealed by surficial deposits that are likely related to the mid-valley structure (CH2M Hill, 1986; Jacobs/URS/Blume, 1988). Based on these data, Jack R. Benjamin and Associates (1994) concluded that the total lengths of faults along the western and eastern margins of the mid-valley horst are 5.6 km and 8 km, respectively.

The age of the most recent surface-faulting event on these faults is not known. The scarps that are in both alluvium and gravel-capped pediments of pre-Bonneville age are judged to pre-date the Bonneville highstand (15.5 ka) (Everitt and Kaliser, 1980; Barnhard and Dodge, 1988). Stratigraphic and geomorphic relationships suggest that these faults are late Pleistocene (Hecker, 1993). The faults exposed in trenches at the site by CH2M Hill (1986) are not expressed at the surface. The age of the most recent movement varies among the faults revealed in the trenches. Some of the faults in the Salt Lake Group of late Tertiary age do not extend into overlying Quaternary deposits. The youngest faults exhibit small displacements (suggestive of single events) in the older alluvium but do not appear to displace the soil formed on these deposits that is judged to be approximately 125 ka (Jacobs/URS/Blume, 1988). The maximum post-Salt Lake Group displacement associated with a single fault plane in these trenches was approximately 1.5 m (Krinitzsky, 1989). Smaller displacements of less than 0.3 m are observed on faults that displace the older Quaternary alluvium. Given the evidence for Pleistocene activity, we conclude that these faults are a capable fault source.

3.2.6 Lookout Pass Fault

Moore and Sorensen (1979) map the west-down Lookout Pass fault for a distance of about 6 km along the western margin of the southernmost Onaqui Mountains, south of Lookout Pass. At its closest approach, the Lookout Pass fault is 36 km from the PFSF site (Plate 1). Hecker (1993) suggests that this fault may have had Quaternary displacement, on the basis of the "fault control of bedrock-alluvium contact" (p. 48). Our aerial reconnaissance of the fault showed an absence of prominent geomorphic expression of faulting. Because the activity of this fault is unknown, we assume that the Lookout Pass fault is a potentially capable fault.

3.2.7 Mercur-Topliff Hill Fault Zone

The Mercur-Topliff Hill fault zone consist of a zone of Quaternary faulting along the western side of the Oquirrh Mountains and Topliff Hill in Rush Valley (Plate 1). At its closest approach, this fault zone is 40 km from the PFSF site. This fault zone is aligned with a series of similar major westward-dipping, range-bounding Quaternary normal faults that includes the Oquirrh (Everitt and Kaliser, 1980; Olig and others, 1995) and East Great Salt Lake (Pechman and others, 1987; Viveiros, 1986) fault zones to the north and the East Tintic Mountain fault zones (Barnhard and Dodge, 1988) to the south (Plate 1). In their seismic hazard model, Youngs and others (1987) treat these faults as individual segments in a large fault zone referred to as the Oquirrh Mountain fault zone. Alternatively, each of these fault zones is described as a separate fault zone in the recent compilation by Hecker (1993).

The Mercur fault zone consists of a 16-km-long alignment of late Pleistocene fault scarps along the western flank of the Oquirrh Mountain in Rush Valley. Based on exposures of faulted alluvium exposed in a mining shaft, together with an uplifted bedrock pediment. Everitt and Kaliser (1980) estimated a minimum of 60 m of Quaternary displacement on the fault. From scarp profile data, the Mercur scarps record displacements of 1.8 to 5.6 m (Barnhard and Dodge, 1988). Solomon (1993) identified a small fault scarp south of the town of Stockton approximately 11 km north of the Mercur fault that exhibits a similar orientation and sense of displacement to the Mercur fault zone scarps. This scarp offsets late Pleistocene Lake Bonneville sediments (15.5 ka), and it is not clear if it is related to surface-faulting events along the Oquirrh fault zone to the north or the Mercur fault zone to the south.

The Topliff Hill fault zone lies along the west flank of the northern East Tintic Mountains, a lower more subdued range to the south of the Oquirrh Mountain range (Hecker, 1993). A zone of fault scarps, which are relatively continuous for a distance of 12 km, exhibit a similar geomorphic position and sense of displacement as those along the Mercur fault zone. These scarps also show evidence for recurrent movement with a cumulative maximum displacement of 5.8 m, but appear to be younger than the Mercur fault scarps based on scarp profile data (Barnhard and Dodge, 1988).

Everitt and Kaliser (1980) concluded that the most-recent surface faulting event along the Mercur-Topliff Hill fault zone post-dated the formation of the Bonneville shoreline and therefore was younger than approximately 14.5 ka. Barnhard and Dodge (1988) reinterpreted a trench log by Everitt and Kaliser (1980), and note that scarps along the Mercur-Topliff Hill fault zone are wave-etched and older than the Bonneville shoreline, and thus are not a result of post-Bonneville surface faulting. Based on scarp morphology the Mercur-Topliff Hill fault zone scarps are interpreted to be late Pleistocene (Barnhard and Dodge, 1988; Hecker, 1993). Based on the presence of scarps across and observed displacement of late Pleistocene deposits, we conclude that the Mercur-Topliff Hill fault zone is a capable tectonic source.

3.2.8 Sheeprock Fault Zone

The Sheeprock fault is a northeast- to northwest-trending, east-dipping normal fault along the northeastern flanks of Sheeprock Mountain. At its closest approach, the Sheeprock fault is 41 km from the PFSF site. A zone of Quaternary fault scarps extend about 10 to 11 km along the fault zone (Everitt and Kaliser, 1980; Barnhard and Dodge, 1988; Hecker, 1993; Bucknam, 1977). Scarp heights range from 1.9 to 16.5 m with some scarps representing repeated surface rupture (Barnhard and Dodge, 1988). A possible Holocene age was inferred for the most-recent event along the Sheeprock fault (Everitt and Kaliser, 1980). However, more recent scarp-profile investigations suggest that the Sheeprock scarps appear to be older than the Topliff Hill, Mercur, and Stansbury scarps, all of which are recognized to pre-date the Bonneville highstand (15.5 ka) (Barnhard and Dodge, 1988). Diffusion-equation modeling of the scarps yielded an age of about 53 ka for the scarps (Hanks and others, 1984). The embayed character of the range front suggests a long period of activity preceding the recent episode of faulting (Everitt and Kaliser, 1980). We conclude that the Sheeprock fault zone is a potentially capable tectonic source.

3.2.9 Oquirrh Fault Zone

The Oquirrh fault zone is a west-dipping normal fault that borders the western side of the Oquirrh Mountains in Tooele Valley. At its closest approach, the Oquirrh fault zone is 45 km from the PFSF site. A variety of names have been used for this fault zone including: the Oquirrh marginal fault (Everitt and Kaliser, 1980); the northern Oquirrh fault zone (Barnhard and Dodge, 1988; Hecker, 1993); and the Oquirrh fault zone (Olig and others, 1995). We follow Olig and others (1995) in referring to the zone of Quaternary faulting along the northern part of the Oquirrh Mountains as the Oquirrh fault zone. The fault zone extends for a least 21 km and has been subdivided into two sections: a northern section that includes fault scarps in alluvium, and a southern section that includes a fault contact between bedrock and alluvium along the range front (Everitt and Kaliser, 1980; Barnhard and Dodge, 1988). An additional segment near Silcox Canyon southwest of Tooele, identified by Everitt and Kaliser (1980) as a scarp of erosional or undetermined origin is identified by Solomon (1993) as a fault scarp.

Scarps along the Oquirrh fault zone range in height between 2.9 and 10.8 m, and surface offsets are between 1.3 and 7.3 m (Barnhard and Dodge, 1988). Locally, the compound scarps represent displacement during more than one surface-faulting earthquake. Scarps of the Oquirrh fault zone displace the Provo shoreline of Lake Bonneville. Studies of scarp morphology suggest that the most recent surface-faulting event occurred between 9 and 13.5 ka (Everitt and Kaliser, 1980; Barnhard and Dodge, 1988). More recently, paleoseismological investigations along the northern section of the Oquirrh fault zone by Olig and others (1995) documented that: (1) the most recent surface faulting event occurred between 4.3 and 6.9 kyr B.P., (2) the second-most-recent event occurred between 20.3 and 26.4 kyr B.P., (3) the net vertical tectonic displacement is between 1.9 and 3.3 m with best estimates of 2.2 and 2.7 m for the most-recent event and 2.3 m for the penultimate event, (4) the recurrence interval between the last two events ranges from 13.3 and 22.1 kyr B.P., (5) calculated slip rates are 0.1 to 0.2 mm/yr for this interval, and (6) the third-most-recent event probably occurred before 33.95 ± 1.16 kyr B.P.

Total length of the Oquirrh fault zone is estimated to be 35 km, which allows for the fault to extend a few kilometers northwards into the Great Salt Lake and includes the isolated, short, discontinuous fault scarps near Stockton. Comparison of the available information regarding timing of the surface-faulting events on the Oquirrh fault zone, and the Mercur fault zone to the south suggests that these fault zones have behaved as independent rupture segments since the Bonneville lake cycle (Olig and others, 1995). Available paleoseismic information is inconclusive regarding a possible rupture segment boundary between the Oquirrh fault zone and the East Great Salt Lake fault zone to the north (Olig and others, 1995). We conclude that the Oquirrh fault zone is a capable tectonic source.

3.2.10 Vernon Hills Fault Zone

The Vernon Hills fault zone is a 5- to 7-km-long, northwest-trending, normal fault within Rush Valley (Everitt and Kaliser, 1980; Bucknam, 1977). At its closest approach, the Vernon Hills fault zone is 47 km from the PFSF site. Along most of the zone, bedrock occurs on both sides of the fault or is juxtaposed against alluvium (Barnhard and Dodge, 1988). Based on scarp morphology and shoreline relations, the most-recent surface-faulting earthquake on the Vernon Hills fault zone appears to pre-date the Bonneville shoreline and therefore is older than 15.5 ka. Scarp heights of 3.3 to 4.3 m and surface offsets of 1.7 to 2.3 m are reported by Barnhard and Dodge (1988). Hecker (1993) designates the fault zone as late Pleistocene. We conclude that the Vernon Hills fault zone is a capable tectonic source.

3.2.11 Lakeside Mountains Fault

A possible Quaternary fault is shown by Anderson and Miller (1979) along the western flank of the Lakeside Mountains, based on an inferred fault control of the bedrock-alluvium contact (Moore and Sorensen, 1979; Young, 1955). The fault as shown by Hecker (1993) is 5 km long. At its closest distance, the fault is 49 km from the PFSF site. Arabasz and others (1989) included the fault (queried as to state of activity) in a compilation of seismic sources in the region. They reference T. P. Barnhard (person. commun., 1987) as having identified the feature as a lineament that may be a shoreline feature. The fault does not appear on the maps of Bucknam (1977) or Barnhard and Dodge (1988). Based on the uncertainty in fault existence and recency of activity, we conservatively judge the fault to be a potentially capable tectonic source.

3.2.12 Simpson Mountains Fault

The Simpson Mountains fault is a northwest-trending, west-dipping fault within the narrow basin to the southwest of the Simpson Mountains. At its closest approach, the Simpson Mountains fault is 52 km south of the PFSF site. Scarps in alluvium southwest of the Simpson Mountains identified by Ertec Western, Inc. (1981) are designated as middle to late Pleistocene (10,000 to 750,000 years) faults by Hecker (1993). The approximately 10-km-long zone of discontinuous scarps are not associated with a well-defined or linear range front. As mapped by Hecker (1993), individual scarps are generally less than 2 km long.

3.2.13 Sheeprock Mountains Fault

The Sheeprock Mountains fault is a northwest-trending, west-dipping fault that borders the western margin of the Sheeprock Mountains (Plate 1). At its closest approach, the Sheeprock Mountains fault is 57 km southeast of the PFSF site. Based on faulted alluvial-fan deposits, Ertec Western, Inc. (1981) identified this fault as having early Pleistocene movement. Although this fault is designated as an early to middle Pleistocene (130,000-1,650,000 years) fault by Hecker (1993), the age of movement, which is based primarily on the age of faulted deposits, is considered a maximum estimate. The fault is located in piedmont alluvial fan deposits approximately 2 to 3 km from the range front. The total length of the fault as shown by Hecker (1993) is approximately 4.5 km. We consider the Sheeprock Mountains fault as a potential capable source.

3.2.14 Puddle Valley Fault Zone

The Puddle Valley fault zone is comprised of a group of fault scarps that extend for a distance of approximately 6 km along the western margin of Puddle Valley, a few kilometers east from the relatively subdued range front of the Grassy Mountains. At its closest approach, the Puddle Valley fault zone is 61 km northwest of the PFSF site. The fault scarps, which are topographically below the Bonneville and Provo shorelines, may represent two spatially distinct surface-rupturing events (Barnhard and Dodge, 1988). On the basis of scarp morphology, scarps at the north end of Puddle Valley appear to be older than the Bonneville shoreline; those at the south end appear to be younger than the Bonneville shoreline but older than the Drum Mountains fault scarps in southern Utah , which have been estimated to be 9,000 years old (Pierce and Colman, 1986). Based on the studies of Barnhard and Dodge (1988), Hecker (1993) suggests that the age of most recent movement is 9 to 15? ka, and the displacement per event is 0.7 to 2.3? m. We conservatively conclude that the Puddle Valley fault zone is a capable tectonic source.

3.2.15 East Great Salt Lake Fault Zone

Gravity and seismic reflection data indicate that a major 82-km-long zone of faulting is concealed beneath the Great Salt Lake along the western margin of the NNW-trending linear topographic high that includes the Promontory Mountains, Fremont Island, and Antelope Island. This west-dipping fault, named the East Great Salt Lake fault zone by Cook and others (1980), is clearly delineated in seismic reflection profiles across the lake (Viveiros, 1986; Mukulich and Smith, 1974; Smith and Bruhn, 1984). At its closest approach, this fault zone is 66 km northeast of the PFSF site. This fault cuts sediments identified as Quaternary based on well data and appears to displace sediments within 10 to 20 m of the lake bottom (Viveiros, 1986; Hecker, 1993; Mukulich and Smith, 1974). A 1.5-km-long zone of *en echelon* fractures beneath the lake west of Antelope Island appears on aerial photos to have slight down-to-the-west displacement and to be unmodified by coastal processes, and thus may date from the latest Holocene (Smith and Bruhn, 1984; Hecker, 1993). A zone of subsidiary faults lies within about 5 km west of the main fault in the southern Great Lake (Hecker, 1993). These faults may represent the northern extension of the Oquirrh fault zone. The relationship between the Oquirrh and East Great Salt Lake fault zones is not well delineated on the compilation map presented by Hecker (1993). We consider the East Great Salt Lake fault as a capable tectonic source.

3.2.16 East Tintic Mountains Fault

The 36-km-long East Tintic Mountains fault is a north-trending, west-dipping fault along the western side of the East Tintic Mountains (Plate 1). At its closest approach, this fault is 72 km southeast of the PFSF site. Isolated, highly dissected scarps in alluvium along the fault appear to be among the oldest in western Utah (Bucknam and Anderson, 1979). Anderson and Miller (1979) mapped buried Quaternary (?) faults extending to the north and south of the alluvial scarps. These faults and faults that form bedrock-alluvium contacts at the south end of the East Tintic Mountains (Morris, 1987) are mapped as Quaternary (?) by Hecker (1993). This fault zone was considered to be a segment of the Oquirrh fault zone as described by Youngs and others (1987). Given the differences in recency and activity along this fault compared with the Mercur-Topliff Hill, Oquirrh, and East Great Salt Lake fault zones to the north, we consider this fault as an independent potentially capable tectonic source.

3.2.17 West Valley Fault Zone

The West Valley fault zone consists of a series of mostly east-dipping normal faults that displace late Quaternary lake deposits in Salt Lake Valley (Plate 1). At its closest approach, the West Valley fault zone is 75 km northeast of the PFSF site. This fault zone was originally called the Jordan Valley fault zone and subsequently renamed the West Valley fault zone (Keaton and others, 1987). The southern portion of the fault zone consists of two subparallel east-facing scarps (the Granger and Taylorsville faults), whereas the northern portion is broader and is characterized by many smaller, east- and west-facing scarps. Locally, the near-surface expression of the fault zone is characterized by monoclinal flexuring and minor step-faulting. The total length of the zone is about 18 km (Keaton and others, 1987). Geomorphic and stratigraphic evidence of two events in the past 12 to 13 ka is documented along the main Granger and Taylorsville faults (Keaton and others, 1987). Geomorphic relations within the northern West Valley fault zone suggest that four or more events occurred in the same time period and that some of the post-Bonneville faulting occurred prior to formation of the Gilbert shoreline (12 ka). Borehole evidence associated with several traces of the northern West Valley fault zone suggests that the most recent event may have occurred 6 to 9 ka and that two or three events may have occurred since 22 to 28 ka (Hecker, 1993; Keaton and others, 1987). As noted by Youngs and others (1987), it is unclear whether movement on the West Valley fault zone is independent or directly tied to movement on the Salt Lake City segment of the Wasatch fault zone. A Holocene slip rate of 0.5-0.6 mm/yr is estimated for the Granger fault and the West Valley fault zone as a whole. Lower rates of 0.1 to 0.2 mm/yr are inferred for the Taylorsville fault over longer periods of time (< 140 ka). The relatively high slip rate calculated for post-Bonneville time suggests that strain release may be due to isostatic rebound within an extensional setting (Hecker, 1993). We consider the West Valley fault zone as a capable tectonic source.

3.2.18 East Lakeside Mountains Fault Zone

A major 38-km-long Quaternary (?) fault is identified in the Great Salt Lake along the eastern margin of the Lakeside Mountains based on gravity and seismic-reflection profile data. At its closest approach, the East Lakeside Mountains fault zone is 78 km north of the PFSF site. This major structure borders the west side of the Great Salt Lake graben (Plate 1). Seismic reflection data indicates that faulting extends up into Quaternary deposits, although the activity of the fault is undetermined (Hecker, 1993). We consider this fault zone as a potential capable source.

3.2.19 Utah Lake Fault Zone

Latest Pleistocene to Holocene(?) faults and associated folds are identified over a 30 km length in Utah Lake based on seismic-reflection profile data (Brimhall and Merritt, 1981). At their closest approach, the Utah Lake faults are 79 km east of the PFSF site. Due to the widely spaced seismic-reflection transects, the fault locations are uncertain. An 8- to 15-m-deep layer identified as the Provo Formation, which is interpreted to be lake bottom sediments probably deposited during the regressive phase of Lake Bonneville (Machette, 1989), is displaced from < 2 to 5 m across individual faults and folds beneath the lake. The reflection profiles suggest that displacements decrease upward in strata above this horizon and occur within several meters of the lake bottom. Based on the uncertainties in the geometries and tectonic significance of these structures, we consider the Utah Lake fault zone to be a potential capable source.

3.2.20 Drum Mountains Fault Zone

The Drum Mountains fault zone is a series of north-trending, east-dipping faults along the eastern margin of the Drum Mountains. At its closest approach, the fault zone is 80 km south of the PFSF site. Bucknam and Anderson (1979) map a 5-km-wide zone of fault scarps within pre-Lake Bonneville age deposits east of the Drum Mountains. The fault zone, as shown by Hecker (1993), is 36 km long. Faulted Provo-level shoreline features provide a maximum age of 13.5 ka for the scarps (Crone, 1983). Scarps range in height from 0.7 to 7.3 m, with average heights of 2.4 m, and show no geomorphic evidence of having multiple events (Hanks and others, 1984). Morphometric analyses of the scarps provide ages of 5.6 ka (Hanks and others 1984) and 9 ka (Pierce and Colman, 1986). Trenching by Crone (1983) showed that Holocene faulting produced 3.7 m of stratigraphic throw, significantly more than the 2.7 m of surface offset measured from nearby scarp profiles. We consider the Drum Mountains fault zone as a capable tectonic source.

3.2.21 Fish Springs Fault

The Fish Springs fault is a north-trending, east-dipping fault along the eastern margin of the Fish Springs Range. At its closest approach, the fault is 81 km southwest of the PFSF site. Bucknam and Anderson (1979) map the Fish Springs fault within alluvial fan deposits near the eastern base of the Fish Springs Range. The fault consists of a single trace about 8 km long, and a northern fault trace about 3 km long. The potential fault rupture length, assuming scarps along both traces represent surface rupture in a single event, is about 12 km long (Bucknam and Anderson, 1979). A lack of scarp dissection and sharp nickpoints in small washes that cross the scarps suggest that the fault scarps are young (Bucknam and Anderson, 1979). The scarps occur below the level of the Bonneville shoreline and offset alluvial fan deposits that overlie shoreline features. The scarps therefore are younger than 12 ka. Field observations by Bucknam and Anderson (1979) suggest a maximum single-rupture surface offset of 3.3 m. We consider the Fish Springs fault as a capable tectonic source.

3.2.22 Wasatch Fault Zone

The Wasatch fault zone is a major 370-km-long structural feature that forms the eastern boundary of the Basin and Range province east of the PFSF site (Plate 1). The Wasatch fault zone contains nine westward-dipping normal fault segments that exhibit late Pleistocene or younger activity (Hecker, 1993). These segments are differentiated on the basis of timing of individual earthquakes and changes in scarp morphology and geometry (Machette and others, 1991). Three of the Holocene segments of the Wasatch fault zone are located within 100 km of the PFSF site: the Salt Lake City, Provo, and Nephi segments. Paleoseismologic studies show that there have been repeated large-magnitude earthquakes on all three of these segments of the Wasatch fault zone. A seismic source model for these segments is provided by Youngs and others (1987).

The 46-km-long Salt Lake City segment of the Wasatch fault zone is located approximately 81 km east of the PFSF site. The Salt Lake City segment consists of three left-stepping surface traces that bound the western base of the Wasatch Range within Salt Lake City (Machette and others, 1991). The most-recent earthquake on the segment probably occurred 1,000 to 1,800 years ago (Hecker, 1993). However, diffusion-equation modeling of scarp degradation suggests a more recent age of 900 years. Based on Holocene fault scarps, average surface displacement per event is 2 m. Latest Quaternary slip rate estimates of 1 mm/yr are assigned to this segment of the Wasatch fault zone (Hecker, 1993).

The 70-km-long Provo segment of the Wasatch fault zone borders the eastern margin of Utah Valley, approximately 98 km northeast of the PFSF site. The most-recent earthquake on the Provo segment likely occurred 500 to 650 years ago based on recent trenching (Machette and others, 1991). Six or seven post-Provo events yield an average recurrence interval of 1,700 to 2,600 years for major earthquakes (Hecker, 1993). Up to 3 m of surface offset per earthquake is estimated for this segment (Machette and others, 1991). Slip rate estimates for the segment vary between 1 and 1.7 mm/yr (Hecker, 1993).

The 43-km-long Nephi segment of the Wasatch fault zone, located approximately 99 km from the PFSF site, is the southernmost fault segment that shows evidence of repeated Holocene movement. The Nephi segment extends from Nephi to Payson and is separated from the Levan segment of the Wasatch fault zone to the south by a 15-km-long gap containing no evidence of faulting (Machette and others, 1991). The Nephi segment is one of the most recently active segments, with scarp morphology suggesting displacement occurred approximately 300 to 500 years ago, although radiocarbon dates suggest an age of about 1,200 for the most-recent earthquake (Hecker, 1993). Middle to late Holocene recurrence intervals for major earthquakes may vary between less than 1,000 years to more than 3,000 years. Provo sediments are offset as much as 2 m along the Nephi segment. Slip rates along the segment range from 0.8 to 1.3 mm/yr, decreasing from north to south (Hecker, 1993).

3.2.23 West Deep Creek Fault

Barnhard and Dodge (1988) mapped the Deep Creek fault along the western margin of the Deep Creek Mountains. At its closet approach the West Deep Creek fault is 99 km southwest of the PFSF site. The 12-km-long fault offsets Quaternary basin-fill gravelly sands down to the west. The southernmost 6-km-long extension of the fault is mapped based on alignment of vegetation lineaments and springs (Barnhard and Dodge, 1988). Surface faulting is probably pre-Bonneville highstand (>15 ka) based on comparison of scarp profiles across the northern half of the fault (Barnhard and Dodge, 1988). Scarps show evidence for multiple episodes of movement with measured cumulative displacements between 1.7 and 3.4 m (Hecker, 1993). We consider the West Deep Creek fault as a capable tectonic source.

3.3 Other Mapped Features in the Vicinity of the Skull Valley Site

3.3.1 "Hickman Knolls Fault and Lineament Zone"

Directly north of Hickman Knolls, Sack (1993) mapped a series of subparallel lineaments in Sections 5, 6, 7, and 8 (T.5S., R.8W.), and referred to the features as the "Hickman Knolls fault and lineament zone". The lineaments occur in a zone that is about 1.5 km wide and 2 km long, and were identified via analysis of 1:60,000-scale aerial photography. The lineaments are evenly spaced at intervals of about 100 m, and all are located directly south of a prominent, west-trending shoreline interpreted as the Stansbury shoreline by Sack (1993). Sack (1993) notes that the lineaments occur within lacustrine fine-grained deposits on the valley floor, and that one lineament extends across "mixed lacustrine and alluvial deposits" and colluvium in the Hickman Knolls. Analysis of aerial photography suggested to Sack (1993) that a possible scarp along this lineament was small.

Our aerial reconnaissance, analysis of small-scale (1:20,000- and 1:40,000-scale) aerial photography, and field investigations confirm the presence of this series of lineaments directly north of Hickman Knolls. Our field studies included reconnaissance of the lineament that extends into the colluvial deposits in Hickman Knolls, and of the lineaments north of Hickman Knolls. The single lineament present in the Hickman Knolls is located along a small, north-trending swale that has developed parallel to bedding within the dolomite bedrock composing the Hickman Knolls. It appears likely that the swale is related to differential erosion of units within the bedrock. The swale projects toward, but is not continuous with, the lineaments present in fine-grained lacustrine deposits further to the north. In addition, there are several wave-cut notches developed on the bedrock that can be traced along the northern margin of Hickman Knolls and that show no change in elevation across the southern projections of any of the lineaments. Considering that the elevation of the Provo and Bonneville shorelines in the southern part of Skull Valley are higher than the top of Hickman Knolls, these notches likely are related to transgressions or regressions closely before or after the development of the Bonneville or Provo shorelines (<15 ka). Thus, we interpret these relations as evidence that the lineament identified by Sack (1993) within Hickman Knolls is not related to surface faulting.

Our field reconnaissance of the lineaments directly north of Hickman Knolls shows that they are composed of linear, asymmetric ridges of sand and silt having approximately 1 m of relief between each ridge crest and adjacent trough. In general, the western sides of the ridges have slightly steeper slopes than the eastern sides, although each ridge crest plunges gently to the north and the regional topographic slope is northerly. Inspection of 1:24,000-scale topographic maps having a contour interval of 3.3 m (10 ft) shows negligible relief across the entire zone of lineaments, which suggests a lack of tectonic displacement. Our analysis of 1:40,000-scale black-and-white aerial photography shows that the westernmost lineaments are curvilinear and merge together to the north, where they are adjacent to the Stansbury shoreline mapped by Sack (1993). The Stansbury shoreline developed at about 20 to 23 ka, during a lake highstand that preceded the Bonneville shoreline (Currey and others, 1983). In addition, our analysis of aerial photography shows that a broad, but still distinct, lineament south of and subparallel to the mapped Stansbury shoreline obliquely traverses the north-trending lineaments identified by Sack (1993). This lineament extends to the west into Section 7

(T.5S., R.8W.), and coincides with a 1- to 2-m-high curvilinear ridge of lacustrine pebble gravel. There is no displacement of this ridge or pebble gravel across the zone of lineaments mapped by Sack (1993).

On the basis of our aerial reconnaissance, analysis of aerial photography, and field reconnaissance, we interpret that the lineaments present directly north of Hickman Knolls are related to lacustrine processes during previous lake highstands, rather than as a result of surface faulting as postulated by Sack (1993). The asymmetry of the ridges, the curvilinear pattern of the westernmost lineaments, and the proximity to the topographically high Hickman Knolls (which were a rocky peninsula during intermediate lake levels) suggest that the ridges are related to complex near-shore sediment transport. When the lakeshore was in the vicinity of Hickman Knolls, the area now containing the lineaments was a small, concave-north bay between the northeastern margin of Hickman Knolls and bedrock knobs directly to the northeast (Sack, 1993). We believe that the lineaments formed after the development of the Stansbury shoreline, as a result of lake regression following the Provo highstand. The ridges appear to be superimposed on deposits associated with the Stansbury shoreline, which probably influenced near-shore sediment transport and deposition within the small, north-facing the bay. Currey (1996) also conducted an investigation of the lineaments north of Hickman Knolls. Based on field reconnaissance, analysis of shallow soil samples, and examination of aerial photographs, he reached a similar conclusion that they formed by lacustrine processes and are not tectonic in origin.

3.3.2 "Northwest Hickman Knolls Lineament Zone"

Sack (1993) also notes the presence of several northwest-trending lineaments located about 6 km northwest of Hickman Knolls, and notes that they trend across the lower piedmont of the Cedar Mountains. These lineaments are within a zone that is about 1.5 km wide and 5 km long, and are in an area mapped by Sack (1993) as underlain by lacustrine and alluvial sediments. Although Sack (1993) maps these features as "Faults or fractures having small or undetermined displacement," her text refers to them as lineaments rather than faults or fractures. Because of the proximity of these features to the PFSF site, our aerial reconnaissance included an overflight of the area containing these features. However, this reconnaissance failed to reveal any prominent lineaments in the vicinity that could be ascribed to tectonic surface rupture. In addition, our analysis of 1:40,000-scale aerial photography showed no prominent lineaments in the vicinity. Analysis of the 1:24,000-scale Hickman Knolls orthophotoquad published by the U.S. Geological Survey similarly revealed no evidence of prominent, fault-related lineaments. The orthophotoquad reveals the presence of a distinct, west-trending shoreline or beach ridge that would be crossed by the lineaments mapped by Sack (1993). There is no evidence of deformation of this shoreline by the mapped lineaments. We conclude that there is no evidence to suggest that the "northwest Hickman Knolls lineament zone" mapped by Sack (1993) is related to tectonic surface rupture.

3.3.3 "Springline Fault"

Rigby (1958) interpreted the presence of a fault beneath alluvium along the eastern edge of Skull Valley between Iosepa and Timpie, based on an alignment of bedrock outcrops and warm saline springs. Hood and Waddell (1968) and Helm (1995) also mapped the 18-km-long fault based on the position of the springs. However, Quaternary geologic mapping by Sack (1993) does not show the inferred fault. A possible nontectonic explanation for the linearity of the springs is intersection of the groundwater table with the Gilbert shoreline mapped by Sack (1993). No geomorphic evidence of surface faulting was observed during our aerial and field reconnaissance conducted for this study on September 2 and 3, 1996. We conclude that the Springline fault is not a capable tectonic source.

3.4.4 Faults Identified by Geosphere Midwest (1997)

Geosphere Midwest (1997) performed a seismic reflection study in the site vicinity. They identified numerous possible faults in bedrock in the general vicinity of the "Hickman Knolls fault and lineament zone" mapped by Sack (1993) and addressed in Section 3.3.1 above. Within the limited resolution of the data, Geosphere Midwest (1997) does not interpret these possible bedrock faults to extend into the overlying sediments. Based on the geomorphic evidence supporting a nontectonic lacustrine origin for the Hickman Knolls fault and lineament zone (Curry, 1996), we conclude that the bedrock faults identified by Geosphere Midwest (1997) are not related to the lineament zone. There is no evidence that the bedrock faults identified by Geosphere Midwest (1997), if present, have been active in the Quaternary. Based on the absence of geomorphic and stratigraphic evidence of activity, we conclude that the possible bedrock faults identified by Geosphere Midwest (1997) are not a capable tectonic source.

TABLE 3-1
POTENTIAL CAPABLE FAULTS
WITHIN 100 KM OF PFSF SITE

Fault	Distance from PFSF Site	Length (km)	Activity*
Stansbury fault	9.5	73	LP
East Cedar Mountains fault	9	72	Q(?)
West Cedar Mountains fault	19	8.5	Q(?)
Clover fault zone	27	4 to 7	LP
Mid-Valley Horst faults	32	6	LP
Lookout Pass fault	36	6	Q(?)
Mercur-Topliff Hill fault zone	40	16	LP
Sheeprock fault zone	41	10 to 11	LP
Oquirrh fault zone	45	21	H-LP
Vernon Hills fault zone	47	5 to 7	LP
Lakeside Mountains fault zone	49	5	Q(?)
Simpson Mountains fault	52	10	MP-LP
Sheeprock Mountains fault	57	4.5	EP-MP
Puddle Valley fault zone	61	6	H-LP
East Great Salt Lake fault zone	66	82	H-LP
East Tintic Mountains fault	72	36	MP-LP
West Valley fault zone	75	18	H-LP
East Lakeside Mountains fault zone	78	38	Q(?)
Utah Lake faults	79	30	H-LP
Drum Mountains fault zone	80	36	H-LP
Fish Springs fault	81	12	H-LP
Wasatch fault zone		370	H-LP
Salt Lake City segment	81	46	H-LP
Provo segment	98	70	H-LP
Nephi segment	99	43	H-LP
West Deep Creek fault	99	12	LP

* Activity based on Hecker (1993).

H-LP	Holocene to latest Pleistocene (0-30,000 yrs)
LP	Latest Pleistocene (10,000-30,000 yrs)
MP-LP	Middle to late Pleistocene (10,000-750,000 yrs)
EP-MP	Early to middle Pleistocene (130,000-1,650,000 yrs)
Q(?)	Quaternary (?) (<1,650,000 yrs)

4.0 DETERMINISTIC GROUND MOTION ASSESSMENT

This study provides a deterministic assessment of the level of ground motions at the Skull Valley PFSF site, using methodologies prescribed by Appendix A to 10 CFR Part 100 and associated guidance documents (e.g., SRP's, Regulatory Guides). The methodology for certain elements has been established by precedent in application of Appendix A (e.g., use of 84^{th}-percentile ground motion levels). The deterministic procedure follows four steps: (1) assessment of capable faults and seismic sources, (2) evaluation of the closest approach of the faults/sources to the site, (3) assessment of maximum earthquake magnitudes for each fault/source, and (4) estimation of ground motions at the site. The fault/source that gives rise to the largest ground motions at the site is deemed the "controlling" source. Section 3.0 discusses the faults in the region that have been identified as capable or potentially capable seismic sources. Two of these sources, the Stansbury (capable) and East Cedar Mountains (potentially capable) faults lie within 10 km of the site and potentially dip beneath the site. The remaining faults identified in Section 3 (Table 3-1) lie at distances of 20 km or greater from the site and are unlikely to produce 84^{th} percentile ground motion levels that are as large as those that would be estimated for these two faults. Therefore, they will not be characterized further. A third seismic source, the potential for a random near by earthquake unassociated with any mapped fault, also is considered.

4.1 Maximum Earthquakes

4.1.1 Approach

The maximum earthquakes associated with the Stansbury and East Cedar Mountains faults are evaluated by assessing the maximum dimensions of rupture for an individual earthquake on each of the faults and then employing empirical relationships between earthquake rupture dimensions and earthquake magnitude developed by Wells and Coppersmith (1994). The rupture dimensions used are maximum rupture length and maximum rupture area. We also consider the use of the relationship developed by Anderson and others (1996), which relates earthquake magnitude to fault slip rate and rupture length. Because these assessments are uncertain, they are specified in terms of probability distributions rather than single values. The resulting uncertainty in maximum magnitude is propagated through ground motion assessment.

Assessment of the maximum rupture lengths is specific to the individual fault. The assessment of the maximum rupture area is obtained be multiplying the maximum rupture length by the maximum rupture width, which is calculated based on the thickness of the seismogenic crust and the dip of the fault. Seismicity data provides the best indication of the thickness of the seismogenic crust in a region (Sibson, 1982, 1984). The data for faults in the Basin and Range province indicates that the largest events nucleate at depths of about 15 km (Smith and others, 1983). Figure 4-1 shows east-west cross sections of the focal depth distribution of earthquakes in the region. The data indicate that most of the earthquakes occur shallower that about 18 km, with some as deep as 25 km. We consider the thickness of the seismogenic crust to be uncertain within the range of 15 to 20 km. The discrete probability distribution of 15 km (0.4), 18 km (0.4), and 20 km (0.2) was used to express this uncertainty. The depths of 15 and 18 km are favored because of the typical depth of large Basin and Range earthquakes and nearly all of the seismicity occurs shallower than 18 km.

Specific data is not available on the dip of the Stansbury and East Cedar Mountains faults. However, most large normal faulting earthquakes in the Basin and Range province have occurred on fault planes with dips in the range of 45° to 65° (Smith and others, 1983). We represent the uncertainty in the fault dip by considering three equally likely values of 45°, 55°, and 65°.

Because the Stansbury and East Cedar Mountains faults dip toward each other and lie about 18 km apart, the faults potentially intersect at depth, depending upon the fault dips. We assume that the Stansbury fault is the dominant fault because it is much more clearly expressed. Thus the maximum depth of the East Cedar Mountains fault is assumed to range from 9 to 20 km, depending on the dip of the two faults.

4.1.2 Maximum Rupture Lengths

Stansbury Fault

The surface trace of the Stansbury fault is considered to have a total length of 73 km, extending from the northern end of the Stansbury Mountains near the village of Timpie, to Lookout Pass at the southern end of the Onaqui Mountains (Figure 4-2). The fault sections identified by Helm (1995) are used herein with minor modifications, including a 24-km-long section from Timpie south to Pass Canyon (Section "A" herein), and a 23-km-long section from Pass Canyon to Johnson Pass (Section "B" herein). In addition, we consider the possibility of additional fault sections south of Johnson Pass on the basis of the mapped fault trace and linear range front between Johnson Pass and The Delle, the substantial relief of the Onaqui Mountains, and the fault trace at the southern end of the range mapped by Sack (1993). We identify fault section "C", which extends from Johnson Pass to The Delle and is 9 km long. We also consider fault section "D", which extends from The Delle to Lookout Pass and is 17 km long (Figure 4-2).

We consider five rupture scenarios for the maximum-magnitude earthquake that incorporate various combinations of the four fault sections noted above. Because of the prominence of fault scarps across late Quaternary alluvial deposits along the Stansbury fault between Pass Canyon and Johnson Pass, as well as the proximity of this section, each of the scenarios includes rupture of section "B". The relatively short rupture of 23 km, in which section "B" ruptures alone, is given a low weight (0.1), because it is likely that the maximum earthquake includes rupture along at least one other section. Scenarios that include rupture of section "B" and an adjacent section are given higher probabilities, including a weight of 0.2 for the 47 km-long rupture of sections "A" and "B", and a weight of 0.3 for the 32-km-long rupture of sections "B" and "C". The 56-km-long scenario in which all three of the northern sections ("A", "B", and "C") rupture is weighted 0.3, based on the presence of evidence of recurrent displacement along all three sections. Lastly, the longest scenario, in which rupture occurs along all four sections of the entire 73-km-long fault, is weighted low (0.1) because of the discontinuity of the fault between The Delle and Lookout Pass.

The assessment of maximum magnitude is based on empirical relationships between magnitude and rupture length, and magnitude and rupture area (Wells and Coppersmith, 1994) and the relationship of Anderson and others (1996) between magnitude, rupture length, and slip rate. These relationships are weighted equally in our analysis. The relationships between magnitude and single-earthquake displacement are not used in this analysis because the scarp height data collected along the fault do not necessarily reflect amounts of net tectonic displacement (Barnhard and Dodge, 1988; Helm, 1995). The maximum magnitude distribution includes all five of the rupture scenarios and reflects the postulated rupture dimensions based on combinations of rupture lengths and widths. As discussed in Section 3.2.1, the estimated slip rate of the Stansbury fault is in the range of 0.1 to 0.2 mm/yr.

We represent the uncertainty in slip rate with the discrete distribution of 0.1 mm/yr (0.3), 0.15 mm/yr (0.5), 0.2 mm/yr (0.2), slightly favoring the lower slip rate estimated from fault-specific data.

East Cedar Mountains Fault

The East Cedar Mountains fault is considered to be potentially capable. We define the fault trace to have a total length of 72 km, extending from the northern end of the Cedar Mountains at Interstate 80, to Dugway at the southern end of the Cedar Mountains (Figure 4-2). As discussed in Section 3.2.2, the fault is not clearly expressed in the surface geology. We consider three possible values for the maximum rupture length, 27, 45, and 72 km. A maximum rupture length of 27 km represents the shortest straight segment of the fault and is comparable to the most well expressed segment of the Stansbury fault across Skull Valley. A maximum rupture length of 45 km represents the longest segment of the postulated fault. These two values of maximum length are given the most weight, 0.4 and 0.5, respectively, because they are representative of maximum rupture lengths assessed for the Stansbury fault. Rupture of the entire postulated length of the fault is given a weight of 0.1 because it is considered to be no more likely than rupture of the entire Stansbury fault. No slip rate data were available for the East Cedar Mountains fault.

4.1.3 Maximum Magnitude Assessments

Maximum earthquake magnitudes were computed for the Stansbury and East Cedar Mountains faults using the distributions of maximum rupture parameters described above and published empirical relationships between coseismic rupture dimensions and moment magnitude, **M**. The selected relationships were the relationship between subsurface rupture length and **M** and rupture area and **M** published by Wells and Coppersmith (1994) and the relationship between rupture length, fault slip rate, and **M** published by Anderson and others (1996). The relationships were weighted equally in computing possible maximum magnitudes. The resulting maximum magnitude probability distributions for the Stansbury and East Cedar Mountains faults are shown on Figure 4-3. The maximum magnitude distribution for the Stansbury fault ranges from moment magnitude **M** 6.5 to 7.5, with a mean value of 7.0. The assessment for the postulated East Cedar Mountain fault ranges from **M** 6.5 to 7.2 with a mean estimate of **M** 6.8.

The minimum distance to earthquakes on the Stansbury fault ranges from 6.7 to 8.6 km, depending on the fault dip. The minimum distance to earthquakes on the postulated East Cedar Mountains fault ranges from 6.4 to 8.2 km , depending on the fault dip.

The application of 10 CFR Part 100 Appendix A to the assessment of maximum earthquakes includes the consideration of the potential for the maximum historical earthquake within the site tectonic province not associated with a specific seismic source to occur "near" the site. The term "near" has, by application, come to mean randomly within a 25-km radius of the site (Kimball, 1983). Most of the large earthquakes that have occurred in the Basin and Range province can be associated with specific faults. For this assessment, we have taken the conservative approach by assessing the maximum size of an earthquake that might occur on an unrecognizable fault. Because the hypothesized fault is unrecognized from surface geologic studies, its maximum magnitude is considered to be the largest earthquake that can occur without rupturing the surface (termed the threshold of surface faulting). Wells and Coppersmith (1993) have studied the presence or absence of surface faulting as a function of magnitude. Their studies have shown that the magnitude at which there is a 50% probability of surface faulting is magnitude 6; at magnitude 5.5 the probability is about 20% and at magnitude 6.5 the probability is about 80%. Based on these analyses, we consider the maximum magnitude for an earthquake occurring randomly in the site vicinity on an unknown source to be uniformly distributed in the range of **M** 5.5 to 6.5, with a mean value of 6.0. The earthquake location is assumed to be random within a 25-km radius circle. The resulting mean distance to the epicenter is 16.7 km. This event is smaller than those considered for the Stansbury fault.

4.2 Ground Motion Assessment

4.2.1 Approach

The ground motion assessments for the maximum earthquakes were made using empirical relationships that predict peak acceleration and response spectral accelerations as a function of earthquake magnitude, source-to-site distance, style of faulting, and generalized site classification. The empirical relationships provide estimates of the median ground motion level and the variability of individual recordings about that median, typically expressed as the standard deviation of a lognormal distribution about the median value. The standard approach used to assess design ground motions from maximum events for nuclear facilities is to use the 84th percentile of the empirical distribution of peak motions. We have extended this approach to include the uncertainty in maximum magnitude, minimum source-to-site distance, and selecting appropriate attenuation relationship in the estimation of the 84th percentile ground motion levels. The formulation used is given by the relationship

$$P(Z>z)=\sum_{m} p(m_i)\cdot\sum_{r} p(r_j|m_i)\cdot\sum_{A} p(A_k)\cdot P(Z>z\ |m_i,r_j,A_k) \qquad \textbf{(4-1)}$$

where $p(m_i)$ is the discrete probability density function for maximum magnitude; $p(r_j)$ is the discrete probability density function for minimum distance given a maximum magnitude; $p(A_k)$ is the discrete probability density (weight) assigned to a particular attenuation relationship; and $P(Z>z|\ m_i,\ r_j,\ A_k)$ is the probability that ground motion parameter Z exceeds level z given maximum magnitude m_i, minimum distance r_j, and attenuation relationship A_k. Equation **(4-1)** is solved iteratively for the value of z that results in $P(Z>z)$ equal to 0.8416 (plus one standard deviation of a normal distribution).

4.2.2 Ground Motion Attenuation Relationships

Two key considerations in the selection of attenuation relationships are the style of faulting/tectonic environment and the generalized site conditions. The site lies within an extensional tectonic environment that is characterized by normal faulting. A number of studies have shown that the predicted ground motions for strike-slip and normal-slip faulting events are comparable (and different from reverse-slip faulting) (e.g., Idriss, 1991; Sadigh and others, 1993, 1997). Recent work (Spudich and others, 1997) indicates that ground motions from extensional tectonic regime earthquakes are lower than those from compressional regime earthquakes. Therefore, we use a mixture of attenuation relationships that have been developed for strike-slip faulting earthquakes occurring in California and relationships for extensional stress regime earthquakes developed for the U.S. Department of Energy's planned nuclear repository at Yucca Mountain, Nevada.

Most empirical ground motion attenuation relationships are developed for two types of generalized site conditions, either "deep soil" (over 100 ft of soil over rock) or "rock" (less than 10 ft of soil over rock). The rock underlying recording sites in California typically is highly weathered and fractured such that the average near surface velocity is on the order of 2,000 ft/sec, with lower values at the surface. This type of bedrock has become to be called "California" rock, or soft rock, to distinguish it from the very hard rock occurring near the surface in much of the eastern United States. The effect of different rock types on site ground motions is now recognized as an important issue in ground motion assessment.

The available data on the subsurface conditions at the site comes from shallow bore holes, seismic refraction surveys, and seismic reflection surveys. The shallow bore hole data (Stone & Webster, 1997) indicate that the site is underlain by about 30 ft of silts and clays, followed by about 25 ft of very dense sands, underlain by very hard silts to a maximum bore hole depth of 100 ft. The seismic reflection surveys (Geosphere Midwest, 1997) indicate that the depth to bedrock at the site is in the depth range of 400 to 800 ft. On the basis of the depth to rock (greater than 100 ft) and the general soil conditions (alluvial soils), one would classify the Skull Valley site as a deep soil site. However, the shallow refraction surveys (Geosphere Midwest, 1997) indicate that the shear wave velocities approach that of soft rock (about 2000 ft/sec at a depth of about 50 ft. Although these velocities are somewhat uncertain, they are generally consistent with the description of the soils as being very hard or very dense. Based on this data, the site profile may have characteristics that are near that of "California rock." Thus we have used both rock and deep soil attenuation relationships to predict 84th-percentile spectra.

Figure 4-4 compares the 84^{th}-percentile peak horizontal acceleration (PGA) attenuation relationships used to estimate the site ground motions. Figure 4-5 compares the 84^{th}-percentile horizontal acceleration response spectra predicted by the various relationships for the mean maximum magnitude of **M** 7 and the average minimum distance of 7.7 km. [Note that the attenuation relationship developed by Spudich and others (1997) uses minimum distance to the surface projection of the rupture. For the Skull Valley PFSF site this distance is 0 because the site lies above the fault plane.] We have used multiple attenuation relationships in the assessment to reflect the uncertainty in estimating near field ground motions from large earthquakes. The selected relationships represent the most recent work in evaluating empirical strong motion data. The relationships of Abrahamson and Silva (1997), Campbell (1997), and Sadigh and others (1993, 1997) provide estimates for both rock and deep soil. We have included two additional relationships. Idriss (1991) provides estimates of ground motion for rock sites. Spudich and others (1997) have updated the relationships of

Boore and others (1993, 1997) for extensional stress regimes. They present relationships for both soil and rock sites. We believe that the rock site relationships of Boore and others (1993, 1997) under estimate the ground motions on rock sites. Therefore, we have used only the deep soil relationships of Spudich and others (1997). Each of the four rock site relationships and the four soil site relationships were given equal weight.

Not all of the selected attenuation relationships for horizontal motions also have associated vertical motion relationships. For rock site conditions, the relationships of Abrahamson and Silva (1997), Campbell (1997) and Sadigh and others (1993) provide vertical estimates. For soil site conditions, only the relationships of Abrahamson and Silva (1997) and Campbell (1997) provide vertical motion estimates. The approach taken was to estimate horizontal and vertical spectra with the same subset of attenuation relationships and use these spectra to compute a ratio of vertical to horizontal motions. This ratio was then used to scale the horizontal spectra computed using the full set of horizontal relationships to produce the vertical 84th percentile spectra.

4.2.3 Recommended Response Spectra

Figure 4-6 shows the horizontal 84th percentile spectra computed for the three nearby sources (e.g., Stansbury fault, postulated East Cedar Mountains fault, and a random source) incorporating the uncertainty in maximum magnitude, source-to-site distance, and selection of attenuation relationships. These three sources are expected to produce larger motions at the site than any of the other faults in the surrounding region. The other faults have comparable maximum magnitudes but are at significantly greater distances. The Wasatch fault is likely to have a larger maximum magnitude, but it is located more than 80 km from the site and the resulting ground motions would be much lower than those shown on Figure 4-6. Among the three local sources, the Stansbury fault is the controlling ground motion source.

Figure 4-7 shows the horizontal and vertical response spectra for rock and deep soil sites for the Stansbury fault. The vertical response spectra were computed using the approach discussed above. The ratio of vertical to horizontal motions is below a value of 0.5 at periods longer than 0.5 seconds. For this study, we used a minimum vertical to horizontal motion ratio of 0.5. Also we used the envelope of the response spectra obtained directly from the subset of vertical attenuation relationships and the vertical spectra obtained by scaling the horizontal spectra. The spectral ordinates for deep soil and rock site conditions are listed in

Table 4-1. The peak horizontal ground accelerations are 0.67 g for both rock and deep soil site conditions. The peak vertical ground accelerations are 0.66 g for deep soil site conditions and 0.69 g for rock site conditions.

As indicated on Figure 4-7, the predicted rock site motions are larger at short spectral periods (high frequencies) and the predicted soil site motions are larger at long spectral periods (low frequencies). Because it is uncertain at this time whether the site behaves as a rock or a deep soil site we recommend that the preliminary design spectra for the site be conservatively taken as the envelope of the rock and soil site response spectra shown on Figure 4-7. These envelope spectra are plotted on Figure 4-8 and listed in Table 4-1.

TABLE 4-1

STANSBURY 84TH-PERCENTILE SPECTRA
HORIZONTAL SPECTRAL ACCELERATIONS (G)

PERIOD	DEEP SOIL	ROCK	ENVELOPE
0.01 (PGA)	0.67	0.67	0.67
0.03	0.67	0.67	0.67
0.05	0.83	0.87	0.87
0.075	1.05	1.08	1.08
0.1	1.26	1.27	1.27
0.15	1.47	1.55	1.55
0.2	1.60	1.63	1.63
0.3	1.65	1.51	1.65
0.5	1.54	1.16	1.54
0.75	1.34	0.83	1.34
1	1.13	0.65	1.13
1.5	0.77	0.42	0.77
2	0.54	0.30	0.54
3	0.33	0.17	0.33
4	0.22	0.11	0.22

VERTICAL SPECTRAL ACCELERATIONS (G)

PERIOD	DEEP SOIL	ROCK	ENVELOPE
0.01 (PGA)	0.66	0.69	0.69
0.02	0.66	0.69	0.69
0.05	1.18	1.20	1.20
0.075	1.48	1.50	1.50
0.1	1.54	1.54	1.54
0.15	1.38	1.37	1.38
0.2	1.18	1.17	1.18
0.3	0.88	0.86	0.88
0.5	0.64	0.58	0.64
0.75	0.53	0.41	0.53
1	0.45	0.33	0.45
1.5	0.33	0.24	0.33
2	0.24	0.17	0.24
3	0.14	0.11	0.14
4	0.098	0.077	0.098

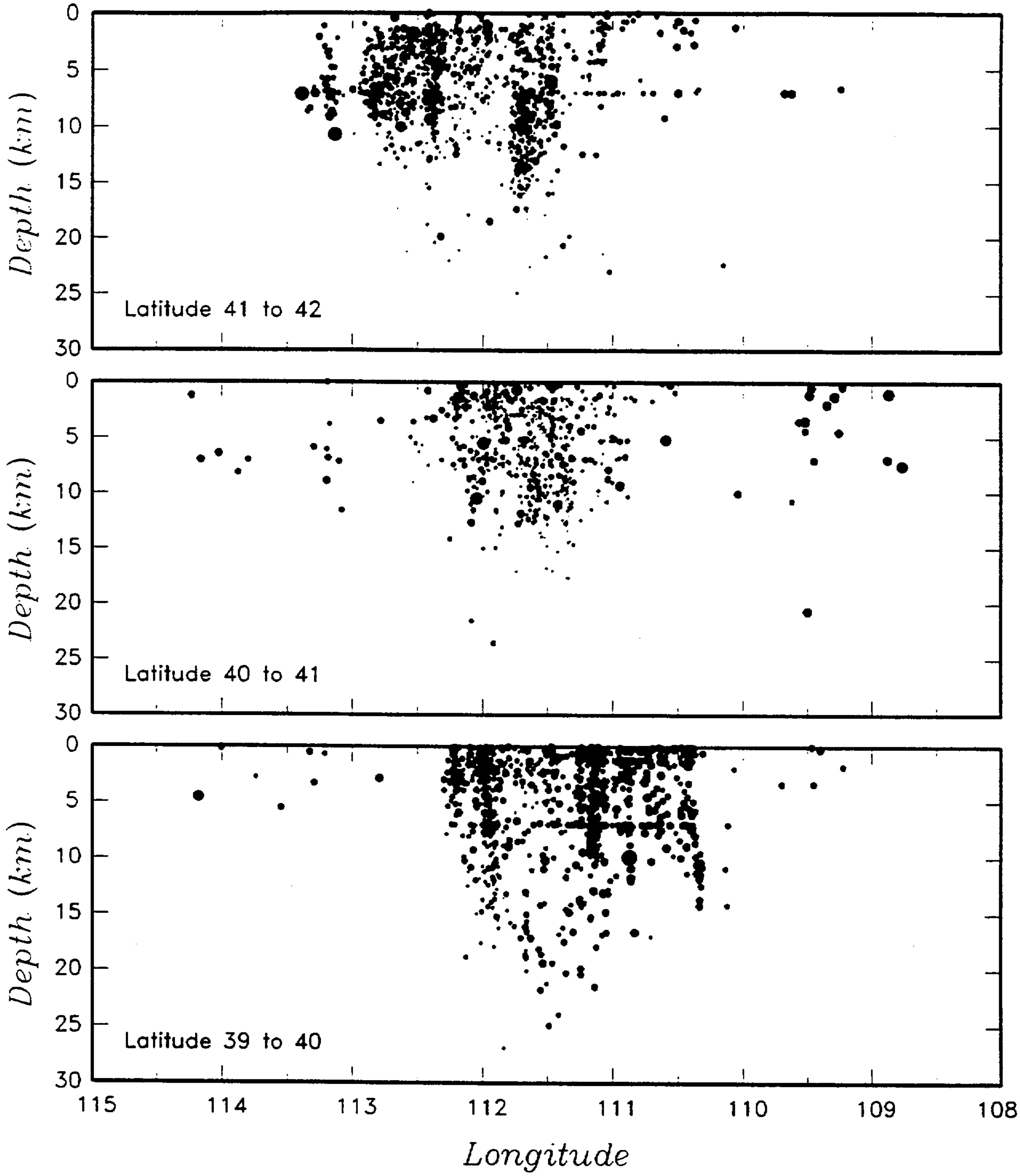


Figure 4–1 Seismicity cross sections along the Wasatch Front

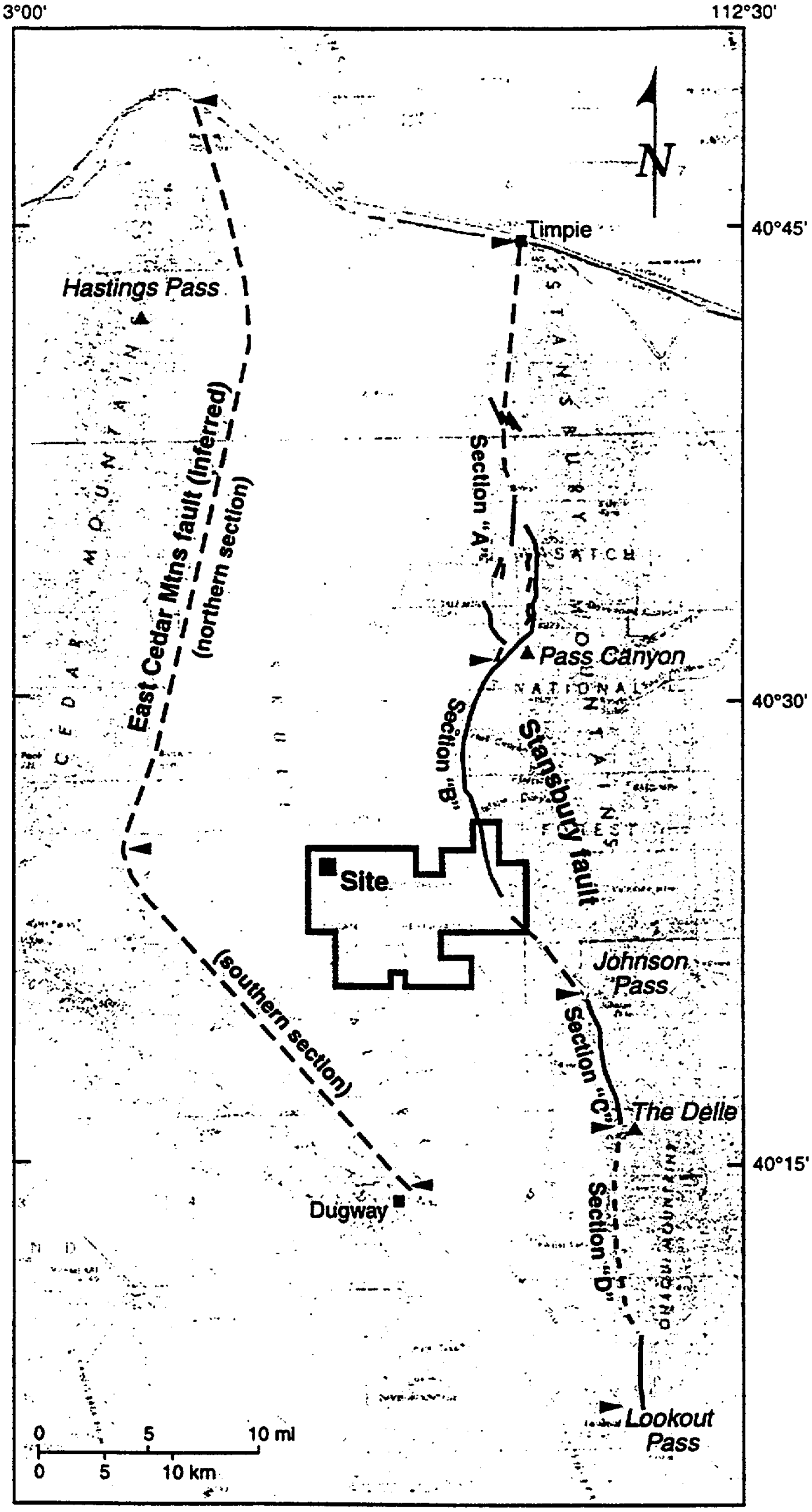


Figure 4-2 Sections of the Stansbury and East Cedar Mountains Faults. East Cedar Mountains fault after Hood and Waddell (1968); Stansbury fault after Helm (1995), Hecker (1993), and Sack (1993). Triangles show section ends.

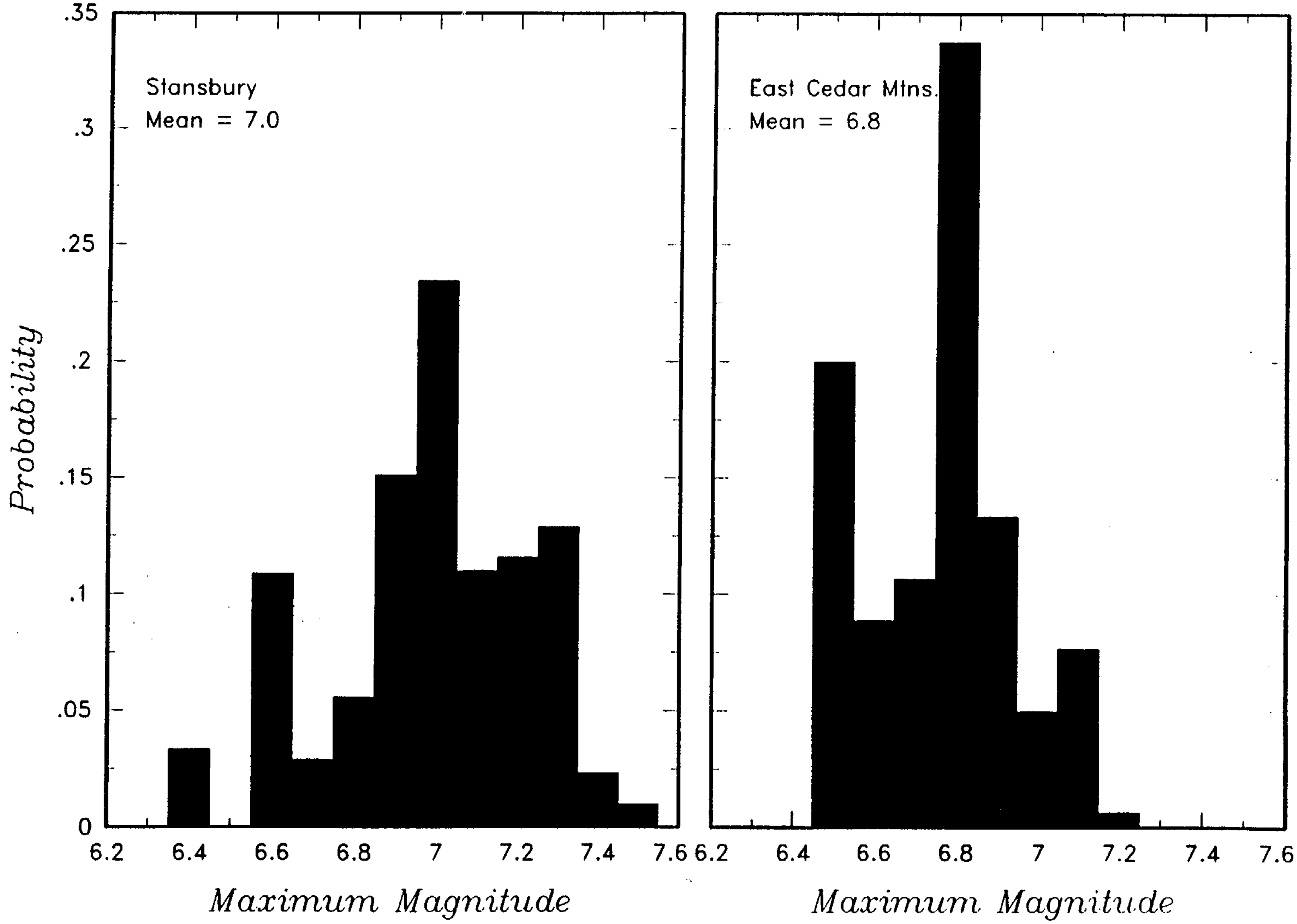


Figure 4–3 Maximum magnitude distributions for the Stansbury and East Cedar Mountains faults

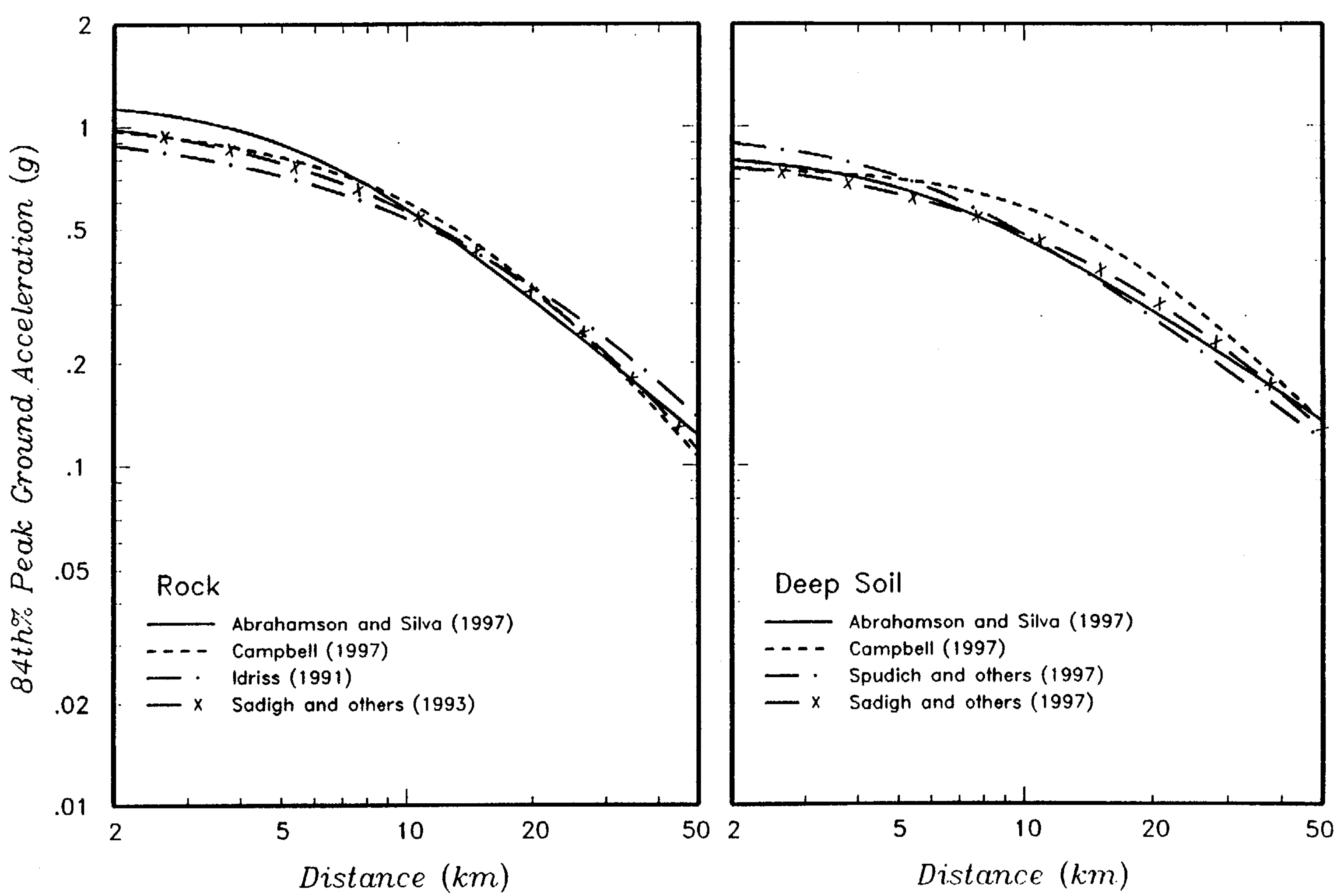


Figure 4–4 Comparison of horizontal PGA Attenuation Relationships

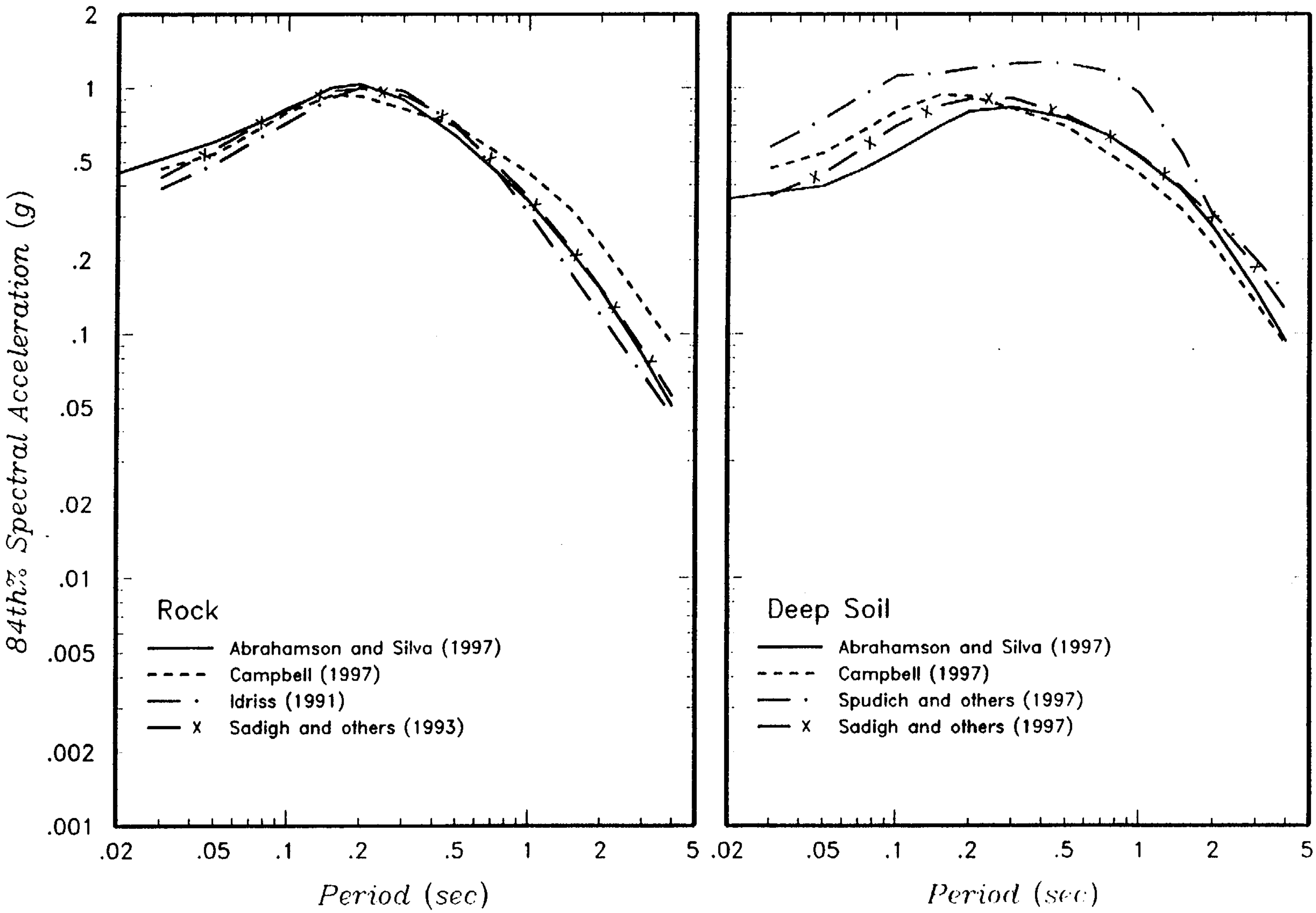


Figure 4-5 Comparison of horizontal acceleration response spectra

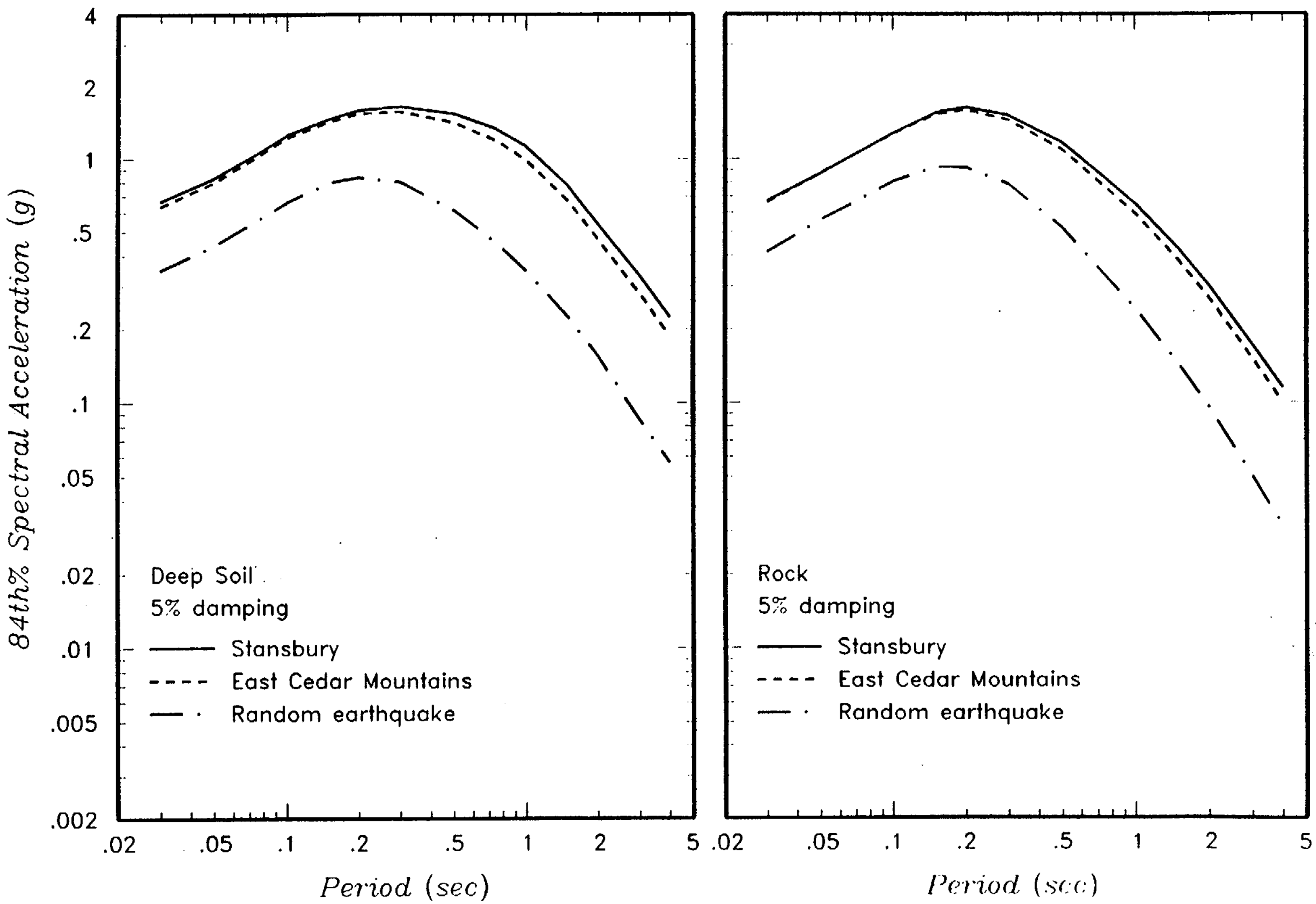


Figure 4–6 Comparison of 84th percentile horizontal response spectra for the three nearby seismic sources

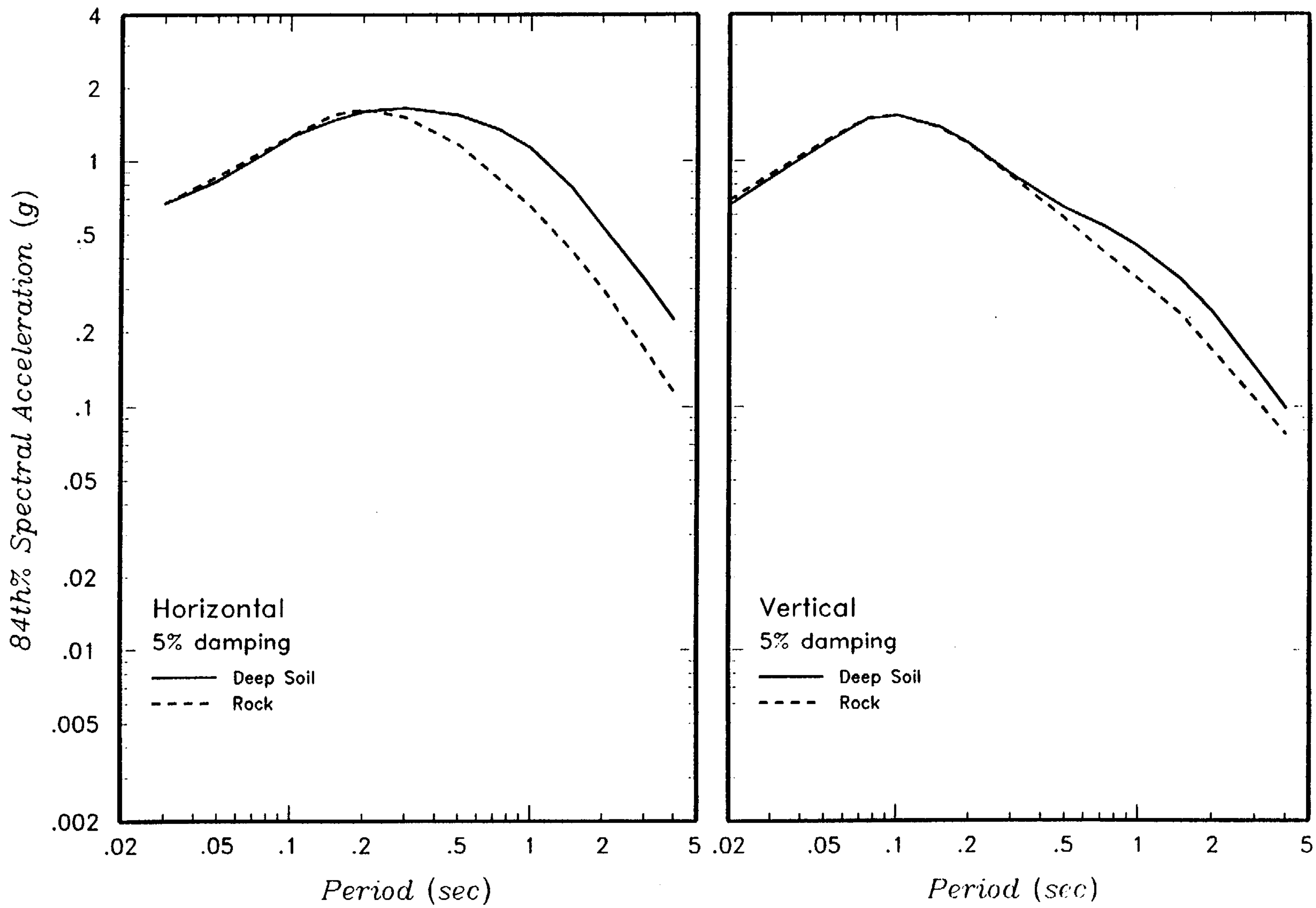


Figure 4-7 Stansbury fault 84th-percentile response spectra

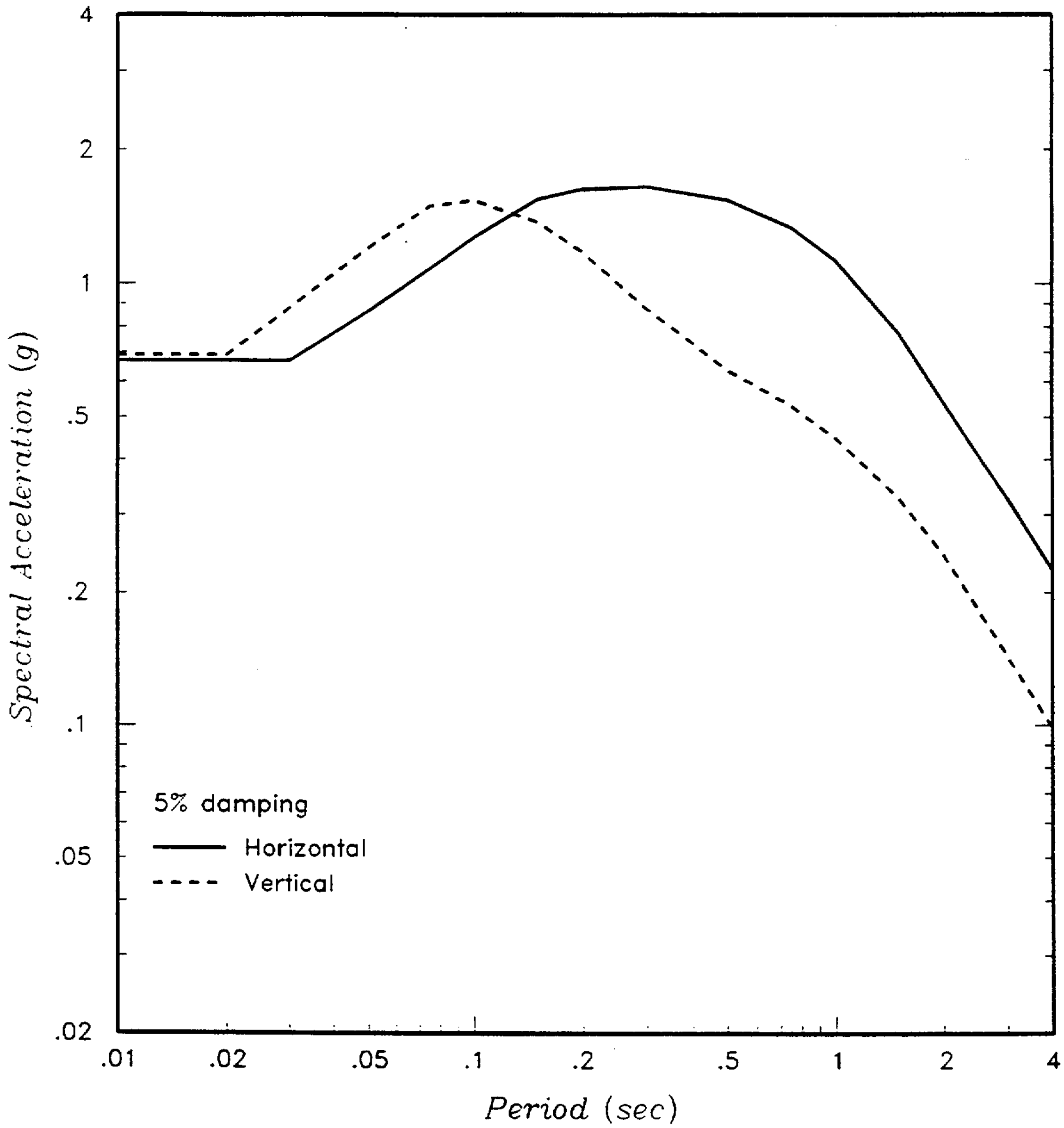


Figure 4-8 Recommended envelope 84th percentile response spectra

5.0 SUMMARY AND CONCLUSIONS

Using the methodologies that have been established for assessing ground motions for design of nuclear power plant facilities (e.g., Appendix A to 10 CFR100, and associated applications), we have developed a deterministic ground motion assessment for the PFSF site in Skull Valley, Utah. After evaluation of the seismotectonic setting and evaluation of potential seismogenic sources within the region, two capable or potentially capable fault sources are identified that lie within 10 km of the site. These are the Stansbury fault, which lies about 9.5 km to the east of the site, and a potential fault along the east side of the Cedar Mountains lying about 9 km to the west of the site. In addition, the potential for a "random nearby" earthquake (by convention lying within 25 km of the site) is also considered. Other capable faults lie more than 20 km from the site and are unlikely to produce 84^{th} percentile ground motion levels that are as large as those estimated for the other sources.

Maximum magnitudes were estimated for each of the sources following common practice in western U.S. settings. No large historical earthquakes have occurred on any of the three sources that would be considered to be potential maximum events. Therefore, maximum rupture dimensions—rupture length and rupture area—were estimated for the two fault sources and empirical relationships used to arrive at moment magnitude estimates. The rupture length estimates incorporated evidence for segmentation of the fault zones and uncertainties in the length of coseismic ruptures. Likewise, uncertainties in the dip and downdip width of the faults was included in the assessment. The maximum magnitude distributions for the Stansbury and East Cedar Mountains faults are shown on Figure 4-3. The resulting mean estimates of maximum magnitude are **M** 7.0 and **M** 6.8 for the Stansbury and East Cedar Mountains faults, respectively.

The maximum magnitude associated with the random nearby source is estimated based on the conservative assumption that this earthquake will occur on an unrecognizable fault. Based on a consideration of the threshold of surface faulting, a maximum magnitude ranging from **M** 5.5 to 6.5, with a mean value of 6 is assessed for the zone. The earthquake location is assumed to be random within a 25-km radius circle, resulting in a mean distance to the epicenter of 16.7 km.

The ground motion assessments for the maximum earthquakes were made using empirical relationships that predict peak acceleration and response spectral accelerations as a function of earthquake magnitude, source-to-site distance, style of faulting, and generalized site classification. The standard approach used to assess design ground motions from maximum events for nuclear facilities is to use the 84th percentile of the empirical distribution of peak motions. We have extended this approach to include the uncertainty in maximum magnitude, minimum source-to-site distance, and selecting appropriate attenuation relationships in the estimation of the 84th percentile ground motions.

To account for the style of faulting, a mixture of attenuation relationships was used that have been developed for strike-slip faulting earthquakes occurring in California and relationships for extensional stress regime earthquakes. The available geophysical and geotechnical data for the site suggest that it may have the characteristics of either a "deep soil" site or may have the characteristics of a "California rock" site. Thus we have used both rock and deep soil attenuation relationships to predict 84th-percentile spectra. We have used multiple attenuation relationships in the assessment to reflect the uncertainty in estimating near field ground motions from large earthquakes.

Because there are few attenuation relationships for vertical motions, the approach taken was to estimate horizontal and vertical spectra with the same subset of attenuation relationships and use these spectra to compute a ratio of vertical to horizontal motions. This ratio was then used to scale the horizontal spectra computed using the full set of horizontal relationships to produce the vertical 84th percentile spectra.

Comparison of the ground motions for the three nearby sources shows that the Stansbury fault is the controlling ground motion source. Figure 4-7 shows the horizontal and vertical response spectra for rock and deep soil sites for the Stansbury fault. The peak horizontal ground accelerations are 0.67 g for both rock and deep soil site conditions. The peak vertical ground accelerations are 0.66 g for deep soil site conditions and 0.69 for rock site conditions. Because it is uncertain at this time whether the site behaves as a rock or a deep soil site, we recommend that the preliminary design spectra for the site be conservatively taken as the envelope of the response spectra shown in Figure 4-7. These envelope spectra are plotted on Figure 4-8 and listed in Table 4-1.

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APPENDIX 2E

ANALYSIS OF VOLCANIC ASH

THE UNIVERSITY OF UTAH

March 11, 1997

John Donnell, Project Manager
Stone & Webster Engineering Corporation
P. O. Box 5406
Denver, CO 80217-5406

Dear Mr. Donnell,

Enclosed is a report on the results of analyses of volcanic ash samples submitted to me by Richard Gillespie. If you have any questions about the report, please let me know.

Sincerely yours,

W.P. Nash

William P. Nash
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Analysis of Volcanic Ash

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Department of Geology and Geophysics
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Salt Lake City , Utah

Summary

- Two samples of volcanic ash, A-1-85 and A-1-90, were analyzed for their chemical composition by electron microprobe. They are chemically identical in composition.

- The unknown samples are chemically similar to the fallout ash of the Walcott Tuff. The Walcott Tuff was erupted approximately 6.4 ± 0.2 million years ago from an eruptive center near Heise, Idaho, on the eastern Snake River Plain, and is a widely distributed ash unit in the western United States.

- The ash samples analyzed do not resemble widespread younger ashes such as the Bishop, Lava Creek or Huckleberry Tuffs.

Analysis of Volcanic Ash

Objective. The objective was to perform a chemical analysis of the glass component in two ash samples (A-1-85 and A-1-90), and to attempt to correlate those samples with a known ash on the basis of chemical similarity.

Procedure. An aliquot of each sample was dried overnight at 110°C, mixed with epoxy and placed on a 1" circular mount. The mount was polished to an optically flat surface, and coated with a thin coat of carbon by vacuum deposition. The samples were analyzed with a Cameca model SX-50 electron microprobe. The analytical conditions were: accelerating voltage 15 KeV, beam current 25 μA, and a beam diameter of 15 μm. Approximately 20 glass shards were analyzed in each sample.

Analytical results. Results of the analyses, together with comparative analytical data for other ashes, are presented in Table 1 in terms of weight percent element. Results of individual glass shard analyses, together with averages, are given in the appendix, where they are presented in both elemental and oxide formats. Table 1 also provides the standard deviation for each element as determined on a laboratory standard.

The two samples provided are identical in composition within the limits of analytical uncertainty. The similarity is apparent in Fig. 1 which plots Fe versus Ca for individual glass shards from the two samples. One glass shard in sample A-1-85 has an anomalously high Fe and Ca content.

Comparison with other ashes. An assessment of the correlation of an unknown ash with a known ash is based on the degree of similarity of the composition of glass shards. The composition of the unknown is compared to known compositions using a statistical distance function described by Perkins et al., 1995 (copy appended). In electron microprobe analysis we use Ca, Cl, Fe, Mn, Mg, Ti and Ba; the elements Al and Si are not used because they show little variation from tuff to tuff. The elements Na, K and F are not used because the concentrations of these elements may be variably changed during post-depositional hydration of glass shards.

The unknown samples were statistically compared with 1,965 analyses of tuffs, representing approximately 450 tuff units younger than 17 million years that occur in the western United States. The unknown samples most closely match the fallout ash of the Walcott Tuff. Comparative analyses of four samples of the Walcott Tuff are presented in Table 1, and individual shard analyses are compared in Figure 2.

The Walcott Tuff was erupted from the Heise volcanic field in the eastern Snake River Plain approximately 6.4±0.2 million years ago. It has also been known in the literature as the Tuff of Blue Creek. Its source is inferred to be the Blue Creek caldera. It was a large volume eruption and is found in a number of locations throughout the western interior of the U. S. as well as in the High Plains of Nebraska and Kansas. A recent description of the Walcott Tuff is provided by Morgan (1992) who presents several whole-rock age dates for the Tuff ranging from 6.3±0.3 to 6.9±0.4, although there is uncertainty about the validity of the oldest date. The value we have adopted in our work (6.4±0.2 Ma) is the average of the four dates on established samples of the Walcott Tuff (Morgan, 1992, Table 1). In the local Utah region, the Walcott Tuff outcrops on the west side of the Salt Lake Valley (sample OQM90-02, Table 1) and has been encountered in several deep exploration wells in the Great Salt Lake.

Your samples do not resemble younger, widespread ashes common to the Great Basin, such as the Bishop, Lava Creek or Huckleberry Tuffs. A comparison to these is provided in Table 1 and Figure 3. Although the unknown samples are somewhat similar to Lava Creek B in terms of Fe and Ca (Fig. 3), the two units are distinctly different in terms of Ti, Mg and Ba contents.

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Comparative Analyses

sample	Unit	Si	Ti	Al	Fe	Mn	Mg	Ca	Ba	K	Na	Cl	F	O	Total
A-1-85	unnamed	34.4	0.11	6.23	0.88	0.03	0.06	0.34	0.06	4.39	2.01	0.10	0.21	51.7	100.5
A-1-90	unnamed	34.7	0.12	6.22	0.87	0.03	0.05	0.33	0.05	4.44	2.17	0.10	0.19	51.7	100.9
WAL93-01	Walcott Tuff	34.4	0.12	6.10	0.84	0.03	0.05	0.32	0.09	4.29	2.41	0.11	0.13	49.7	98.6
PAL93-06	Walcott Tuff	34.0	0.12	6.02	0.82	0.03	0.05	0.31	0.09	4.45	2.02	0.10	0.16	52.4	100.6
AMF93-01	Walcott Tuff	34.4	0.12	6.10	0.85	0.03	0.05	0.33	0.09	4.32	2.34	0.11	0.17	50.6	99.5
OQM90-02	Walcott Tuff	34.0	0.12	6.05	0.84	0.03	0.05	0.33	0.08	4.37	2.29	0.11	0.15	51.0	99.4
oc-92-5	Bishop Tuff	35.2	0.03	6.40	0.52	0.03	0.02	0.30	0.00	3.73	2.32	0.08	0.04	51.7	100.3
oc92-02	Lava Creek B	34.7	0.06	6.20	1.04	0.03	0.01	0.36	0.01	4.16	2.23	0.14	0.15	50.5	99.7
brd92-01	Huckleberry	34.5	0.05	6.18	1.15	0.02	0.01	0.40	0.02	4.11	2.29	0.14	0.13	51.3	100.2
Std. Dev.	Analytical standard	0.35	0.007	0.06	0.02	0.004	0.007	0.008	0.010	0.34	0.21	0.004	0.029	0.63	0.67

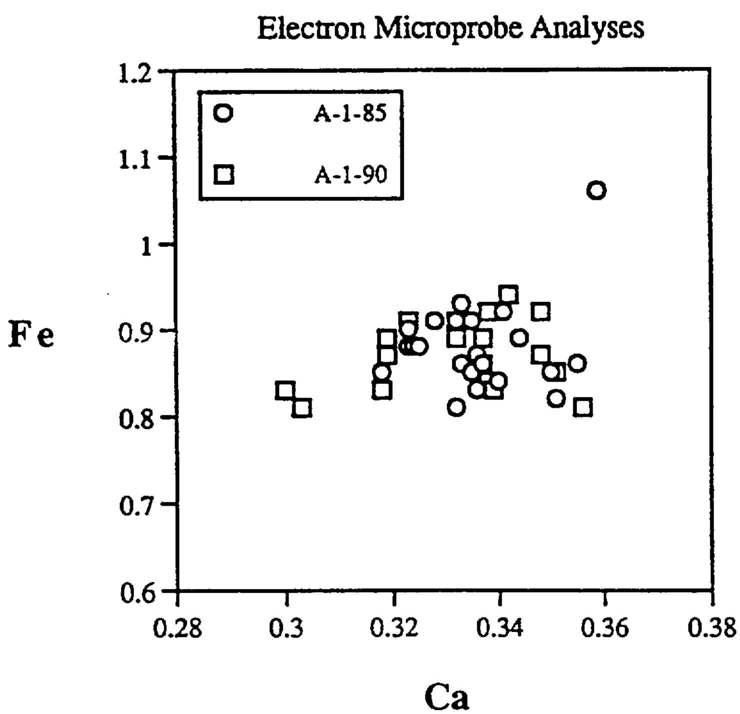

Figure 1. Analyses of individual glass shards from samples A-1-85 and A-1-90 .

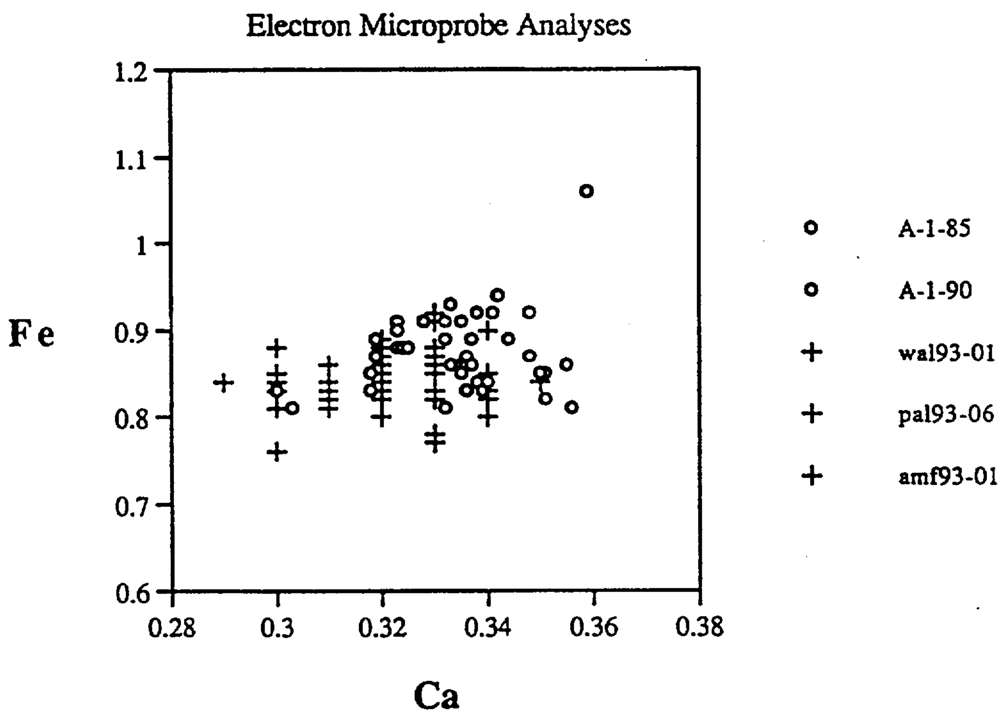

Figure 2. Analyses of individual glass shards from samples A-1-85 and A-1-90 and three samples of the Walcott tuff

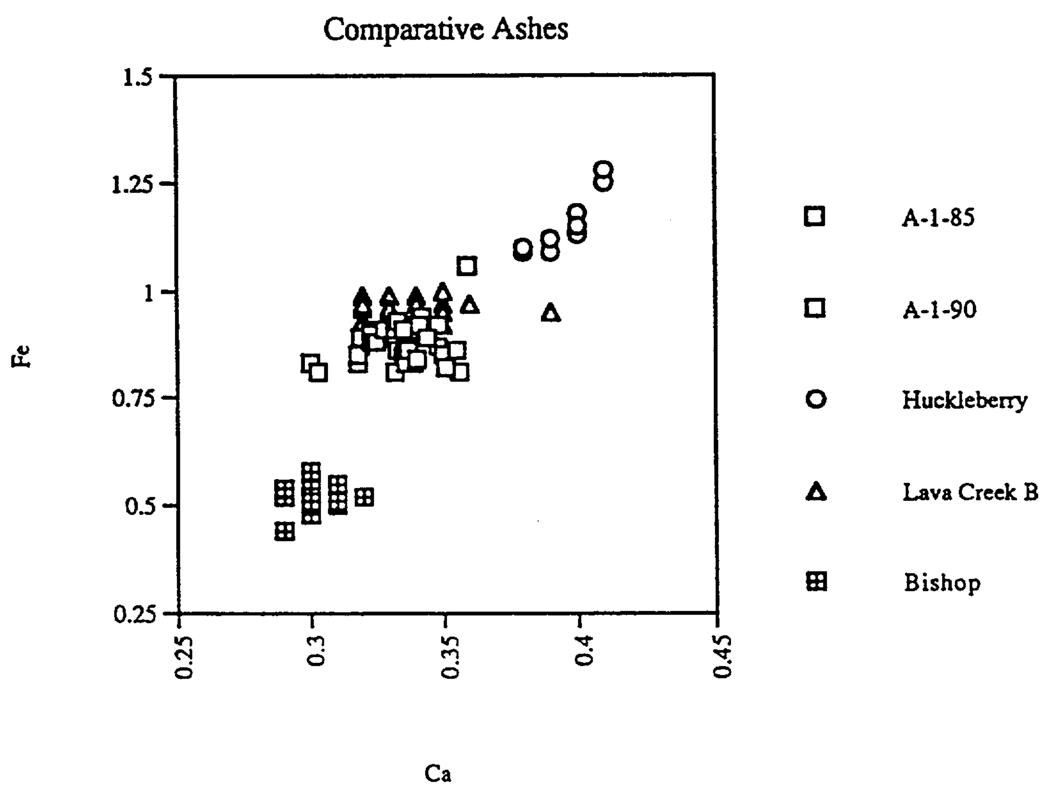

Figure 3. Analyses of individual glass shards from samples A-1-85 and A-1-90 and widespread Quaternary ashes.

Individual Shard Analyses - Elemental

Sample	Si	Ti	Al	Fe	Mn	Mg	Ca	Ba	K	Na	Cl	F	O	Total
A-1-85	34.5	0.10	6.23	0.82	0.04	0.05	0.35	0.08	4.64	2.05	0.09	0.21	51.3	100.5
A-1-85	34.4	0.10	6.22	0.85	0.03	0.06	0.35	0.06	4.29	2.23	0.09	0.26	52.5	101.4
A-1-85	34.0	0.11	6.17	0.86	0.03	0.06	0.33	0.00	4.58	2.05	0.08	0.24	51.1	99.6
A-1-85	34.6	0.12	6.22	0.85	0.05	0.05	0.34	0.04	4.39	2.45	0.10	0.21	51.7	101.1
A-1-85	34.3	0.13	6.26	0.84	0.03	0.05	0.34	0.06	4.50	1.99	0.11	0.28	52.0	100.9
A-1-85	34.4	0.14	6.27	0.86	0.01	0.07	0.34	0.08	4.43	2.09	0.11	0.20	52.0	101.0
A-1-85	34.1	0.11	6.17	0.81	0.02	0.06	0.33	0.04	4.58	1.99	0.11	0.15	51.7	100.2
A-1-85	34.3	0.10	6.14	0.83	0.01	0.04	0.34	0.04	4.59	1.95	0.11	0.19	51.2	99.8
A-1-85	34.7	0.12	6.29	0.85	0.06	0.06	0.32	0.03	4.40	2.22	0.11	0.20	51.5	100.9
A-1-85	34.6	0.11	6.33	0.88	0.06	0.06	0.32	0.08	4.37	2.10	0.11	0.18	51.7	100.9
A-1-85	34.2	0.12	6.13	0.88	0.01	0.04	0.32	0.07	4.59	2.08	0.11	0.18	51.1	99.8
A-1-85	34.3	0.10	6.23	0.87	0.01	0.06	0.34	0.09	4.49	2.17	0.11	0.18	51.5	100.4
A-1-85	34.4	0.10	6.21	0.86	0.02	0.07	0.36	0.06	4.51	2.07	0.12	0.15	51.6	100.6
A-1-85	34.5	0.10	6.26	0.92	0.05	0.07	0.34	0.11	4.37	2.17	0.12	0.18	52.4	101.5
A-1-85	35.0	0.15	6.29	0.88	0.05	0.06	0.33	0.07	2.35	0.35	0.10	0.26	53.1	98.9
A-1-85	34.5	0.13	6.26	0.89	0.03	0.06	0.34	0.06	4.62	2.09	0.10	0.21	51.4	100.6
A-1-85	34.0	0.13	6.22	0.93	0.05	0.05	0.33	0.10	4.33	1.66	0.10	0.21	52.0	100.0
A-1-85	34.4	0.11	6.24	0.91	0.05	0.05	0.33	0.00	4.48	2.18	0.13	0.18	52.1	101.1
A-1-85	34.4	0.05	6.23	0.90	0.05	0.06	0.32	0.05	4.47	2.19	0.09	0.23	51.9	100.9
A-1-85	34.3	0.09	6.21	0.91	0.01	0.07	0.34	0.07	4.61	1.90	0.09	0.22	51.3	100.1
A-1-85	34.7	0.07	6.20	0.91	0.04	0.07	0.33	0.05	4.61	2.06	0.09	0.19	51.4	100.7
A-1-85	34.0	0.13	6.30	1.06	0.03	0.08	0.36	0.08	4.43	2.09	0.10	0.27	51.7	100.6
A-1-90	35.0	0.10	6.25	0.81	0.01	0.06	0.30	0.07	4.38	2.37	0.11	0.15	51.3	100.9
A-1-90	34.5	0.14	6.27	0.92	0.01	0.05	0.35	0.03	4.37	2.30	0.10	0.18	51.3	100.5
A-1-90	34.5	0.13	6.25	0.91	0.03	0.06	0.32	0.09	4.39	2.09	0.10	0.25	52.4	101.5
A-1-90	34.7	0.10	6.16	0.87	0.03	0.05	0.32	0.05	4.32	2.26	0.10	0.25	51.6	100.8
A-1-90	34.6	0.13	6.25	0.89	0.05	0.04	0.32	0.07	4.39	2.30	0.11	0.18	51.4	100.7
A-1-90	34.6	0.13	6.27	0.83	0.05	0.06	0.30	0.01	4.43	2.38	0.11	0.20	51.4	100.8
A-1-90	34.5	0.12	6.22	0.87	0.00	0.05	0.35	0.07	4.37	2.16	0.11	0.16	52.0	100.9
A-1-90	34.4	0.13	6.10	0.89	0.02	0.05	0.34	0.05	4.53	2.25	0.12	0.16	52.1	101.1
A-1-90	34.6	0.15	6.16	0.86	0.03	0.05	0.34	0.09	4.45	2.15	0.10	0.16	51.9	101.0
A-1-90	34.8	0.09	6.25	0.81	0.05	0.05	0.36	0.08	4.68	1.96	0.11	0.17	51.5	100.9
A-1-90	34.9	0.10	6.26	0.94	0.00	0.07	0.34	0.03	4.34	2.18	0.09	0.20	51.7	101.2
A-1-90	34.7	0.14	6.17	0.83	0.01	0.05	0.32	0.05	4.25	2.30	0.10	0.18	51.6	100.6
A-1-90	34.5	0.15	6.22	0.84	0.03	0.06	0.34	0.08	4.43	2.14	0.11	0.15	51.6	100.7
A-1-90	34.6	0.12	6.26	0.85	0.05	0.05	0.35	0.06	4.48	2.29	0.10	0.18	51.4	100.8
A-1-90	34.8	0.12	6.24	0.91	0.05	0.05	0.33	0.05	4.43	2.09	0.10	0.22	51.8	101.2
A-1-90	34.9	0.13	6.21	0.86	0.03	0.06	0.34	0.05	4.54	2.13	0.10	0.20	52.0	101.5
A-1-90	34.5	0.13	6.19	0.83	0.03	0.05	0.34	0.00	4.19	2.12	0.10	0.21	52.4	101.1
A-1-90	35.0	0.11	6.12	0.86	0.05	0.05	0.34	0.06	4.64	1.94	0.11	0.17	51.3	100.7
A-1-90	34.7	0.12	6.30	0.92	0.03	0.07	0.34	0.05	4.64	2.11	0.11	0.22	50.7	100.3
A-1-90	34.6	0.14	6.27	0.89	0.04	0.06	0.33	0.04	4.62	1.94	0.11	0.19	51.8	101.1

Individual Shard Analyses - Oxides

Sample	SiO2	TiO2	Al2O3	Fe2O3	MnO	MgO	CaO	BaO	Na2O	K2O	Cl	F	Oxide sum	H2O	–O	Total
A-1-85	73.8	.16	11.8	1.18	.06	.09	.49	.09	2.8	5.6	.09	0.21	96.4	4.9	0.11	101.2
A-1-85	73.5	.16	11.8	1.22	.04	.09	.49	.07	3.0	5.2	.09	0.26	95.9	6.3	0.13	102.1
A-1-85	72.6	.18	11.6	1.22	.04	.10	.47	.00	2.8	5.5	.08	0.24	94.8	5.4	0.12	100.1
A-1-85	74.0	.20	11.7	1.21	.07	.08	.47	.04	3.3	5.3	.10	0.21	96.7	5.0	0.11	101.6
A-1-85	73.4	.22	11.8	1.20	.04	.09	.48	.07	2.7	5.4	.11	0.28	95.8	5.9	0.14	101.6
A-1-85	73.5	.23	11.9	1.22	.02	.11	.47	.08	2.8	5.3	.11	0.20	95.9	5.7	0.11	101.5
A-1-85	73.0	.18	11.6	1.16	.02	.10	.46	.04	2.7	5.5	.11	0.15	95.0	5.8	0.09	100.7
A-1-85	73.3	.17	11.6	1.19	.01	.07	.47	.04	2.6	5.5	.11	0.19	95.3	5.2	0.11	100.3
A-1-85	74.2	.20	11.9	1.21	.08	.10	.44	.03	3.0	5.3	.11	0.20	96.8	4.8	0.11	101.5
A-1-85	74.0	.19	11.9	1.26	.08	.10	.45	.09	2.8	5.3	.11	0.18	96.5	5.0	0.10	101.4
A-1-85	73.2	.20	11.6	1.25	.01	.07	.45	.08	2.8	5.5	.11	0.18	95.5	5.0	0.10	100.4
A-1-85	73.4	.16	11.8	1.24	.02	.11	.47	.10	2.9	5.4	.11	0.18	95.9	5.2	0.10	101.0
A-1-85	73.7	.17	11.7	1.23	.03	.11	.50	.06	2.8	5.4	.12	0.15	96.0	5.2	0.09	101.1
A-1-85	73.7	.17	11.8	1.32	.06	.11	.48	.12	2.9	5.3	.12	0.18	96.3	6.0	0.10	102.2
A-1-85	74.8	.25	11.9	1.25	.06	.10	.45	.07	0.5	2.8	.10	0.26	92.5	7.3	0.13	99.7
A-1-85	73.7	.22	11.8	1.27	.03	.10	.48	.06	2.8	5.6	.10	0.21	96.4	4.9	0.11	101.2
A-1-85	72.6	.22	11.7	1.33	.07	.08	.47	.11	2.2	5.2	.10	0.21	94.3	6.4	0.11	100.6
A-1-85	73.6	.18	11.8	1.30	.06	.08	.46	.00	2.9	5.4	.13	0.18	96.1	5.8	0.11	101.8
A-1-85	73.6	.08	11.8	1.28	.07	.10	.45	.06	2.9	5.4	.09	0.23	96.1	5.6	0.12	101.5
A-1-85	73.3	.14	11.7	1.31	.01	.11	.47	.08	2.6	5.6	.09	0.22	95.6	5.2	0.11	100.7
A-1-85	74.3	.11	11.7	1.31	.05	.11	.46	.06	2.8	5.6	.09	0.19	96.8	4.6	0.10	101.3
A-1-85	72.8	.22	11.9	1.52	.03	.13	.50	.09	2.8	5.3	.10	0.27	95.7	5.7	0.14	101.2

Individual Shard Analyses - Oxides

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	BaO	Na_2O	K_2O	Cl	F	Oxide sum	H_2O	–O	Total
A-1-90	74.9	.17	11.8	1.15	.01	.10	.42	.08	3.2	5.3	.11	0.15	97.4	4.1	0.09	101.4
A-1-90	73.8	.24	11.8	1.31	.02	.09	.49	.03	3.1	5.3	.10	0.18	96.5	4.6	0.10	101.0
A-1-90	73.8	.22	11.8	1.30	.03	.09	.45	.10	2.8	5.3	.10	0.25	96.2	6.1	0.13	102.2
A-1-90	74.2	.17	11.6	1.24	.04	.07	.45	.06	3.0	5.2	.10	0.25	96.4	5.0	0.13	101.3
A-1-90	74.0	.22	11.8	1.27	.06	.07	.45	.08	3.1	5.3	.11	0.18	96.6	4.7	0.10	101.2
A-1-90	74.1	.22	11.8	1.19	.06	.10	.42	.02	3.2	5.3	.11	0.20	96.7	4.7	0.11	101.3
A-1-90	73.8	.19	11.8	1.24	.00	.08	.49	.08	2.9	5.3	.11	0.16	96.2	5.6	0.09	101.7
A-1-90	73.5	.22	11.5	1.28	.03	.08	.47	.06	3.0	5.5	.12	0.16	95.9	5.9	0.09	101.7
A-1-90	74.0	.24	11.6	1.23	.04	.08	.47	.10	2.9	5.4	.10	0.16	96.3	5.4	0.09	101.6
A-1-90	74.4	.16	11.8	1.16	.07	.08	.50	.08	2.6	5.6	.11	0.17	96.7	4.7	0.10	101.3
A-1-90	74.6	.16	11.8	1.34	.00	.11	.48	.04	2.9	5.2	.09	0.20	96.9	4.8	0.11	101.6
A-1-90	74.1	.24	11.7	1.19	.01	.07	.44	.05	3.1	5.1	.10	0.18	96.3	5.0	0.10	101.2
A-1-90	73.8	.25	11.8	1.19	.04	.09	.47	.08	2.9	5.3	.11	0.15	96.2	5.1	0.09	101.2
A-1-90	74.1	.20	11.8	1.22	.06	.09	.49	.06	3.1	5.4	.10	0.18	96.8	4.6	0.10	101.3
A-1-90	74.4	.20	11.8	1.30	.06	.07	.46	.06	2.8	5.3	.10	0.22	96.8	5.0	0.12	101.7
A-1-90	74.7	.22	11.7	1.22	.04	.09	.47	.05	2.9	5.5	.10	0.20	97.2	5.0	0.11	102.1
A-1-90	73.8	.22	11.7	1.19	.04	.08	.47	.00	2.9	5.0	.10	0.21	95.7	6.2	0.11	101.8
A-1-90	74.8	.19	11.6	1.22	.06	.08	.47	.07	2.6	5.6	.11	0.17	97.0	4.3	0.09	101.2
A-1-90	74.1	.21	11.9	1.31	.04	.11	.47	.05	2.8	5.6	.11	0.22	96.9	3.8	0.12	100.6
A-1-90	74.1	.23	11.8	1.27	.06	.09	.46	.05	2.6	5.6	.11	0.19	96.6	5.2	0.10	101.7

Sample Averages - Elemental

Sample	Si	Ti	Al	Fe	Mn	Mg	Ca	Ba	K	Na	Cl	F	O	Total
A-1-85	34.4	0.11	6.23	0.88	0.03	0.06	0.34	0.06	4.39	2.01	0.10	0.21	51.7	100.5
A-1-90	34.7	0.12	6.22	0.87	0.03	0.05	0.33	0.05	4.44	2.17	0.10	0.19	51.7	100.9

Sample Averages - Oxide

Sample	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	BaO	Na_2O	K_2O	Cl	F	sum	H_2O	–O	Total
A-1-85	73.5	.18	11.8	1.26	.04	.10	.47	.07	2.7	5.3	.10	0.21	95.7	5.5	0.11	101.1
A-1-90	74.2	.21	11.8	1.24	.04	.09	.47	.06	2.9	5.4	.10	0.19	96.7	5.0	0.10	101.6

CHAPTER 3

PRINCIPAL DESIGN CRITERIA

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CHAPTER 3

PRINCIPAL DESIGN CRITERIA

This chapter identifies the principal design criteria for the Private Fuel Storage Facility (PFSF). The principal design criteria provide a record of design bases derived from 10 CFR 72 and applicable industry codes and standards referenced herein for comparison with the actual design, which is presented in subsequent chapters.

3.1 PURPOSES OF INSTALLATION

The purpose of the PFSF is to provide interim storage for up to 40,000 MTU of pressurized water reactor (PWR) or boiling water reactor (BWR) spent fuel from commercial nuclear power plants throughout the United States.

The PFSF shall utilize canister-based dry cask storage systems, where multiple spent fuel assemblies are stored in a dry inert environment inside a sealed metal canister that is placed inside a concrete cask and stored outdoors on a concrete pad. The storage system shall provide physical protection, heat removal, radiation shielding, criticality control, and confinement for the safe storage of spent fuel. The storage systems shall be designed to maintain retrievability of the canister for future removal offsite.

The dry cask storage systems used at the PFSF shall be the HI-STORM 100 Cask System (HI-STORM) designed by Holtec International (Holtec) and the TranStor Storage Cask System (TranStor) designed by Sierra Nuclear Corporation (SNC). Holtec has submitted a storage Safety Analysis Report (SAR) to the U.S. Nuclear Regulatory Commission (NRC) for the HI-STORM 100 Cask System (Reference 1). SNC has submitted a storage SAR to the NRC for the TranStor Storage Cask System (Reference 2).

3.1.1 Materials to be Stored

The PFSF shall be designed to store commercial BWR and PWR spent nuclear fuel with zircaloy or stainless steel cladding including failed fuel, BWR fuel channels, PWR control components, and mixed oxide (MOX) fuel. The spent fuel characteristics from these plants shall be encompassed by the design fuel characteristics that are established by the storage systems used at the PFSF.

The types of fuel to be stored at the PFSF are based on the types of fuel each storage system is licensed to store and PFSF design requirements. A summary of the fuel types that can be stored at the PFSF is shown in Table 3.1-1 for PWR fuel types and Table 3.1-2 for BWR fuel types.

The bounding design fuel characteristics for the PFSF, which are based on the capabilities of each storage system utilized at the PFSF are summarized in Table 3.1-3.

3.1.2 General Operating Functions

3.1.2.1 Transportation and Storage Operations

The PFSF shall be designed to use a passive dry storage technology. Canister transfer and cask placement or removal operations are the major activities.

Prior to receipt at the PFSF, the spent fuel is loaded in a canister at the originating nuclear power plant. The canister is surveyed for contamination, decontaminated if necessary, drained, vacuum dried, filled with helium, and sealed closed prior to shipping. The canister is then loaded into a shipping cask. The shipping cask is protected by impact limiters and mounted on a shipping cradle, and attached to a rail car and shipped to the PFSF.

The PFSF design shall utilize one of two transport alternatives to haul the shipping cask from the railroad mainline to the site. The first is to haul the shipping cask by highway on a heavy haul tractor/trailer from an intermodal point to the PFSF. Using the highway alternative, the intermodal transfer point shall include the necessary components (crane, rail siding, and truck access area) to accommodate the rail to tractor/trailer transfer. The second alternative is to haul the shipping cask by rail on a railroad spur to be constructed. Using the rail spur option, the railroad spur and associated equipment shall be designed in accordance with railroad industry standards.

At the PFSF the canister shall be transferred from the shipping cask to the storage cask. The shipping cask shall be off-loaded from the transport vehicle inside the Canister Transfer Building using an overhead crane and placed in a shielded transfer cell. Once the shipping cask has been opened a transfer cask shall be placed on top of the shipping cask and the canister hoisted up and secured into the transfer cask. The transfer cask shall then be moved by crane onto the top of a concrete storage cask and the canister shall be lowered into the storage cask. The storage cask lid shall be installed and bolted. The storage cask shall then be moved to the cask storage pad using a cask transporter. Storage of the loaded concrete storage cask shall include temperature monitoring and periodic surveillance of the storage casks.

When the fuel is to be shipped offsite, the storage cask shall be moved back into the Canister Transfer Building using the cask transporter. The transfer cask shall be placed on top of the storage cask and the canister lifted up and secured into the transfer cask. The transfer cask shall then be moved by crane onto the top of a shipping cask. The canister shall be lowered into the shipping cask, which shall be closed and shipped offsite.

The PFSF shall be designed with the necessary equipment (such as, the Canister Transfer Building, cranes, cask transporter, storage area) to accommodate shipping cask receipt, canister transfer from the shipping cask to the concrete storage cask, cask transport to and from the storage pads as detailed above with provisions for security, health physics, maintenance, document control, and inventory management.

3.1.2.2 Onsite Generated Waste Processing, Packaging and Storage

The selected canister-based storage systems shall be designed to confine spent fuel within a sealed canister at the originating nuclear power plant. Therefore, handling of spent fuel is not required and no radioactive waste is generated at the PFSF.

Solid dry radioactive waste generated created by performing health physics surveys (i.e. smears, disposable clothing) shall be collected, identified, packaged in low level waste (LLW) containers, marked in accordance with 10 CFR 20 requirements, and temporarily stored in the LLW holding cell of the Canister Transfer Building while awaiting shipment to an offsite low-level radioactive disposal facility.

There shall be no other systems or facilities for processing, packaging, storing, or transporting any other type of radioactive waste at the PFSF.

3.1.2.3 Utilities

The PFSF shall be designed to include utilities necessary for facility operation. These utilities include (1) electrical power for operation of equipment, lights, monitoring equipment, communication systems, security systems; (2) backup electrical power for operation of security systems, emergency lights, monitoring equipment, and communication systems; and (3) mechanical systems for operation of fire protection equipment, building HVAC systems, compressed air systems, water supply systems, and septic systems. Utilities do not need to be classified as Important to Safety unless their function could affect the safe operation of a SSC that is classified as Important to Safety

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3.2 STRUCTURAL AND MECHANICAL SAFETY CRITERIA

This section of the principal design criteria establishes requirements that satisfy 10 CFR 72.122(b), which identifies the general design criteria that requires structures, systems, and components (SSCs) classified as Important to Safety be designed to withstand the effects of environmental conditions and natural phenomena in their structural and mechanical design. SSCs classified as Important to Safety shall be designed with sufficient capability to withstand the worst-case loads under normal, off-normal, and accident-level conditions such that their capability to perform safety functions is not impaired. Accident-level conditions include credible accidents, natural phenomena, and hypothetical events. Loads considered for the PFSF are categorized as follows:

Load	Normal	Off-normal	Accident-Level
Dead Loads	x		
Live Loads	x		
Handling Loads	x	x	
Snow and Ice Loads	x		
Wind Loads	x		
Internal/External Pressure	x	x	
Lateral Soil Pressure	x	x	x
Thermal Loads	x	x	x
Accident Loads			
Explosion Overpressure			x
Drop/Tipover			x
Accident Pressurization			x
Fire			x
Tornado Winds/Missiles			x
Floods			x
Earthquake			x

Design criteria for these loads are described in this chapter and shall be used in the design of all SSCs classified as Important to Safety.

The SSCs that are classified as Important to Safety include:

- The Dry Cask Storage Systems - The dry cask storage systems (HI-STORM and TranStor) shall consist of metal canisters for spent fuel storage, concrete storage casks, a metal transfer cask, lifting attachments, and associated equipment.

- Cask Storage Pads - The cask storage pads shall provide a stable and level support surface for the concrete storage casks.

- Canister Transfer Building - The Canister Transfer Building shall be a reinforced concrete, one-story, high-bay structure that houses the canister transfer cranes and supports shipping cask receiving and canister transfer operations. The Canister Transfer Building shall use cells designed for canister transfer operation with thick concrete walls to shield personnel from radiation doses.

- Canister Transfer Cranes - The overhead bridge and semi-gantry cranes shall be single-failure-proof. The overhead bridge crane shall have a maximum capacity of 200 tons and shall be used to load and unload shipping casks from the shipment vehicle or transfer the canisters between the shipping cask and the storage cask. The semi-gantry crane shall have a minimum capacity of 150 tons and shall be used to transfer the canisters between the shipping cask and the storage cask.

The HI-STORM and TranStor storage systems design criteria are fully described in their respective SARs. Where the storage systems design criteria do not bound the PFSF design criteria, the storage systems design shall be shown in subsequent chapters as complying with the PFSF site-specific design criteria. The storage system design parameters that require site-specific analysis and/or design and the Sections where they are addressed areas follows:

Site Specific Design Criteria	Storage System	Section Addressed
• Cask stability during a seismic event	HI-STORM TranStor	4.2.1.5.1(H) 4.2.2.5.1(H)
• Storage cask temperature monitoring verses daily inspection of vent blockage	HI-STORM TranStor	N/A 5.4.1
• Radiation doses for 4000 cask array to the RA, OCA, and nearest residence	both	7.3.3.5 and 7.6
• Off-normal contamination release event	HI-STORM TranStor	8.1.5 N/A
• Hypothetical storage cask tipover onto a PFSF concrete storage pad	both	8.2.6
• Hypothetical loss of confinement	HI-STORM TranStor	8.2.7 N/A
• Fire	both	8.2.5

3.2.1 Dead Load

Dead load is defined as the self weight of the structure, including all permanently installed equipment, and loads due to differential settlement, creep and shrinkage.

3.2.2 Live Loads

Live loads are defined as all equipment not permanently installed, lift loads, and all loads other than dead loads that might be experienced that are not separately identified and used in the applicable load combinations. These include normal and off-normal handling and impact loads from equipment. Impact loads for the cranes include equipment loads imposed on the crane through supporting members of the building and loads induced by the acceleration and deceleration of the crane bridge, gantry, or trolley.

3.2.3 Snow and Ice Loads

Snow loads, which are considered as live loads, shall be determined in accordance with ASCE-7 (Reference 3). The southern portion of Tooele County at the Skull Valley Indian Reservation has a ground snow load (p_g) of 10 psf as shown on Figure 7-1 of ASCE-7. Design snow loads and placement of loads on structures shall follow the procedures outlined in ASCE-7.

3.2.4 Internal/External Pressure

Internal and external pressure loads are defined as loads resulting from the differential pressure between the helium fill gas inside the canister and the environmental pressure. The pressure may be positive (internal pressure) or negative (external pressure). The pressure must be considered for both normal and off-normal conditions, except for pressurization from a fuel rod rupture, which is an accident-level condition addressed under accident loads.

3.2.5 Lateral Soil Pressure

Lateral soil loads must be considered where applicable as they would result from normal, off-normal, and accident conditions. Lateral soil pressure includes lateral pressure resulting from soil and hydrostatic loads external to the structure transmitted to the structure by the adjacent soil mass.

3.2.6 Thermal Loads

Thermal loads are defined as loads resulting from normal, off-normal, and accident-level condition temperature distributions and thermal gradients within the structure, expansions and contractions of components, and restraints to expansions and contractions, except for thermal loads that are separately identified and used in the load combination. The range of design ambient temperatures at the site is -35° to +110° F (References 5 and 6).

Accident-level thermal loads are due to a temperature rise resulting from the loss of cooling air for an extended period of time or loads resulting from the maximum anticipated heat loads such as, a fire or burial under debris.

3.2.7 Accident Loads

Accident loads are defined as loads due to the direct and secondary effects of an off-normal or design basis accident that could result from an explosion, drop, tipover, pressurization, fire, or other human-caused occurrences. The accident events to be addressed in the design of the facility are discussed in Chapter 8.

3.2.8 Tornado and Wind Loadings

The design of SSCs shall consider loading associated with maximum site-specific meteorological conditions, including tornado and extreme wind. The tornado and wind loading used in the design shall be in accordance with ANSI/ANS 57.9 (Reference 4), NUREG-0800 (Reference 7), Regulatory Guide 1.76 (Reference 8), and ASCE-7.

3.2.8.1 Applicable Design Parameters

The normal design basis wind shall have a velocity of 90 mph as shown in Figure 6-1 of ASCE-7. The design basis wind is defined as a 3-second gust speed at 33 ft above ground for Exposure C category and is associated with an annual frequency of 2E-2 times per year.

The extreme design basis wind shall be derived from the design basis tornado. Tooele County is located in Tornado Intensity Region III as defined by Regulatory Guide 1.76, where the following design basis tornado characteristics are specified:

Design Basis Tornado Characteristics

Maximum Wind Speed	240 mph
Rotational Wind Speed	190 mph
Translational Speed	50 mph
Radius of Max. Wind Speed	150 ft
Pressure Drop	1.5 psi
Rate of Pressure Drop	0.6 psi/sec

3.2.8.2 Determination of Forces on Structures

Forces resulting from the design basis wind and the design basis tornado shall be considered in the design. The method used to convert wind loading into forces on a structure shall be in accordance with NUREG-0800 (Section 3.3.1, Wind Loadings, and Section 3.3.2, Tornado Loadings).

3.2.8.3 Ability of Structure to Perform Despite Failure of Structure Not Designed for Tornado Load

The PFSF shall be designed to ensure that SSCs that are not designed for tornado loads do not adversely affect the safety functions of SSCs that are classified as Important to Safety.

SSCs that are classified as Important to Safety but not designed for tornado loads shall be located so as to be protected by a SSC that is classified as Important to Safety and designed for tornado loads.

The Canister Transfer Building shall be designed to withstand tornado-generated wind loadings and missiles in order to protect SSCs housed within the building that are not designed for tornado loads.

3.2.8.4 Tornado Missiles

SSCs that are classified as Important to Safety shall be designed for tornado-generated missiles.

The loaded concrete storage casks shall remain stable and the confinement boundary not breached when subjected to tornado-generated missiles.

The storage pads and Canister Transfer Building shall remain stable and structurally intact when subjected to tornado-generated missiles.

Tornado-generated missiles need not be considered in the design of the canister, overhead bridge and semi-gantry cranes, or transfer cask since the canister is protected by the storage cask and the cranes and transfer cask are protected by the Canister Transfer Building.

Postulated tornado missiles shall be in accordance with NUREG-0800, Section 3.5.1.4, for Spectrum I missiles. The tornado-generated missiles shall include:

- 1800 kg automobile
- 125 kg 8" armor piercing artillery shell
- 1" solid steel sphere

As described in NUREG-0800, all missiles shall be assumed to impact at 35 percent of the maximum horizontal wind speed of the design basis tornado (240 mph x .35 = 84 mph). The first two missiles are assumed to impact at normal incidence; the last is assumed to impinge upon barrier openings in the most damaging directions.

The barrier design procedure associated with tornado-generated missiles shall be in accordance with NUREG-0800, Section 3.5.3.

3.2.9 Water Level (Flood) Design

The site is located in Skull Valley, an area of western Utah with a semi-arid climate, receiving low annual precipitation. Precipitation ranges from 7 to 12 inches per year. The site has no flowing or intermittent streams nearby, however, there is evidence of minor drainage channels created by infrequent thunderstorms or snow melt runoff.

Two major watersheds have been identified which can contribute runoff to the PFSF site area as described in Section 2.4.1.2. A relatively large watershed from the Stansbury Mountains is identified as basin I and a relatively small watershed from the nearby Hickman Knolls is identified as basin II. Basin I is separated from basin II by an earthen berm which will be constructed at the PFSF to control runoff from these offsite sources.

Analyses of the probable maximum precipitation (PMP) were performed to determine a probable maximum flood (PMF) for stormwater drainage basins I and II. The basin I PMF water elevation predicted at the location nearest the site, approximately 6,500 ft downstream (north) from the access road, is 4,453.4 feet. The site grade elevations are higher than 4,460 feet. Consequently, all SSCs that are classified as Important to Safety are located above the basin I PMF flood plain.

Basin II stormwater runoff from Hickman Knolls drains as a sheet flow toward the PFSF site. An earthen berm and drainage ditch system will be constructed on the south and west sides of the PFSF storage site to divert the PMF stormwater flows around the site and into the Skull Valley natural drainage system. Consequently, all SSCs that are classified as Important to Safety are protected from the sheet flow associated with the basin II PMF by an earthen berm.

Therefore, forces due to flood waters and flood protection measures need not be considered in the design of SSCs that are classified as Important to Safety.

3.2.10 Seismic Design

The design of SSCs classified as Important to Safety shall consider loadings associated with the ISFSI Design Earthquake (DE) as defined in 10 CFR 72.102. The ISFSI DE is equivalent to a Safe Shutdown Earthquake (SSE) as defined by 10 CFR 100, Appendix A. Regulatory Guide 1.29 (Reference 10) was used to define the SSCs that are required to withstand the loadings associated with the ISFSI DE. These SSCs are identified in Regulatory Guide 1.29 as seismic Category I.

3.2.10.1 Input Criteria

Tooele County is located west of the Rocky Mountain Front, which is defined in 10 CFR 72.102 as approximately 104° west longitude. A deterministic ground motion analysis was performed to establish the appropriate seismic design basis for the facility as described in Section 2.6.

In addition, a site-specific geotechnical investigation was performed to ensure the geological characteristics and soil are stable under earthquake conditions as described in Section 2.6.

3.2.10.1.1 Design Response Spectra

The ISFSI DE for the PFSF is described by site-specific response spectrum curves anchored at 0.67 g in two directions of the horizontal plane and 0.69 g in the vertical plane. The response spectra curves are free field at the ground surface and conservatively envelope both soil and rock type site characteristics. The horizontal and vertical design response spectra curves for the site are shown in Appendix 2D, Figure 4-8.

3.2.10.1.2 Design Response Spectra Derivation

Site-specific horizontal and vertical design response spectra curves for the facility are developed in accordance with 10 CFR 100, Appendix A (Reference 11) as described in the Deterministic Earthquake Ground Motion Analysis (Reference 12).

3.2.10.1.3 Design Time History

Design time histories shall be used in the cask stability analyses and in the storage pad design. Statistically independent artificial time histories shall be developed in accordance with NUREG-0800, Sections 3.7.1 and 3.7.2 shall be shown to envelope the site-specific response spectra.

3.2.10.1.4 Use of Equivalent Static Loads

The HI-STORM storage system is dynamically analyzed and does not use equivalent static loads.

Equivalent static loading is used on the TranStor storage system since the concrete cask is a very rigid body with natural frequencies in excess of the zero period acceleration cutoff. No dynamic amplification by the cask is expected.

Equivalent static loads are not used for onsite structures since dynamic analyses are used in the seismic analysis and design.

3.2.10.1.5 Critical Damping Values

Critical damping values shall be in accordance with Regulatory Guide 1.61 (Reference 13) for a SSE.

3.2.10.1.6 Basis for Site-Dependent Analysis

Site-specific vibratory ground motion is established through evaluation of the seismology, geology, and the seismic and geologic history of the site and surrounding region. This information is contained in the site-specific deterministic earthquake ground motion analysis (Reference 12).

3.2.10.1.7 Soil-Supported Structures

The soil-supported structures that shall be analyzed for the ISFSI DE are the concrete cask storage pads and the Canister Transfer Building. These structures shall be founded on in-situ soil at a minimum depth of 2 ft 6 inches for frost protection. The depth of soil over bedrock is between 520 ft and 880 ft below the surface of the site (Reference 9).

3.2.10.1.8 Soil-Structure Interaction

Soil-structure interaction shall be considered in the design of soil-supported structures by including the effects of the soil properties established during the geotechnical investigation program and as represented by discrete soil springs or a finite element layered system as described in ANSI/ANS 57.9, Appendix C.

Soil boring logs and soil properties of the PFSF site are contained in Chapter 2, Appendix 2A.

3.2.10.2 Seismic-System Analysis

3.2.10.2.1 Seismic Analysis Methods

Seismic analysis methods shall be in accordance with standard practices and methods as described in ANSI/ANS 57.9, NUREG-0800, ASCE-4 (Reference 14), and others referenced herein.

The seismic response of each structure shall be determined by preparing a mathematical model of the structure and calculating the response of the model to the prescribed seismic input.

The HI-STORM storage system seismic analysis methods are described in the HI-STORM SAR, Section 11.2.1. The TranStor storage system seismic analysis methods are described in the TranStor SAR, Section 11.2.5. Site-specific cask stability analysis shall be performed to account for the site-specific seismic response spectra curves, soil-structure interaction, and the actual PFSF pad size and arrangement.

The concrete storage pads shall be analyzed with a dynamic seismic time history analysis using a finite element model with soil-structure interaction considered by the use of dynamic soil springs. Various combinations of cask placements shall be considered to determine the controlling load case.

The Canister Transfer Building shall be analyzed for seismic loads using a modal response spectrum analysis and considering soil-structure interaction.

The overhead bridge and semi-gantry cranes shall be analyzed considering the Maximum Critical Load (maximum lifted load whose uncontrolled movement or release could adversely affect the operation of SSCs classified as Important to Safety) in combination with a seismic event in accordance with NUREG-0554 (Reference 15). A set of amplified response spectra curves at the crane rail locations shall be developed for use in the crane seismic analysis and design.

3.2.10.2.2 Natural Frequencies and Response Loads

The modal analysis considers the natural frequency of the system as well as the other significant modes of vibration. Response loads are determined from the appropriate response spectra at the calculated frequencies.

3.2.10.2.3 Procedure Used to Lump Masses

The inertial mass properties of each structure shall be modeled using the discretization of mass formulation whereby the structural mass and associated rotational inertia are discretized and lumped at node points of the model. Node points where masses are lumped shall be located at the center of gravity of the member or component represented in the model.

3.2.10.2.4 Rocking and Translational Response Summary

Rocking and translational response shall be modeled by including equivalent rocking and translational soil springs in accordance with the spring constants described in Table 3300-2 of ASCE-4.

3.2.10.2.5 Methods Used to Couple Soil with Seismic-System Structures

The soil can be represented by discrete springs or a finite element model to represent the soil substratum.

3.2.10.2.6 Methods Used to Account for Torsional Effects

The storage pads and the Canister Transfer Building shall be modeled and analyzed as 3-dimensional multimass systems. Therefore, torsional effects due to eccentricities of the mass are taken into account in the analysis.

3.2.10.2.7 Methods for Seismic Analysis of Dams

There are no dams onsite or in the immediate area.

3.2.10.2.8 Methods to Determine Overturning Moments

Overturning stability shall be assured for the storage casks on the pads.

Overturning stability of loaded concrete casks located on the storage pad shall be proved by both storage system vendors with a dynamic analysis using the site-specific seismic design parameters and considering soil-structure interaction.

3.2.10.2.9 Analysis Procedure for Damping

Critical damping values shall be developed in accordance with Regulatory Guide 1.61 for a SSE.

3.2.10.2.10 Seismic Analysis of Overhead Cranes

The overhead bridge and semi-gantry cranes shall be analyzed for seismic effects in accordance with the requirements of NUREG-0554 for single-failure-proof cranes. The seismic analysis of the cranes shall include the Maximum Critical Load in the lifted position during a seismic event. The seismic analysis methods shall be in accordance with ASME NOG-1 (Reference 16). A set of amplified response spectra curves at the crane rail locations shall be developed for use in the crane seismic analysis and design.

3.2.10.2.11 Seismic Analysis of Specific Safety Features

SSCs classified as Important to Safety shall meet the requirements of 10 CFR 72.122(b)(2), which requires SSCs be designed such that a design earthquake will not result in an uncontrolled release of radioactive material or increased radiation exposure to workers or members of the general public.

3.2.11 Combined Load Criteria

The design shall consider all appropriate loads and load combinations as required by the specific SSC design code(s). Design loads shall be determined from normal, off-normal, and accident-level conditions. Design loads shall be combined to simulate the most adverse load conditions

3.2.11.1 HI-STORM Storage System Load Combinations

Loads and load combinations used in the design of the HI-STORM 100 Cask System are identified in the HI-STORM SAR, Sections 2.2.7 and 3.1.2.1.2. Exceptions to the various code criteria is shown in HI-STORM SAR, Table 2.2.15.

HI-STORM Canister

The canister shell and internals are required by the HI-STORM SAR to be designed to the applicable requirements of Subsections NB and NG of the ASME BPVC, Section III (Reference 17). The load combinations for all normal, off-normal and accident conditions and corresponding Service Levels of the canister design are as follows:

<u>ASME Design</u>

P_i or P_o (ASME BPVC pressure design)

<u>Normal Conditions</u> (ASME Service Level A)

$D + T + P_i + H$

$D + T + P_o + H$

<u>Off-Normal Conditions</u> (ASME Service Level B)

$D + T' + H + (P_i' \text{ or } P_o')$

<u>Accident-Level Conditions</u> (ASME Service Level D)

$D + T + P_i + H'$

$D + T + (P_i^* \text{ or } P_o^*)$

Where:

D	=	Dead Load
T	=	Thermal (normal operating temperature)
T′	=	Thermal (off-normal temperature)
P_i	=	Normal Internal Pressure
P_o	=	Normal External Pressure
P_i'	=	Off-normal Internal Pressure
P_o'	=	Off-normal Exterior Pressure
P_i^*	=	Accident Internal Pressure
P_o^*	=	Accident External Pressure
H	=	Normal Handling Loads
H′	=	Accident-Level Handling Load (drop)

The number of load combinations was reduced by defining the internal and external pressures (P_i and P_o) such that they bound other surface-intensive loads of snow, tornado wind, flood, and explosion.

The stress intensity limits for the canister confinement boundary (governed by Subsection NB of the ASME BPVC, Section III) and the canister internals (governed by Subsection NG of the ASME BPVC, Section III) are shown in Table 3.2-1.

The damaged fuel container is governed by Subsection NF for normal conditions of the ASME BVPC, Section III.

HI-STORM Storage Cask and HI-TRAC Transfer Cask

The load combinations for the HI-STORM storage cask, canister, and HI-TRAC transfer cask under normal, off-normal, and accident conditions are as follows:

Normal Conditions (ASME Service Level A)

D + T + H

Off-Normal Conditions (ASME Service Level B)

D + T′ + H

Accident-Level Conditions (ASME Service Level D)

D + T + H′

D + T + (E or F or W′ + M) (storage cask only)

Where:

D	=	Dead Load
T	=	Thermal (normal operating temperature)
T′	=	Thermal (off-normal temperature)
H	=	Normal Handling Loads
H′	=	Accident-Level Handling Load (drop)
E	=	Earthquake
F	=	Flood (not applicable to this site)

W' = Tornado wind

M = Tornado Missile Loads

The stress intensity limits for the steel structure of the HI-STORM storage cask and HI-TRAC transfer cask (governed by Subsection NF of the ASME BPVC, Section III for plate and shell components) are shown in Table 3.2-2. Limits for the Level D condition are obtained from Appendix F of the ASME BPVC, Section III for the steel structure of the storage cask. The storage cask concrete structure is design is governed by ACI-349.

The ASME BPVC is not applicable to the HI-TRAC transfer cask for accident conditions, service level D conditions. The HI-TRAC cask shall be shown by analysis to not deform and cause an applied load to the canister, have any shell rupture, or have the top lid or transfer lid detach. The HI-TRAC lifting trunnion design is governed by ANSI N14.6.

3.2.11.2 TranStor Storage System Load Combinations

Loads and load combinations used in the design of the TranStor Storage Cask System are identified in the TranStor SAR, Section 2.2.7. The TranStor storage cask system is subjected to normal, off-normal, and accident loads and events. These loads and events are defined as follows:

Normal	Dead Weight, Pressure, Handling, Thermal, Snow, Winds, Rain.
Off-Normal	Severe Environmental Conditions, Surface Contamination, Interference During Basket Lowering From Transfer Cask to Storage Cask, Blockage of One-Half of Air Inlets, Off-Normal Handling
Accident	Complete Blockage of Air Inlets, Maximum Heat Load, Fuel Pin Rupture, Tornado (wind and missiles), Flood, Seismic, Explosion, Hypothetical Tipover

TranStor Canister

The canister shell and internals are designed to the applicable requirements of ASME BPVC, Section III, Division 1, Subsections NC and NG. The load combinations for all normal, off-normal and accident conditions and corresponding Service Levels of the canister design are as follows:

Normal Conditions (ASME Service Level A)

$D + T_1 + P$

$D + T_2 + P + H_1$

$D + T_1 + P + H_1$

Off-Normal Conditions (ASME Service Level B and C)

$D + T_3 + P$ (Service Level B)

$D + (T_1 \text{ or } T_2 \text{ or } T_3) + P + H_2$

Accident-Level Conditions (ASME Service Level D)

$D + T_1 + P + (A \text{ or } E \text{ or } F \text{ or } W_t)$

$D + (T_1 \text{ or } T_2) + P_a + H_1$

$D + T_4 + P$

Where:

D	=	Dead Load (Canister w/ fuel)
T_1	=	Thermal (inside storage cask = 75°F)
T_2	=	Thermal (inside transfer cask = 75°F)
T_3	=	Thermal (inside storage cask = -40°F or 100°F)
T_4	=	Thermal (inside storage cask = max heat load of 125°F)
P	=	Normal Pressure
P_a	=	Accident Pressure
H_1	=	Normal Handling
H_2	=	Off-normal Handling

A = Drop or cask Tipover

E = Earthquake

F = Flood (not applicable to this site)

W_t = Tornado wind and missile loads

The analytical methods allowed by the ASME Code shall be employed. Stress intensities caused by pressure, temperature, and mechanical loads are combined before comparing to ASME code allowables.

In addition, the canister is classified as a special lifting device and designed to the requirements of ANSI N14.6 and NUREG 0612. The lifting criteria are:

Maximum Principal stress during the lift (with 10% dynamic load factor) $\leq$ (S_y/6 or S_u/10) for non-redundant load path or (S_y/3 or S_u/5) for redundant load path.

The structural design criteria are summarized in Table 3.2-3.

<u>TranStor Storage Cask</u>

Normal loads due to pressure, temperature, and dead weight act in combination with all other loads. No two accident events were postulated to occur simultaneously. However, loads due to one event, such as tornado wind and tornado missile loads, were assumed to act in direct combination.

The load combinations specified in ANSI 57.9 for concrete structures and ACI 349 are used as follows:

Normal Conditions

$U_c > 1.4D + 1.7L$

Off-Normal Conditions

$U_c > 0.75\ (1.4D + 1.7L + 1.7T + 1.7W)$

Accident-Level Conditions

$U_c > D + L + T + (E \text{ or } A \text{ or } W_t)$

$U_c > D + L + T_a$

Where:

U_c	=	Minimum available strength capacity of a cross section or member calculated per the requirements and assumptions of ACI-349
D	=	Dead load
L	=	Live load
W	=	Wind loads
W_t	=	Tornado wind and missile loads
E	=	ISFSI Design Earthquake load
T	=	Thermal loads
T_a	=	Accident-level thermal loads
A	=	Accident loads

There are no loads associated with liquid or soil pressure on the cask, therefore the terms F and H in ACI-349 are not included. The ACI-349 design rules are used to demonstrate the structural adequacy of reinforced concrete in the storage cask. The steel liner and air ducts of the storage cask are stay-in-place forms and radiation shielding.

TranStor Transfer Cask

The transfer cask is a special lifting device and is designed and fabricated to the requirements of ANSI N14.6 and NUREG 0612 for the load path components. The design criteria are:

Maximum Principal stress during the lift (with 10% dynamic load factor) $\leq$ (S_y/6 or S_u/10) for non-redundant load path or (S_y/3 or S_u/5) for redundant load path.

Load bearing members of the transfer cask are subjected to Charpy impact testing per ANSI N14.6, as discussed in TranStor SAR Section 3.4.5.

3.2.11.3 Cask Storage Pad Load Combinations

The cask storage pads shall be conventional mat foundations of reinforced concrete construction.

Loads and load combinations used in the design of the concrete storage pads shall be in accordance with ANSI/ANS 57.9 and ACI-349 (Reference 18) and shall include skip loading conditions to account for incremental cask placement.

Load factors and allowable stresses used in the design shall be in accordance with ACI-349.

The concrete storage pad design shall consider the following load combinations as included in, or derived from, ANSI/ANS 57.9 and ACI-349:

Normal Conditions

$U_c > 1.4D + 1.7L$

$U_c > 1.4D + 1.7L + 1.7H$

Off-Normal Conditions

$U_c > 0.75\ (1.4D + 1.7L + 1.7H + 1.7T)$

$U_c > 0.75\ (1.4D + 1.7L + 1.7H + 1.7T + 1.7W)$

Accident-Level Conditions

$U_c > D + L + H + T + (E \text{ or } A \text{ or } W_t \text{ or } F)$

$U_c > D + L + H + T_a$

Where:

U_c = Minimum available strength capacity of a cross section or member calculated per the requirements and assumptions of ACI-349

D = Dead load

L = Live load

H = Lateral soil pressure

W = Wind loads

W_t = Tornado wind and missile loads

E = ISFSI Design Earthquake load

T = Thermal loads

T_a = Accident-level thermal loads

A = Accident loads

F = Flood loads (not applicable to this site)

The allowable soil bearing pressures beneath the cask storage pad are described in Section 2.6.1.12.

The maximum storage pad stiffness shall be limited to 30.65 E6 lb/inch, which assures that accelerations resulting from a hypothetical tipover or vertical end drop from a height of 10 inches, for a HI-STORM storage cask, are limited to a 45 g design basis acceleration.

3.2.11.4 Canister Transfer Building Load Combinations

3.2.11.4.1 Canister Transfer Building Structure

The Canister Transfer Building is a reinforced concrete and steel structure. The design of the structure shall be in accordance with the ANSI/ANS 57.9, ACI-349, and ANSI/AISC N690 (Reference 19). Load factors and allowable stresses used in the design shall be in accordance with ACI-349 and ANSI/AISC N690.

The design of the reinforced concrete portions of the structure shall consider the following load combinations as included or derived from ANSI/ANS 57.9 and ACI 349:

Normal Conditions

$U_c > 1.4D + 1.7L$

$U_c > 1.4D + 1.7L + 1.7H$

Off-Normal Conditions

$U_c > 0.75\ (1.4D + 1.7L + 1.7H + 1.7T)$

$U_c > 0.75\ (1.4D + 1.7L + 1.7H + 1.7T + 1.7W)$

Accident-Level Conditions

$U_c > D + L + H + T + (E \text{ or } A \text{ or } W_t \text{ or } F)$

$U_c > D + L + H + T_a$

Where:

U_c = Minimum available strength capacity of a cross section or member calculated per the requirements and assumptions of ACI-349

D = Dead load

L = Live load

H = Lateral soil pressure

W = Wind loads

W_t = Tornado wind and missile loads

E = ISFSI Design Earthquake load

T = Thermal loads

T_a = Accident-level thermal loads

A = Accident loads

F = Flood loads (not applicable to this site)

Live load shall include crane loads in accordance with ASME NOG-1 positioned to create a worst-case loading condition. All appropriate load combinations identified in ASME NOG-1, as shown in Section 3.2.12.4 herein, shall also be considered in the building design.

The design of the structural steel portions of the Canister Transfer Building shall consider the following load combinations as included or derived from ANSI/ANS 57.9 and the ANSI/AISC N690:

Normal Conditions

S and $S_v > D + L$ or $D + L + H$

Off-Normal Conditions

$1.3\,(S \text{ and } S_v) > D + L + H + W$

$1.5S > D + L + H + T + W$

$1.4\,S_v > D + L + H + T + W$

Accident-Level Conditions

$1.6S > D + L + H + T + (E \text{ or } W_t \text{ or } F)$

$1.4\ S_v > D + L + H + T + (E \text{ or } W_t \text{ or } F \text{ or } A)$

$1.7S > D + L + H + (T + A) \text{ or } T_a$

$1.4\ S_v > D + L + H + T_a$

Where:

S	=	Strength of a section, member, or connection calculated in accordance with ANSI/AISC N690
S_v	=	Shear strength of a section, member, or connection calculated in accordance with ANSI/AISC N690
D	=	Dead load
L	=	Live load
W	=	Wind load
W_t	=	Tornado wind and missile loads
E	=	ISFSI Design Earthquake load
F	=	Flood loads (not applicable to this site)
T	=	Thermal load
A	=	Loads due to a drop of a heavy load (not applicable to this project)
H	=	Lateral soil pressure (not applicable to building steel)
T_a	=	Off-normal thermal (not applicable to building steel)

Live load shall include crane loads in accordance with ASME NOG-1 positioned to create a worst-case loading condition. All appropriate load combinations identified in ASME NOG-1, as shown in Section 3.2.12.4 herein, shall also be considered in the building design.

3.2.11.4.2 Canister Transfer Building Foundation

The foundation for the Canister Transfer Building shall be conventional spread footings of reinforced concrete construction.

Loads and load combinations used in the design of foundations shall be in accordance with ANSI/ANS 57.9 and ACI-349 and shall include crane loads positioned to create a worst-case loading condition.

Load factors and allowable stresses used in the design shall be in accordance with ACI-349.

Foundation design for the Canister Transfer Building shall consider the following load combinations per ANSI/ANS 57.9:

Normal Conditions

$U_f > 1.4D + 1.7\,L + 1.7G$

$U_f > 1.4D + 1.7L + 1.7H + 1.7G$

Off-Normal Conditions

$U_f > 0.75\,(1.4D + 1.7L + 1.7H + 1.7T + 1.7G)$

$U_f > 0.75\,(1.4D + 1.7L + 1.7H + 1.7T + 1.7W + 1.7G)$

Accident-Level Conditions

$U_f > D + L + H + T + G + (E \text{ or } A \text{ or } W_t \text{ or } F)$

$U_f > D + L + H + T_a + G$

Where:

U_f = Minimum available strength capacity of a foundation cross section or member calculated in accordance with the requirements and assumptions of ACI-349

D = Dead load

L = Live load

G = Function of required minimum soil capacity

H = Lateral soil pressure

W = Wind loads

W_t = Tornado wind and missile loads

E = ISFSI Design Earthquake load

T = Thermal loads

T_a = Accident-level thermal loads

A = Accident loads

F = Flood loads (not applicable to this site)

Live load shall include crane loads in accordance with ASME NOG-1 positioned to create a worst-case loading condition. All appropriate load combinations identified in ASME NOG-1 shall also be considered in the foundation design.

Allowable soil pressure shall be determined based on the type of foundation, whether strip or square, and the size of the foundation as shown in Tables 2.6-10 and 2.6-11. Section 2.6.1.12 provides further discussion.

Foundations shall be founded at a minimum depth of 2 ft 6 inches below frost grade for frost protection in accordance with the PFSF Geotechnical Design Criteria (Reference 9).

3.2.11.5 Canister Transfer Crane Load Combinations

The canister transfer cranes (overhead bridge crane and the semi-gantry crane) shall be classified as a Type I cranes in accordance with ASME NOG-1 since the cranes are used to handle critical loads. A Type I crane is defined as a crane that is designed and constructed to remain in place and support a critical load during and after a seismic event and has single-failure-proof features such that any credible failure of a single component will not result in the loss of capability to stop and/or hold the critical load. A critical load is defined as any lifted load whose uncontrolled movement or release could result in potential offsite radiation exposure. The single-failure-proof crane design shall meet the requirements of NUREG-0554, NUREG-0612 (Reference 20), and ASME NOG-1.

The canister transfer cranes shall be designed in accordance with the following load combinations per ASME NOG-1.

Normal Conditions

$$P_c = P_{db} + P_{dt} + (P_{lr} \text{ or } P_p)$$

$$P_c = P_{db} + P_{dt} + P_{lr} + (P_v \text{ or } P_{ht} \text{ or } P_{hl}) + P_{wo}$$

Off-Normal Conditions

$$P_c = P_{db} + P_{dt} + P_a + P_{wo}$$

Accident-Level Conditions

$$P_c = P_{db} + P_{dt} + P_{cs} + P_e + P_{wo}$$

$$P_c = P_{db} + P_{dt} + P_e + P_{wo}$$

$$P_c = P_{db} + P_{dt} + P_{wt}$$

Where:

P_c = Load combination
P_{db} = Bridge dead load
P_{dt} = Trolley dead load
P_{lr} = Design rated lift load
P_p = Facility operation induced loads transmitted to crane
P_v = Vertical impact loads
P_{ht} = Transverse horizontal load
P_{hl} = Longitudinal horizontal load
P_{wo} = Crane wind load (not applicable inside Canister Transfer Building)
P_a = Abnormal (off-normal) event load
P_{cs} = Credible critical load with IFSFI DE (or SSE) load
P_e = ISFSI DE (or SSE) load
P_{wt} = Tornado wind load (not applicable inside Canister Transfer Building)

Extreme environmental loads shall include the SSE as being equal to the ISFSI DE. The Operating Basis Earthquake (OBE) is not applicable for the PFSF design.
The Maximum Critical Load, noted in NUREG-0554, shall be equal to the crane design capacity (200 tons for the overhead bridge crane and 150 for the semi-gantry crane) and shall be used as the basis for the credible critical load determined per ASME NOG-1.

The canister transfer cranes shall be designed using a response spectrum dynamic seismic analysis as described in ASME NOG-1, Section 4150. The analysis shall be performed by the crane vendor and shall include the development of amplified response spectrum (horizontal and vertical) at the crane rail elevation of the Canister Transfer Building. The amplified response spectrum shall be based on the site response spectrum (Appendix 2D, Figure 4-8) as modified by the effects of the soil-structure interaction and response of the Canister Transfer Building.

Allowable stresses used in the crane designs shall be in accordance with ASME NOG-1.

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3.3 SAFETY PROTECTION SYSTEMS

3.3.1 General

The PFSF shall be designed for safe containment and storage of the spent fuel. The PFSF shall withstand normal, off-normal, and postulated accident conditions without release of radioactive material. The major design elements that assure that the safety objectives are met are the HI-STORM and TranStor storage systems, the cask storage pads, the Canister Transfer Building, and the canister transfer cranes.

The primary safety functions of the HI-STORM and TranStor storage system principal components (canister, concrete storage cask, and transfer cask) are as follows:

1. Canister

   - Provides confinement of the spent nuclear fuel and associated radioactive material.
   - Provides criticality control.
   - Provides heat transfer capability so that the fuel clad temperature does not exceed allowables.
   - Provides radiation shielding (together with a concrete cask or transfer cask).

2. Concrete storage cask

   - Protects the canister from weather and postulated environmental events such as earthquakes and tornado missiles.
   - Facilitates heat transfer (ventilated) of the canister.
   - Provides radiation shielding.

3. Transfer cask

- Serves as a special transfer and lifting device for movement of the spent fuel canister.
- Provides physical protection of the canister during canister transfer operations.
- Provides radiation shielding to minimize exposure rates during transfer operations.
- Facilitates heat transfer of the canister.

The primary safety function of the cask storage pads is to:

- Provide a stable and level surface for the concrete storage casks.
- Provide required yielding for drop/tipover of the storage casks.

The primary safety functions of the Canister Transfer Building are to:

- Provide tornado and wind protection during transfer operations.
- Provide protection from tornado-generated missiles.
- Provide radiation shielding during transfer operations.
- Provide the support for the canister transfer cranes.
- Provides fire suppression

The primary safety function of the overhead bridge and semi-gantry cranes is to:

- Provide the single-failure-proof lifting capability for shipping cask load/unload operations and canister transfer operations.

As discussed in the following sub-sections, the PFSF design shall incorporate design features addressing each of the above functions to assure safe execution of PFSF operations.

3.3.2 Protection By Multiple Confinement Barriers and Systems

This section of the principal design criteria establishes requirements that satisfy 10 CFR 72.122(h), which identifies general design criteria requirements to protect and confine the spent fuel.

3.3.2.1 Confinement Barriers and Systems

The primary confinement barrier for spent nuclear fuel is the canister. The canister is required to maintain confinement for normal storage conditions and all postulated accidents with the protection of the concrete storage cask or transfer cask.

The canister shall be designed to provide a confinement barrier for spent nuclear fuel. The canister confinement barrier shall be designed in accordance with ASME Boiler and Pressure Vessel Code, Section III.

The canister internals, which are used to constrain fuel assemblies during storage, shall be designed in accordance with ASME Section III, Subsection NG.

The canister shall be designed to withstand credible drop accidents (drops less than 10 inches while in the storage cask) without impairing fuel retrievability. The canister shall also be designed to maintain leak tightness and ensure that there is no leakage of radioactive material under all postulated loading conditions.

3.3.2.2 Ventilation Offgas

There are no ventilation offgas systems at the PFSF. The welded sealed canister precludes the need for offgas systems.

3.3.3 Protection by Equipment and Instrumentation Selection

3.3.3.1 Equipment

The SSCs that have been identified as Important to Safety, per Section 3.4, for the PFSF are:

- HI-STORM 100 Cask System canister, concrete storage cask, transfer cask, and lifting devices.
- TranStor Storage Cask System canister, concrete storage cask, transfer cask, and lifting devices.
- Cask Storage Pads.
- Canister Transfer Building.
- Canister Transfer Cranes (overhead bridge and semi-gantry).

The design criteria for these components are summarized in Section 3.6.

3.3.3.2 Instrumentation

This section of the principal design criteria establishes requirements that satisfy 10 CFR 72.122(i), which identifies general design criteria that requires instrumentation and control systems be provided to monitor systems that are classified as Important to Safety. These systems shall be monitored over the anticipated ranges for normal and off-normal operation.

Temperature monitors shall be installed to monitor the air outlet or concrete lid temperature of the loaded storage casks.

Radiation monitors shall be utilized during the canister transfer process to ensure occupational exposures are within 10 CFR 20 limits and during the storage process to ensure that doses to the public are within 10 CFR 72.104 limits.

The canister transfer cranes shall be provided with limit switches to assure bridge and trolley movements are within acceptable limits and load cells to assure the lifted load does not exceed the crane capacity.

3.3.4 Nuclear Criticality Safety

This section of the principal design criteria establishes requirements that satisfy 10 CFR 72.124(a) and (b), which identifies general design criteria that requires handling, transfer, and storage systems be designed for nuclear criticality safety. These systems shall be designed to maintain subcriticality such that K_{eff} remain below 0.95 under all conditions (i.e., normal handling, off-normal handling, storage, and postulated accidents) as recommended by NUREG-1536 (Reference 21). All canisters arriving at the PFSF shall be in the dry condition (i.e., no moderator).

3.3.4.1 Control Methods for Prevention of Criticality

Subcritical conditions shall be maintained by the canister internal geometry, which establishes fuel assembly separation. Poison plates are included in the canister basket design to meet the requirements of 10 CFR 71, however, no credit shall be taken for the poison plates since it is assumed there is no moderator (i.e. dry). The design shall assume a fuel assembly enrichment equal to or greater than the maximum initial fuel assembly enrichment that will be stored. No credit shall be taken for burnup.

3.3.4.2 Error Contingency Criteria

The values of K_{eff} shall include error contingencies and calculational and modeling biases. K_{eff} shall equal the calculated K_{eff} plus criticality code bias, plus two times sigma uncertainty to yield a 95 percent statistical confidence level.

3.3.4.3 Verification Analysis

The model used for calculating K_{eff} shall be an NRC approved computer program. Models not previously approved shall be verified by comparison to benchmark experimental data.

3.3.5 Radiological Protection

This section of the principal design criteria establishes requirements that satisfy 10 CFR 72.126(a), which identifies general design criteria that requires radiation protection systems (including SSC design, location, shielding, and testing) be provided to minimize personnel radiation exposure; 10 CFR 72.126(b), which identifies general design criteria that requires alarm systems be provided to warn personnel of abnormally high radiation concentrations; and 10 CFR 72.126(c), which identifies general design criteria that requires a means to measure and monitor radioactive effluents and direction radiation be provided.

Provisions for radiological protection by confinement barriers and systems are described in Section 3.3.2.1. Additional radiological protection design criteria is presented in the following sections.

3.3.5.1 Access Control

The boundary of the Restricted Area (RA) of the PFSF shall be determined such that the dose to any individual outside the RA will not exceed 2 mrem/hr in accordance with 10 CFR 20.1301. Access to the RA shall be normally limited to those individuals performing canister transfer or storage cask placement operations, maintenance and surveillance activities, and security functions. Personnel entering the RA shall be required to wear dosimetry.

Thermoluminecent dosimeters (TLDs) shall be located at the perimeter of the RA and owner controlled area (OCA) and shall be monitored on a periodic basis. The OCA boundary shall be determined such that (1) the annual dose equivalent to any real individual located beyond the boundary will not exceed 25 mrem/yr whole body and 75 mrem/yr thyroid for normal operation in accordance with 10 CFR 72.104 and (2) the dose to any individual located on or beyond the nearest boundary will not exceed 5 rem to the whole body or any organ from a design basis accident in accordance with 10 CFR 72.106.

3.3.5.2 Shielding

Radiation shielding shall be provided to help ensure that dose rates are maintained As-Low-As-Reasonably-Achievable (ALARA) during transfer operations and storage periods. The storage and transfer casks shall provide most of the required shielding. Temporary shielding shall be used where necessary to reduce doses and maintain ALARA. The Canister Transfer Building and Security and Health Physics Building shall also be designed to include radiation shielding. The Administration Building and Operations and Maintenance Building shall be located remotely from the storage area to avoid unnecessary doses to administrative personnel.

The maximum doses to individual members of the public are defined by the RA and OCA boundaries as shown in Section 3.3.5.1 above. Estimates of off-site collective doses at the RA and OCA boundary are addressed in Section 7.3.3.5.

The maximum total effective dose equivalent (TEDE) for personnel working at the PFSF shall not exceed 5 rem/year in accordance with 10 CFR 20.1201. Estimates of on-site collective doses for various PFSF operations are addressed in Section 7.4.

3.3.5.3 Radiological Alarm Systems

There are no credible events that could result in releases of radioactive products from inside the canister to any effluents or unacceptable increases in direct radiation. In addition, the releases postulated as the result of the hypothetical accidents described in Chapter 8 are of a very small magnitude. However, area radiation monitors with audible alarms shall be provided in the Canister Transfer Building for canister transfer operations.

3.3.6 Fire and Explosion Protection

This section of the principal design criteria establishes requirements that satisfy 10 CFR 72.122(c), which identifies general design criteria that requires SSCs classified as Important to Safety be designed and located so they can continue to perform their safety functions effectively under credible fire and explosion exposure conditions.

The PFSF shall be an open gravel surfaced area. No combustible material of any consequence shall be stored at the PFSF. The quantity of fuel carried in the cask transporter shall be limited by the size of the fuel tank to a relatively small amount, so that only a small fire of short duration would be possible near any casks located on the pads or in a canister transfer cell. The quantity of fuel carried in the heavy haul tractor/trailer unit, if used, shall also be limited by the size of the fuel tank to minimize a potential fire duration in the Canister Transfer Building load/unload bay. If railroad transport is provided to the PFSF, either the railroad locomotive fuel tank shall be limited in size or the railroad locomotive shall not be allowed in the Canister Transfer Building to prevent the possibility of a fire in the building from the large quantity of fuel in the locomotive. The design for the SSCs shall encompass any temperature gradients resulting from a fire from these scenarios.

Determination of overpressure conditions due to explosions at the PFSF shall be in accordance with Regulatory Guide 1.91 (Reference 22). Per Regulatory Guide 1.91, a 1 psi overpressure would be produced by a detonation of the following quantities of explosives at the approximate distances shown:

Mode of Transport	Amount of Hazardous Cargo	At a Distance of
Highway Truck	50,000 lb	1660 ft
Railroad Car	132,000 lb	2290 ft
River Vessel	10,000,000 lb	10,000 ft

Since the distances from the PFSF to the nearest highway, railroad, and river exceeds the distances shown above for a 1 psi overpressure, the SSCs are not required to be designed for explosives.

3.3.7 Materials Handling and Storage

This section of the principal design criteria establishes requirements that satisfy 10 CFR 72.128(a) and (b), which identify general design criteria that requires spent fuel storage and handling equipment be designed to ensure adequate safety under normal and accident conditions and that radioactive waste treatment facilities be provided.

This section also establishes requirements that satisfy 10 CFR 72.122(l), which identifies general design criteria that requires the storage system be designed to allow ready retrieval of the spent fuel for shipping offsite.

3.3.7.1 Spent Fuel Handling and Storage

All spent fuel handling and storage at the PFSF shall be performed with the spent fuel contained in the sealed metal canister. The design for handling and storage components shall ensure that the spent fuel canister confinement integrity is maintained.

The design shall ensure that handling components can safely be used to retrieve canisters from the storage casks and load them into shipping casks for shipment offsite throughout the life of the PFSF.

3.3.7.2 Radioactive Waste Treatment

Since the spent fuel is contained in the sealed metal canister, there is expected to be negligible radioactive contamination at the PFSF. The PFSF shall include provisions to package and store health physics survey material and dry wipes used to remove contamination in the event some minor radioactive contamination is found.

3.3.7.3 Waste Storage Facilities

A low level waste (LLW) holding cell shall be provided to store health physics survey material and dry wipes used to remove contamination check casks for radioactive contamination. The holding cell shall be designed to maintain ALARA and store a few LLW containers until the LLW is shipped offsite. No other waste storage facilities are required at the PFSF.

3.3.8 Industrial and Chemical Safety

Spent fuel canister transfer operations at the PFSF shall be performed in accordance with 29 CFR 1910.179 (Reference 23), which is an Occupational Safety and Health (OSHA) Standard for operating overhead and gantry cranes.

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3.4 CLASSIFICATION OF STRUCTURES, SYSTEMS, AND COMPONENTS

The SSCs of the PFSF are classified as Important to Safety or Not Important to Safety. A tabulation of the SSCs by their classification is shown in Table 3.4-1. The criteria for selecting the classification for particular SSCs are based on the following definitions:

Important to Safety

A classification per 10 CFR 72.3 for any structure, system, or component whose function is to maintain the conditions required to safely store spent fuel, prevent damage to spent fuel containers during handling and storage, and provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

Not Important to Safety

A quality classification for items or services that do not have a safety related function and that are not subject to special utility requirements or NRC imposed regulatory requirements.

SSCs classified as Important to Safety shall be designed, constructed, and tested in accordance with the Quality Assurance (QA) Program described in Chapter 11. The level of importance to safety for each SSC shall be based on QA classification categories as detailed in NUREG/CR-6407 (Reference 24). The classifications are intended to standardize the QA control applied to activities involving spent fuel storage systems. These classifications are defined as follows:

Classification Category A - Critical to Safe Operation

Category A items include SSCs whose failure or malfunction could directly result in a condition adversely affecting public health and safety. The failure of a single item could cause loss of primary containment leading to release of radioactive material, loss of shielding, or unsafe geometry compromising criticality control.

Classification Category B - Major Impact on Safety

Category B items include SSCs whose failure or malfunction could indirectly result in a condition adversely affecting public health and safety. The failure of a Category B item, in conjunction with the failure of an additional item, could result in an unsafe condition.

Classification Category C - Minor Impact on Safety

Category C items include SSCs whose failure or malfunction would not significantly reduce the packaging effectiveness and would not be likely to create a situation adversely affecting public health and safety.

The QA determination for the SSCs that are classified as Important to Safety are discussed in the following sections. A QA classification for these SSCs establishes the requirements that satisfy 10 CFR 72.122(a) general design criteria, which specifies SSCs Important to Safety be designed, fabricated, erected, and tested to quality standards

3.4.1 Spent Fuel Storage Systems

3.4.1.1 Canister

The canister is classified as Important to Safety, Classification Category A since it serves as the primary confinement structure for the fuel assemblies and is designed to remain intact under all accident conditions analyzed in Chapter 8.

3.4.1.2 Concrete Storage Cask

The storage cask is classified as Important to Safety, Classification Category B since it is designed to remain intact under all accident conditions analyzed in Chapter 8 and serves as the primary component for protecting the canister during storage and provide radiation shielding and canister heat rejection.

3.4.1.3 Transfer Cask

The transfer cask is classified as Important to Safety, Classification Category B since it is designed to support the canister during transfer lift operations and provide radiation shielding and canister heat rejection.

3.4.1.4 Lifting Devices

The lifting devices (lift yoke, trunnions, and canister lift attachments) are classified as Important to Safety, Classification B to preclude the accidental drop of a canister.

3.4.2 Cask Storage Pads

The cask storage pads are classified as Important to Safety, Classification Category C to ensure a stable and level support surface for the storage cask under normal, off-normal, and accident-level conditions.

3.4.3 Canister Transfer Building

The Canister Transfer Building is classified as Important to Safety, Classification Category B to protect the canister from adverse natural phenomena during shipping cask load/unload operations and canister transfer operations. The building shall provide physical protection from tornado winds and missiles, radiological shielding inside to workers during transfer operations, and support for the canister transfer cranes.

3.4.4 Canister Transfer Cranes

The overhead bridge and semi-gantry canister transfer cranes are classified as Important to Safety, Classification Category B to preclude the accidental drop of a shipping cask without impact limiters during load/unload operations or canister during the canister transfer operations.

3.4.5 Design Criteria for Other SSCs Not Important to Safety

The design criteria for SSCs classified as Not Important to Safety, but which have security or operational importance, such as security systems, standby power systems, cask transport vehicles, flood prevention earthwork, fire protection systems, radiation monitoring systems, and temperature monitoring systems, are addressed in subsequent chapters of this SAR. These SSCs shall be required to comply with their applicable codes and standards to ensure compatibility with SSCs that are Important to Safety and to maintain a level of quality that shall ensure that they will mitigate the effects of off-normal or accident-level events as required.

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3.5 DECOMMISSIONING CONSIDERATIONS

This section of the principal design criteria satisfies 10 CFR 72.130, which requires provisions be made to facilitate decontamination of structures and equipment, minimize the quantity of radioactive wastes and contaminated equipment, and facilitate the removal of radioactive wastes and contaminated materials.

The PFSF shall be designed to facilitate safe and economical decommissioning activities in an expedient manner. Canister-based dry cask storage systems shall be used at the site because the canisters are designed to confine the spent fuel and facilitate its removal offsite. The spent fuel shall be sealed within the canister at the originating power plant to preclude contaminating other equipment and to enable the sealed canisters to be shipped and stored without having to open the canister or handle fuel assemblies. The PFSF shall be required to operate in a manner that supports decommissioning activities throughout the life of the facility.

The PFSF shall be designed to minimize the quantity of radioactive wastes generated and the amount of equipment that becomes contaminated. The canisters are not expected to have external surface contamination since measures are employed at the originating power plant to assure the external surfaces of the canisters are maintained in a clean condition. This minimizes the possibility of contaminating the Canister Transfer Building, canister transfer equipment, and storage casks. The Canister Transfer Building concrete floor, interior surfaces of the concrete transfer cells walls, and the low level waste holding cell shall be coated with paints or epoxy that accommodate and facilitate decontamination. Activation of the storage casks and concrete storage pads following long-term storage are expected to be negligible, allowing the release of the storage casks and pads as uncontrolled material. As canisters are shipped offsite and storage casks become available, the casks shall be reused for storage of any new incoming spent fuel canisters in order to minimize potential future waste.

The PFSF site will not use site drainage collection systems that would require decommissioning since there are no liquid effluents at the site.

Solid LLW created from health physics survey materials and dry decontamination shall be disposed of in LLW containers authorized for transport to a LLW disposal facility.

The PFSF shall be designed to facilitate the removal of radioactive wastes and contaminated materials. When the storage period for any particular canister of spent fuel is completed, the canister shall be transferred into a shipping cask and shipped offsite. The concrete storage cask shall then be surveyed, and any contamination or activation products removed for disposal as LLW. The design of the storage casks, with the internal surfaces completely lined with steel, facilitates any decontamination efforts which may be required. Storage Cask components which are determined to be below specified activation and contamination levels shall be segregated for disposal as uncontrolled material.

The fences, electrical support structures, and other storage area equipment will not require special decommissioning activities since no contamination is expected to be transferred to these structures.

The PFSF shall be designed and operated to maintain radiation exposures ALARA during all decommissioning and decontamination activities.

Further decommissioning considerations are addressed by the storage system vendors in Section 2.4 of the HI-STORM and TranStor SARs, and in Appendix B of the PFSF License Application, "Preliminary Decommissioning Plan."

3.6 SUMMARY OF DESIGN CRITERIA

A summary of design criteria is shown in Table 3.6-1. The table summarizes design parameters developed in this chapter, including the spent fuel stored at the PFSF site, and structural, thermal, radiation protection/shielding, criticality, and confinement design of the SSCs that are Important to Safety.

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3.7 REFERENCES

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4. ANSI/ANS 57.9, Design Criteria For An Independent Spent Fuel Storage Installation (Dry Storage Type), 1984.

5. Local Climatological Data, Annual Summary with Comparative Data for 1991, Salt Lake City, Utah, National Oceanic and Atmospheric Administration, National Environmental Satellite Data and Information Service, National Climatic Data Center, March 1992.

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18. ACI-349, Code Requirements for Nuclear Safety Related Concrete Structures, American Concrete Institute, 1990.

19. ANSI/AISC N690-1994, Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities, American Institute of Steel Construction, 1994.

20. NUREG-0612, Control of Heavy Loads at Nuclear Power Plants, U.S. Nuclear Regulatory Commission, 1980.

21. NUREG-1536, Standard Review Plan for Dry Cask Storage Systems, Nuclear Regulatory Commission, 1997.

22. Regulatory Guide 1.91, Evaluations of Explosions Postulated to Occur on Transportation Routes near Nuclear Power Plants, U.S. Nuclear Regulatory Commission, February 1978.

23. 29 CFR 1910.179, Overhead and Gantry Cranes, Occupational Safety and Health Standards (OSHA).

24. NUREG/CR-6407, (INEL-95/0551), Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety, 1996.

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TABLE 3.1-1

TYPES OF PWR FUEL THAT CAN BE STORED AT THE PFSF

ASSEMBLY CLASS	CLAD	HI-STORM	TRANSTOR
B&W 15x15	Zr	✓	✓
B&W 15x15 SS	SS	✓	✓
B&W 17x17	Zr		✓
CE 14x14	Zr	✓	✓
CE 14x14 ANF	Zr		✓
CE 15x15	Zr	✓	✓
CE 15x16	Zr		✓
CE 16x16	Zr	✓	✓
WE 14x14 Std.	Zr	✓	✓
WE 14x14 OFA	Zr	✓	
WE 14x14 SS	SS	✓	✓
WE 14x14 MOX	SS	✓	✓
WE 15x15 Std.	Zr	✓	✓
WE 15x15 OFA	Zr	✓	
WE 15x15 ANF	Zr	✓	✓
WE 15x15 SS	SS	✓	✓
WE 17x17 LOPAR (Std.)	Zr	✓	✓
WE 17x17 OFA	Zr	✓	✓
WE 17x17 ANF	Zr		✓
WE 17x17 Vantage 5H	Zr	✓	
WE 17x17 ANF SPC design	Zr	✓	
WE 17x18	SS		✓
All assm. not listed w/ int. enrich. & Burnup up to 4.4% & 60 GWD	Zr, SS		✓

ANF - Advanced Nuclear Fuel (also known under Exxon and Siemens Power Corp., SPC)
B&W - Babcock & Wilcox
CE - Combustion Engineering (also known under ABB)
LOPAR - Low parasitic fuel
MOX - Mixed Oxide Fuel
OFA - Optimized Fuel Assembly
SS - Stainless Steel
WE - Westinghouse Electric
Zr - Zircaloy

TABLE 3.1-2

TYPES OF BWR FUEL THAT CAN BE STORED AT THE PFSF

ASSEMBLY CLASS	CLAD	HI-STORM	TRANSTOR
GE 6x6	Zr	✓	✓
GE 6x6 ANF	Zr	✓	✓
GE 6x6 MOX	Zr	✓	
GE 7x7	Zr	✓	✓
GE 7x7 GE-2a	Zr	✓	✓
GE 7x7 GE 2b	Zr	✓	✓
GE 7x7 GE-3 (Improved)	Zr	✓	✓
GE 8x8 GE-4	Zr	✓	✓
GE 8x8 GE-5 (Retrofit)	Zr	✓	✓
GE 8x8 GE-9	Zr	✓	✓
GE 8x8 GE-10	Zr	✓	✓
GE 8x8 ANF	Zr	✓	✓
GE 8x8 PF	Zr	✓	
GE 9x9 GE-11	Zr	✓	✓
GE 9x9 ANF	Zr	✓	✓
GE 9x9 ANF 9X	Zr		✓
GE 10x10 AC	SS	✓	✓
GE 10x10 ANF	SS	✓	
GE 10x10 ABB SVEA-96	Zr	✓	✓
All assm. not listed w/ int. enrich. & Burnup up to 3.7% & 50 GWD	Zr or SS		✓

ABB - ABB Atom
AC - Allis Chamers
ANF - Advanced Nuclear Fuel (also known under Exxon and Siemens Power Corp., SPC)
GE - General Electric
MOX - Mixed Oxide Fuel
PF - Prototype fuel
SS - Stainless Steel
Zr - Zircaloy

TABLE 3.1-3
(Sheet 1 of 2)

PFSF BOUNDING DESIGN FUEL CHARACTERISTICS
(Based on vendor design capabilities)

HI-STORM

FUEL PARAMETER	PWR intact	BWR intact	PWR stainless steel	BWR stainless steel	BWR damaged fuel
Max. No. of Assemblies/Canister	24	68	24	68	68
Physical Characteristics					
Max. Assembly Width, in.	8.54	5.80	8.42	5.62	4.7
Max. Assembly Length, in.	176.8	176.2	138.8	102.5	135
Max. Assembly Weight, lb	1680	700	1421	400	400
Max. Active Fuel Length, in.	150	150	122	83	110
Fuel Clad Material	Zircaloy	Zircaloy	Stainless steel	Stainless steel	Zircaloy
Boral min. ^{10}B areal density (g/cm^2)	N/A	N/A	N/A	N/A	0.022
Thermal and Radiological Characteristics					
Max. Heat Generation (w)	1177	398.9	662.0	78.8	0.115
Max. Initial Enrichment (wt % U^{235})	Varies - See HI-STORM SAR Table 2.1.3	Varies See HI-STORM SAR Figure 2.1.2	4.0	4.0	2.7
Max. Burnup (GWD/MTU)	Varies - See HI-STORM SAR Figure 2.1.6	Varies - See HI-STORM SAR Figure 2.1.6	38	20	30
Min. Cooling Time (years)	Varies - See HI-STORM SAR Figure 2.1.6	Varies - See HI-STORM SAR Figure 2.1.6	8	10	18

TABLE 3.1-3
(Sheet 2 of 2)

PFSF BOUNDING DESIGN FUEL CHARACTERISTICS
(Based on vendor design capabilities)

TranStor

FUEL PARAMETER	Intact, failed, and partial assemblies, fuel debris[(1)]	
	PWR	BWR
Max. No. of Assemblies/Canister	24	61
Physical Characteristics		
Max. Assembly Length, in. (with or without control components)	178.25	178.25
Max. Assembly Weight, lb with or without channels or control components)	1680	700
Fuel Rod Clad Material	Zircaloy or Stainless	Zircaloy or Stainless
Thermal and Radiological Characteristics		
Max. Heat Generation (w)	1083	426
Max. Initial Enrichment (wt % U^{235})	Varies - See TranStor SAR Table 12.2-2 & 12.2-3	Varies - See TranStor SAR Table 12.2-4 & 12.2-5
Max. Burnup (GWD/MTU)	Varies - See TranStor SAR Table 12.2-2 & 12.2-3	Varies - See TranStor SAR Table 12.2-4 & 12.2-5
Min. Cooling Time (years)	Varies - See TranStor SAR Table 12.2-2 & 12.2-3	Varies - See TranStor SAR Table 12.2-4 & 12.2-5

NOTES:

(1). Failed fuel and fuel debris shall be confined in an overpack container within the basket

TABLE 3.2-1

STRUCTURAL DESIGN CRITERIA FOR THE HI-STORM CANISTER CONFINEMENT BOUNDARY PER ASME NB-3220[1]

STRESS CATEGORY	DESIGN	ASME SERVICE CONDITION		
		LEVELS A & B	LEVEL C	LEVEL D[2]
Primary Membrane, P_m	S_m	N/A[3]	AMAX ($1.2S_m$ or S_y)	AMIN ($2.4S_m$, $0.7S_u$)[4]
Local Membrane, P_L	$1.5S_m$	N/A	AMAX ($1.8S_m$ or $1.5S_y$)	150% of P_m Limit
Membrane plus Primary Bending, $P_L + P_b$	$1.5S_m$	N/A	$4.8S_m$[5] AMAX ($1.8S_m$ or $1.5S_y$)	150% of P_m Limit
Primary Membrane plus Primary Bending, $P_m + P_b$	$1.5S_m$	N/A	N/A	150% of P_m Limit
Membrane plus Primary Bending plus Secondary, $P_L + P_b + Q$	N/A	$3S_m$	N/A	N/A

NOTES

1. Stress combinations including F (peak stress) apply to fatigue evaluations only.
2. Governed by Appendix F, Paragraph F-1331 of the ASME Code, Section III.
3. No specific stress intensity limit applicable.
4. Average primary shear stress across a section loaded in pure shear shall not exceed $0.42S_u$.
5. This limit is on the triaxial stresses.

TABLE 3.2-2

STRUCTURAL DESIGN CRITERIA FOR THE STEEL STRUCTURES OF THE HI-STORM STORAGE CASK AND HI-TRAC[1] TRANSFER CASK PER ASME NF-3260

STRESS CATEGORY	ASME SERVICE CONDITION[2]			
	DESIGN + LEVEL A	LEVEL B	LEVEL C	LEVEL D[3]
Primary Membrane, P_m	S	1.33S	1.5S	AMAX ($1.2S_y$, $1.5S_M$) but $< 0.7S_u$
Primary Membrane plus Primary Bending, $P_m + P_b$	1.5S	1.995S	2.25S	150% of P_m
Shear Stress	N/A	$< 0.42S_u$	$< 0.42S_u$	$< 0.42S_u$

NOTES

1. Only service condition Level A is applicable to the HI-TRAC steel structure.
2. Limits for Design and Levels A, C are on maximum stress. Limits for Level D are on maximum stress intensity.
3. Governed by Appendix F, Paragraph F-1331 of the ASME Code, Section III.

TABLE 3.2-3

STRUCTURAL DESIGN CRITERIA FOR STEEL COMPONENTS USED IN THE TRANSTOR CANISTER

COMPONENT / (APPLICABLE CODE)	CRITERIA
1. Basket Normal Operation (ASME III, NC/shell/ and NG/internals/, Service Level A)	$P_m \leq S_m$ $P_m + P_b \leq 1.5\ S_m$ $P_L + P_b + Q \leq 3S_m$
Lifting Devices (ANSI N14.6 and NUREG 0612, 10% dynamic factor)	Redundant load path: max principal stress $\leq S_u/5$ or $S_y/3$ Non-redundant load path: max principal stress $\leq S_u/10$ or $S_y/6$
2. Basket Off-Normal Operation (ASME III, NC/shell/ and NG/internals/, Service Level B)	$P_m < 1.1\ S_m$ $P_L + P_b < 1.65\ S_m$ $P_L + P_b + Q < 3\ S_m$
3. Basket Off-Normal Operation (ASME III, NC/shell/ and NG/internals/, Service Level C)	$P_m < 1.2\ S_m$ (shell), $< 1.5\ S_m$ (sleeve) $P_L + P_b < 1.8\ S_m$ (shell), $< 2.25\ S_m$ (sleeves)
4. Basket Accident Conditions, (ASME III, NC/shell/ and NG/internals/, Service Level D, NUREG/CR-6322)	$P_m \leq 2.4\ S_m$ or $0.7\ S_u$ (whichever is less) $P_L + P_b \leq 3.6\ S_m$ or $1.0\ S_u$ (whichever is less) Buckling interaction ratios < 1
5. Brittle Fracture (ASME III, NC/shell/ and NG/internals/)	Selection of structural material with adequate toughness. Control by operating procedures based on minimum temperature. Carbon steel below 5/8" in thickness and stainless steel are exempt from fracture toughness testing and requirements.

TABLE 3.4-1

QUALITY ASSURANCE CLASSIFICATION OF STRUCTURES, SYSTEMS, AND COMPONENTS

IMPORTANT TO SAFETY	NOT IMPORTANT TO SAFETY
Classification Category A	Storage Facility Infrastructure
Spent Fuel Canister	Security and Heath Physics Building
	Administration Building
Classification Category B	Operations and Maintenance Building
Concrete Storage Cask	Intrusion Detection System
Transfer Cask	CCTV System
Associated Lifting Devices	Restricted Area Lighting
Canister Transfer Building	Security Alarm Stations
Canister Transfer Overhead Bridge Crane	Electrical Power - UPS
Canister Transfer Semi-gantry Crane	Electrical Power - Backup Diesel Generator
	Electrical Power - Normal
Classification Category C	Yard/Building Lighting
Cask Storage Pads	Cask Transporter
	Radiation Monitors
	Temperature Monitoring System
	Communication Systems
	Fire Detection/Suppression
	Water Supply Systems
	Septic Systems
	Access Road
	Road Transport Alternative components
	Railroad Spur Alternative components

TABLE 3.6-1
(Sheet 1 of 5)

SUMMARY OF PFSF DESIGN CRITERIA

DESIGN PARAMETERS	DESIGN CONDITIONS	APPLICABLE CRITERIA AND CODES
GENERAL		
PFSF Design Life	40 years	PFSF Specifications
Storage Capacity	40,000 MTU of commercial spent fuel	PFSF Specifications
Number of Casks	approximately 4,000 casks	PFSF Specifications
SPENT FUEL SPECIFICATIONS		
Type of Fuel	See Tables 3.1-1 and 3.1-2	HI-STORM SAR TranStor SAR
Fuel Characteristics	See Table 3.1-3	HI-STORM SAR TranStor SAR
STORAGE SYSTEM CHARACTERISTICS		
Canister Capacity	<u>HI-STORM</u> 24 PWR assemblies/canister 68 BWR assemblies/canister <u>TranStor</u> 24 PWR assemblies/canister 61 BWR assemblies/canister	HI-STORM SAR, Section 1.1 TranStor SAR, Section 1.1
Weights (maximum)	<u>HI-STORM</u> Storage Cask - 267,664 lbs. Loaded Canister - 86,131 lbs. Transfer Cask - 151,963 lbs. Shipping Cask - 153,080 lbs. <u>TranStor</u> Storage Cask - 223,435 lbs. Loaded Canister - 84,460 lbs. Transfer Cask - 126,630 lbs. Shipping Cask - 160,330 lbs.	 HI-STORM SAR, Table 3.2.1 " HI-STORM SAR, Table 3.2.2 Shipping SAR, Table 2.2.1 TranStor SAR, Table 3.2-1 " " Shipping SAR, Table 2.2-1

TABLE 3.6-1
(Sheet 2 of 5)

SUMMARY OF PFSF DESIGN CRITERIA

DESIGN PARAMETERS	DESIGN CONDITIONS	APPLICABLE CRITERIA AND CODES
STRUCTURAL DESIGN		
Wind	90 mph, normal speed	ASCE-7
Tornado	240 mph, maximum speed 190 mph, rotational speed 50 mph, translational speed 150 ft, radius of max speed 1.5 psi, pressure drop 0.6 psi/sec rate of drop	Reg. Guide 1.76
Tornado Missiles (at 84 mph)	1800 kg automobile 125 kg 8" armor piercing artillery shell 1" solid steel sphere	NUREG-0800, Section 3.5.1.4
Flood	N/A - PFSF is not in a flood plain and is above the PMF elevation	PFSF SAR Section 2.3.2.3
Seismic	0.67g, horz.(both directions) & 0.69 g vert. max peak ground acceleration	10 CFR 72.102, 10 CFR 100, App. A
Snow & Ice	P(g) = 10 psf	ASCE-7
Allowable Soil Pressure	Static = 4 ksi max Dynamic = Varies by footing type/size	PFSF SAR Section 2.6.1.12
Explosion Protection	N/A - PFSF is located beyond distances from transportation routes from where cargo explosions could cause overpressures > 1 psi.	Reg. Guide 1.91
Ambient Conditions	Temperature = -35 to 110°F Humidity = 0 to 100 %	NOAA Data-Salt Lake City UT DNR Tech Pub. 18
HI-STORM 100 Cask System Load Criteria	Canister: Internals: Storage Cask: Transfer Cask: } See HI-STORM SAR, Table 2.2.6	ASME III, NB ASME III, NG ASME III NF, ACI-349 ASME III NF, ANSI N14.6

TABLE 3.6-1
(Sheet 3 of 5)

SUMMARY OF PFSF DESIGN CRITERIA

DESIGN PARAMETERS	DESIGN CONDITIONS	APPLICABLE CRITERIA AND CODES
TranStor Storage Cask System Load Criteria	Canister: Internals: Storage Cask: Transfer Cask: } See TranStor SAR, Section 2.2.7	ASME III, NC ASME III, NG ANS 57.9, ACI-349 ANSI N14.6
Cask Storage Pads Load Combinations	<u>Normal Conditions</u> $U_c > 1.4D + 1.7L$ $U_c > 1.4D + 1.7L + 1.7H$ <u>Off-Normal Conditions</u> $U_c > 0.75(1.4D + 1.7L + 1.7H + 1.7T)$ $U_c > 0.75(1.4D + 1.7L + 1.7H + 1.7T + 1.7W)$ <u>Accident-Level Conditions</u> $U_c > D + L + H + T + (E \text{ or } A \text{ or } W_t \text{ or } F)$ $U_c > D + L + H + T_a$	ANSI/ANS 57.9 ACI-349
Canister Transfer Building Structure Load Combinations (Reinforced Concrete)	<u>Normal Conditions</u> $U_c > 1.4D + 1.7L$ $U_c > 1.4D + 1.7L + 1.7H$ <u>Off-Normal Conditions</u> $U_c > 0.75(1.4D + 1.7L + 1.7H + 1.7T)$ $U_c > 0.75(1.4D + 1.7L + 1.7H + 1.7T + 1.7W)$ <u>Accident-Level Conditions</u> $U_c > D + L + H + T + (E \text{ or } A \text{ or } W_t \text{ or } F)$ $U_c > D + L + H + T_a$	ANSI/ANS 57.9 ACI-349
Canister Transfer Building Structure Load Combinations (Structural Steel)	<u>Normal Conditions</u> S and $S_v > D + L$ or $D + L + H$ <u>Off-Normal Conditions</u> $1.3(S \text{ and } S_v) > D + L + H + W$ $1.5S > D + L + H + T + W$ $1.4 S_v > D + L + H + T + W$ <u>Accident-Level Conditions</u> $1.6S > D + L + T + (W_t \text{ or } E)$ $1.4 S_v > D + L + T + (W_t \text{ or } E)$	ANSI/ANS 57.9 ANSI/AISC N690

TABLE 3.6-1
(Sheet 4 of 5)

SUMMARY OF PFSF DESIGN CRITERIA

DESIGN PARAMETERS	DESIGN CONDITIONS	APPLICABLE CRITERIA AND CODES
Canister Transfer Building Foundation Load Combinations	Normal Conditions $U_f > 1.4D + 1.7L + 1.7G$ $U_f > 1.4D + 1.7L + 1.7H + 1.7G$ Off-Normal Conditions $U_f > 0.75\,(1.4D + 1.7L + 1.7H + 1.7T + 1.7G)$ $U_f > 0.75\,(1.4D + 1.7L + 1.7H + 1.7T + 1.7W + 1.7G)$ Accident-Level Conditions $U_f > D + L + H + T + G + (E \text{ or } A \text{ or } W_t \text{ or } F)$ $U_f > D + L + H + T_a + G$	ANSI/ANS 57.9 ACI-349
Canister Transfer Crane Designs	Type I, single-failure-proof 200 ton overhead bridge crane 150 ton semi-gantry crane	ASME NOG-1, NUREG 0554, & NUREG 0612
Canister Transfer Crane Load Combinations	Normal Conditions $P_c = P_{db} + P_{dt} + (P_{lr} \text{ or } P_p)$ $P_c = P_{db} + P_{dt} + P_{lr} + (P_v \text{ or } P_{ht} \text{ or } P_{hl}) + P_{wo}$ Off-Normal Conditions $P_c = P_{db} + P_{dt} + P_a + P_{wo}$ Accident-Level Conditions $P_c = P_{db} + P_{dt} + P_{cs} + P_e + P_{wo}$ $P_c = P_{db} + P_{dt} + P_e + P_{wo}$ $P_c = P_{db} + P_{dt} + P_{wt}$	ASME NOG-1
THERMAL DESIGN		
Design Temperatures (°F) (maximum)	HI-STORM — Norm / Off-norm / Acc Stor. cask conc. 300 / 300 / 1200 Stor. cask steel 350 / 350 / 1350 Fuel Cladding 716 / 716 / 1058 TranStor Outer cask conc. 150 / 150 / 200 Inner cask conc. 200 / 225 / 350 PWR Cladding 621 / 1058 / 1058 BWR Cladding 673 / 1058 / 1058	HI-STORM SAR, Table 2.2.3 TranStor SAR, Table 4.1-1

TABLE 3.6-1
(Sheet 5 of 5)

SUMMARY OF PFSF DESIGN CRITERIA

DESIGN PARAMETERS	DESIGN CONDITIONS	APPLICABLE CRITERIA AND CODES
RADIATION PROTECTION/SHIELDING DESIGN		
Storage Systems Design Dose Rate Limits	HI-STORM cask side surface - 35 mrem/hr cask inlet/exit vent area - 50 mrem/hr cask top surface - 10 mrem/hr TranStor 1 meter from cask side - 15 mrem/hr 1 meter from cask top - 200 mrem/hr	HI-STORM SAR, Section 2.3.5.2 TranStor SAR, Section 2.3.5.2
Individual Workers Dose Rate	Total eff. dose equiv.(TEDE) - 5 rem/yr Dose to eye lens - 15 rem/yr Dose to skin & extremities - 50 rem/yr	10 CFR 20.1201
Restricted Area Boundary Dose Rate	2 mrem/hr, max.	10 CFR 20.1301
Owner Controlled Area Boundary Dose Rate	25 mrem/yr whole body & 75 mrem/yr thyroid, max. 5 rem accident dose (one time)	10 CFR 72.104 10 CFR 72.106
CRITICALITY DESIGN		
Control Method	Geometry of fuel assemblies assuming no moderator	HI-STORM SAR, 2.3.4.1 TranStor SAR, 2.3.4.1
K_{eff}	< 0.95	NUREG-1536
CONFINEMENT DESIGN		
Confinement Method	Welded closed steel canister	HI-STORM SAR, 2.3.2.1 TranStor SAR, 2.3.2.1
Confinement Barrier Design	HI-STORM canister: ASME III, NB TranStor canister: ASME III, NC	HI-STORM SAR, 2.3.2.1 TranStor SAR, 2.3.2.1
Maximum Leak Rate	1E-4 cm^3 / sec	HI-STORM SAR, 12.3.8 TranStor SAR, 2.3.2.1

CHAPTER 4

FACILITY DESIGN

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CHAPTER 4

FACILITY DESIGN

4.1 SUMMARY DESCRIPTION

This chapter identifies the Facility Design for the Private Fuel Storage Facility (PFSF). The Principal Design Criteria used as a basis for the Facility Design is described in Chapter 3. The design of the structures, systems, and components (SSCs) and how the design ensures quality standards are met in accordance with 10 CFR 72.122(a) is described.

The descriptions presented in this chapter specifically focus on SSCs that are classified as being Important to Safety; SSCs that are not Important to Safety are also addressed where appropriate. The SSCs that are classified as being Important to Safety are identified in Chapter 3 as the storage systems, cask storage pads, canister transfer cranes, and Canister Transfer Building.

The PFSF utilizes two dry type canister storage systems, the HI-STORM 100 Cask System (HI-STORM) designed by Holtec International (Holtec) and the TranStor Storage Cask System (TranStor) designed by Sierra Nuclear Corporation (SNC). Holtec submitted a Safety Analysis Report (SAR) to the U.S. Nuclear Regulatory Commission (NRC) for the HI-STORM system (Reference 1) and SNC submitted a SAR to the NRC for the TranStor system (Reference 2).

The HI-STORM and TranStor storage system SARs contain the generic design of their respective storage system and transfer equipment. This chapter summarizes the generic design and how the generic design complies with the site-specific criteria at the PFSF.

The PFSF is designed in accordance with the General Design Criteria set forth in 10 CFR 72, Subpart F. Table 4.1-1 summarizes compliance with these criteria.

4.1.1 Location and Layout

The PFSF is located on the Skull Valley Indian Reservation in northwestern Utah, approximately 27 miles west-southwest of Tooele City. The site location is shown on Figure 1.1-1. The PFSF site layout is shown on Figure 1.1-2 and the PFSF general arrangement is shown on Figure 1.2-1.

4.1.2 Principal Features

The principal features of the PFSF consist of the storage area, including cask storage pads, the Canister Transfer Building, shown on Figure 4.1-1, and the Security and Health Physics Building, shown on Figure 4.1-2. The cask storage pads, the Canister Transfer Building, and the Security and Health Physics Building are located within the Restricted Area (RA). The Canister Transfer Building facilitates the transfer of the canister from the shipping cask to the storage cask and houses the overhead bridge and semi-gantry cranes used in the transfer process. The Security and Health Physics Building is the entrance point for the RA and houses offices and equipment for security and health physics personnel. The RA provides security and physical protection of spent fuel and restricts access because of potential radiation doses from the spent fuel. The RA consists of approximately 99 acres of storage area surrounded by a chain link security fence, 20 ft isolation zone, and chain link nuisance fence. The design capacity of the RA is approximately 500 concrete cask storage pads capable of storing up to 8 concrete storage casks each for a total of approximately 4,000 storage casks. The storage pad area is surfaced with compacted gravel to enable transport of the storage casks from the Canister Transfer Building to the storage pads.

The storage area is surrounded by a perimeter road. The Administration Building, shown on Figure 4.1-3, and the Operations and Maintenance (O&M) Building, shown on Figure 4.1-4, which are not directly associated with the actual handling or storage of spent fuel, are located approximately one-half mile and one-third mile respectively southeast of the storage area. The Administration, and the O&M buildings house offices and equipment for administrative and maintenance personnel.

The facility layout is also designed to ensure that all SSCs are accessible to emergency equipment in the event of an emergency condition per 10 CFR 72.122(g).

4.1.2.1 Site Boundary

The PFSF site boundary is identified by the owner controlled area (OCA). The OCA boundary is shown on Figure 1.1-2.

4.1.2.2 Controlled Area

The controlled area, established by providing a minimum distance of 100 meters from storage and handling operations to the controlled boundary in accordance with 10 CFR 72.106, is the same as the site boundary discussed in Section 4.1.2.1 above, defined as the OCA.

4.1.2.3 Site Utility Supplies and Systems

The site requires few utility supplies and systems. None of the SSCs classified as Important to Safety require utility services to maintain their safety function. Therefore, the site utility services do not need to be considered as being Important To Safety and need no redundant components, as otherwise would be required by 10 CFR 72.122(k). Electric power is provided to the PFSF for lighting, general utilities, security system, and cranes. Although the overhead bridge and semi-gantry cranes are Important to Safety, their safety function does not rely on electric power. A standby diesel-generator provides backup power for the security system, emergency lighting loads, storage cask temperature monitoring system, and communication systems.

4.1.2.4 Storage Facilities

There are no ancillary storage facilities such as holding ponds, chemical gas storage vessels, or other open-air tanks required to maintain Important to Safety functions at the PFSF. However, the PFSF does utilize a water tank for fire protection and propane gas supply tanks for the Administration, O&M, and Security and Health Physics building heating. The water tank is located near the Administration Building and the propane tanks are located near each of the buildings served. The Canister Transfer Building is heated with electrical units.

4.1.2.5 Stacks

There are no stacks required or provided at the PFSF.

4.2 STORAGE STRUCTURES

The storage SSCs are used to safely store spent fuel at the PFSF. The storage SSCs at the PFSF consist of the following:

- HI-STORM 100 Cask System
- TranStor Storage Cask System
- Cask storage pads

The storage SSCs are designed to ensure adequate safety and to mitigate the effects of site environmental conditions, natural phenomena, and accidents in accordance with 10 CFR 72.122(b) and 10 CFR 72.128(a). The SSC design is described in Chapter 8 and in the HI-STORM and the TranStor SARs.

The storage SSCs are designed to permit testing, inspection, and maintenance of the systems in accordance with 10 CFR 72.122(f). The acceptance test and maintenance program of the storage systems are specified in HI-STORM SAR Chapter 9 and TranStor SAR Chapter 9. Because of the passive nature of the storage system design, inspection and maintenance requirements are minimal. Surveillance requirements associated with operational control and limits are described in Chapter 10. Inspection and testing is performed in accordance with the Quality Assurance program described in Chapter 11.

Each of the storage SSCs are described in the following sections. Figures are provided to illustrate the components and their function.

4.2.1 HI-STORM 100 Cask System

The HI-STORM storage system consists of metal canisters, concrete storage casks, and associated transfer equipment. The following sections provide an analysis of the HI-STORM storage system canister and storage cask design relative to the storage requirements of the PFSF. Types and characteristics of fuel to be stored, site environmental conditions, support structures, and support systems are shown to be within the design criteria envelope of the HI-STORM SAR, thus ensuring no unanalyzed safety conditions for storage using the HI-STORM storage system exist at the PFSF. The HI-STORM canister transfer equipment is described in Section 4.7.3.

4.2.1.1 Design Specifications

The design, fabrication, and construction specifications used for the HI-STORM storage system components are identified in the HI-STORM SAR Table 2.2.6 and are summarized as follows:

- Metal canister -

Pressure boundary	ASME BPVC Section III, Subsection NB
Internal assembly	ASME BPVC Section III, Subsection NG

- Concrete storage cask -

Steel	ASME BPVC Section III, Subsection NF
Concrete	ACI-349

4.2.1.2 System Layout

The HI-STORM storage system consists of a sealed metal canister placed inside of a vertical concrete storage cask. Each canister holds up to 24 PWR or 68 BWR spent fuel assemblies in an internal basket.

4.2.1.2.1 Plans and Sections

The HI-STORM storage components are illustrated in Figure 4.2-1. The metal canister is shown in Figure 4.2-2 and the concrete storage cask in Figure 4.2-3.

4.2.1.2.2 Confinement Features

The HI-STORM canister is the primary confinement boundary for the HI-STORM storage system. The confinement features of the canister consist of the canister shell, a bottom base plate, the canister lid, and the canister closure ring, which form a totally welded vessel for the storage of spent fuel assemblies. The confinement features of the HI-STORM canister are further discussed in Section 4.2.1.5.5.

4.2.1.3 Function

The HI-STORM storage system is used to safely store spent nuclear fuel under dry storage conditions. The system maintains confinement, prevents criticality, provides for passive cooling by natural convection, and provides shielding under all normal, off-normal, and accident conditions that may occur during storage or handling operations at the PFSF.

4.2.1.4 Components

The major components of the HI-STORM storage system that are classified as Important to Safety are a sealed metal canister and a concrete storage cask.

The canister (called a multi-purpose canister or MPC in the HI-STORM SAR) is a totally sealed, welded structure of cylindrical profile with flat ends. Each canister consists of a honeycomb fuel basket, a baseplate, canister shell, a lid, and a closure ring. The canister provides the confinement boundary for the stored fuel. The design of the canister provides a means to dissipate heat and the capability to withstand large impact loads associated with potential accidents. Canisters with different internal arrangements accommodate PWR and BWR intact spent fuel, failed fuel, and MOX fuel. The lid provides top shielding and lifting provisions for the canister. The fuel basket assembly provides support for the fuel assemblies. Canisters employ the use of fuel assembly geometry and poison plates for criticality control. Flux traps are located between each storage cell on the PWR canister to provide additional criticality control. The canister is constructed entirely from stainless steel except for the neutron absorber. The outer diameter and cylindrical height of each canister are fixed.

The HI-STORM concrete storage cask (called a storage overpack in the HI-STORM SAR) is a concrete and steel cylindrical structure that serves as a missile barrier, radiation shield, provides flow paths for natural convective heat transfer, provides stability for the system, and absorbs energy for the canister for non-credible hypothetical tipover accident events.

The storage cask has a steel/concrete/steel composition to attenuate the loads transmitted to the canister during a natural phenomenon or non-credible hypothetical accident event and provides a shield against the radiation emitted by the spent fuel. The 2 inch thick inner liner and 0.75 inch thick outer steel shell are filled with 26.75

inches of 4,000 psi concrete . The storage cask contains large penetrations near its lower and upper extremities to permit natural circulation of air to provide for the passive cooling of the canister and spent fuel. The cask has four air inlet channels located in the base of the cask and four air outlet vents located near the top of the cask. The cooling air enters the inlet channels and flows upward in the annulus between the canister and the concrete cask.

The physical characteristics of the canister and storage cask are listed in Tables 4.2-1 and 4.2-2, respectively.

4.2.1.5 Design Bases and Safety Assurance

The design bases for the HI-STORM storage system are detailed in the HI-STORM SAR. Structural, thermal, shielding, criticality, and confinement design are applicable to the HI-STORM storage system and are addressed in the following sections.

4.2.1.5.1 Structural Design

The structural evaluation for the HI-STORM storage system is contained in HI-STORM SAR Chapter 3. Analysis of the storage system components has been performed for normal, off-normal and accident/natural phenomenon conditions. The structural analyses show the structural integrity of the HI-STORM system is maintained under all credible loads with a high level of assurance to support the conclusion that the heat transfer, confinement, criticality control, radiation shielding, and retrievability criteria are met.

The following verifies that the PFSF site specific criteria are enveloped by the HI-STORM storage system design.

A. Dead and Live Loads

Dead loads are addressed in HI-STORM SAR Sections 3.4.4.3.1 and 3.4.4.3.2. The dead load of the storage cask includes the weight of the concrete and steel cask and the storage canister loaded with spent fuel. As identified in HI-STORM SAR Table 2.1.6, the dead load of the storage cask is calculated assuming the heaviest PWR assembly (B&W 15 x 15 fuel assembly type, wt = 1,680 lb) and the heaviest BWR assembly (GE 8 x 8 fuel assembly type, wt = 700 lb). The dead loads of the canister and the storage cask are shown to be within applicable code allowables and therefore meet the PFSF design criteria in Section 3.2.1 for dead loads.

The storage cask is subjected to two live loads, both of which act on the top of the storage cask: snow loads and the HI-TRAC transfer cask weight (during transfer operations) containing a fully loaded canister. The HI-STORM SAR uses a conservative worst case ground snow load of 100 psf per HI-STORM SAR Table 2.2.8, which exceeds the PFSF site snow load of 10 psf applicable to this geographic location. The live load capacity of the storage cask from the weight of the HI-TRAC transfer cask with a fully loaded canister is shown in HI-STORM SAR Section 3.4.4.3.2.1 to be adequate. Therefore, the live loads used in the HI-STORM analysis bound the PFSF design criteria specified in Sections 3.2.2 and 3.2.3 for live loads and snow loads.

B. Internal and External Pressure

Internal and external pressure loads are addressed in HI-STORM SAR Section 3.4.4.3.1.2. The design pressure applied to the canister is 100 psig for internal pressures and 0 psig (ambient) for external pressures for normal and off-normal conditions per HI-STORM SAR Table 2.2.1. For accident conditions, the design pressure applied to the canister is 125 psi for internal and 60 psi for external. HI-STORM SAR Table 4.4.14 indicates pressures calculated to exist in the canister under various conditions. The canisters are originally backfilled with helium to a pressure of approximately 30 psi at an assumed temperature of 70° F, then increase to pressures of 63.4 psi for the HI-STORM PWR canister (MPC-24) and 58.0 psi for the HI-STORM BWR canister (MPC-68) as temperatures equilibrate to those associated with the 80° F day/night average ambient temperatures evaluated in the thermal analysis. Additionally, Holtec evaluated canister internal pressures that would occur for 1, 10, and 100 percent fuel rod cladding rupture, assuming all rod fill gas and a conservative fraction of fission product gases (HI-STORM SAR Table 4.3.4) are released from the failed rods into the canister. With 100 percent fuel rod cladding rupture at normal operating temperatures, canister pressure was calculated to reach 88.2 psi for the MPC-24 and 86.5 psi for the MPC-68, which are below the design internal pressure for accident conditions of 125 psi. The stresses resulting from the internal and external pressure loads were shown to be within code allowables and therefore meet the PFSF design criteria in Section 3.2.4 for internal and external pressures.

C. Thermal Loads

Thermal expansion induced mechanical stresses due to non-uniform temperature distribution are identified in HI-STORM SAR Section 3.4.4.2. It is determined that there is adequate space (gap) between the canister shell and basket, and canister shell and storage cask, that there will not be interference during conditions of thermally induced expansion or contraction. HI-STORM SAR Table 4.4.15 provides a summary of HI-STORM system component temperature inputs for the structural evaluation, consisting of temperature differences in the basket periphery and canister shell between the top and bottom portions of the HI-STORM PWR canister (MPC-24) and BWR canister (MPC-68). This table indicates temperature differences between the top and bottom sections of the basket periphery of approximately 260° F, and approximately 200° F between top and bottom sections of the canister shell, assuming normal operating temperatures. These temperature gradients were used to calculate resultant thermal stresses in the canister that were included in the load combination analysis. The stresses resulting from the temperature gradients were shown to be within code allowables and therefore meet the PFSF design criteria in Section 3.2.6 for thermal loads.

D. Handling Loads

Handling loads for normal and off-normal conditions are addressed in HI-STORM SAR Sections 2.2.1.2, 2.2.3.1, and 3.1.2.1.1.2. The normal handling loads that were applied included vertical lifting and transfer of the HI-STORM storage cask with a loaded canister through all movements. The canister and storage cask were designed to withstand loads resulting from off-normal handling assumed to be the result of a vertical drop. The lifting heights were developed to limit the deceleration levels within design allowables and therefore meet the PFSF design criteria in Section 3.2.2 for handling live loads.

E. Cask Drop and Tipover

Cask drop and tipover loads are addressed in HI-STORM SAR Sections 3.1.2.1.1.1, 3.1.2.1.1.2, and 3.4.4.3.1 and Appendix 3A. Tipover of a loaded storage cask is a non-credible hypothetical accident, as discussed in Section 8.2.6 of this SAR. It is demonstrated that the HI-STORM storage casks are stable and will not tip over in the event of the PFSF Design Earthquake, nor in the event of tornado winds with concurrent impact of the tornado-driven design missile (an automobile) at the top of the storage cask.

Holtec analyzes a vertical end drop and a tipover accident in HI-STORM SAR Appendix 3A, establishing design basis vertical and horizontal acceleration values for the HI-STORM storage cask system of 45 g. With the cask weight, cask dimensions, and center of gravity being known quantities and the cask conservatively treated as a rigid body, calculations determine the storage pad stiffness that produces an acceleration of 45 g in the non-credible hypothetical tipover accident. Using this approach, the limiting stiffness for the storage pad was calculated to be 30.65 E6 lb/inch. This value bounds the calculated PFSF storage pad stiffness value of 10.8 E6 lb/inch. Therefore, non-credible hypothetical tipover of a HI-STORM storage cask at the PFSF would result in an acceleration less than 45 g and lower stresses than those evaluated in the HI-STORM SAR.

Based on the limiting storage pad design criteria stiffness calculated for the non-credible hypothetical tipover accident, Holtec calculated the maximum drop height for a vertical end drop of the loaded HI-STORM storage cask that would result in a deceleration of 45 g. This height was determined to be 10 inches. There are no operations at the PFSF where a storage cask would be raised above the 10 inch analyzed drop height. The cask transporter, used to move storage casks from the Canister Transfer Building to the storage pads, lifts the cask approximately 4 inches above the surface. The transporter is designed to mechanically limit the heights below 10 inches. The cask drop analyzed in the HI-STORM SAR bounds the PFSF design criteria in Section 3.2.7 for accident drop loads since the HI-STORM storage cask will not be dropped from a height approaching 10 inches, and because the PFSF storage pads are not as stiff as that considered in the 10 inch vertical end drop analysis in the HI-STORM SAR.

For the canister, the peak acceleration of 45 g established for the side and end drops is bounded by the 60 g acceleration calculated for drop accidents analyzed in Section 2.7.1 of the HI-STAR 10 CFR 71 Shipping SAR (Reference 3). Since the accelerations are bounding, the stresses (produced by 60 g vertical and horizontal accelerations) analyzed by the HI-STAR stress analyses and determined to be acceptable also bound stresses that would result from the HI-STORM tipover and end drop accidents.

For the storage cask, HI-STORM SAR Section 3.4.4.3.2.3 evaluates the buckling capacity of the cask based on the 10 inch vertical end drop and resulting 45 g acceleration. No credit was taken for the structural stiffness of the radial concrete shielding. The minimum factor of safety for material allowable stresses for all portions of the cask structure is 1.13. The tipover event evaluated in the HI-STORM SAR specifies that the cask lid must remain in place due to the 45 g horizontal acceleration. HI-STORM SAR Section 3.4.4.3.2.2 demonstrates that the minimum factor of safety for the cask lid and lid bolts is 1.194, which exceeds the minimum required 1.13 factor of safety.

F. Tornado Winds and Missiles

Tornado wind and tornado missile loads are addressed in HI-STORM SAR Sections 3.1.2.1.1.5 and 3.4.8. The loads are based on a worst case design basis tornado in accordance with Regulatory Guide 1.76 (Reference 4) for Intensity Region I and postulated tornado-generated missiles in accordance with NUREG-0800 (Reference 5) for Spectrum I missiles. The site is located in Tornado Intensity Region III per Regulatory Guide 1.76, which has less severe tornado conditions than Region I. The postulated missile loads used in the HI-STORM analysis are the same as in the PFSF design criteria. Since the HI-STORM design tornado wind loads exceed the PFSF design criteria and tornado-generated missile loads are the same as the PFSF design criteria described in Section 3.2.8, the HI-STORM design meets PFSF design criteria.

G. Flood

Flood loads are addressed in HI-STORM SAR Sections 3.1.2.1.1.3 and 3.4.6. The HI-STORM storage system is designed to withstand hydrostatic pressure (full submergence) up to a depth of 125 ft and horizontal loads due to water velocity up to 16.24 fps without tipping or sliding. The PFSF is above probable maximum flood conditions, therefore, the HI-STORM design meets the PFSF design criteria in Section 3.2.9 for flood design.

H. Earthquake

Earthquake loads are addressed in the HI-STORM SAR Sections 2.2.3.7 and 3.4.7 and Appendix 3B. The HI-STORM SAR shows that the storage system will withstand the imposed loads and not tip over when subjected to a generic seismic event. A generic seismic event was defined for the HI-STORM system using response spectra curves from Regulatory Guide 1.60 (Reference 6) with a zero period acceleration of up to 0.80 g in three orthogonal directions.

The cask vendor also performed a site specific analysis and determined the storage cask will withstand the imposed loads and not tip over when subjected to the site specific seismic event (References 7 and 8). The site specific seismic event is defined by site specific response spectra curves with a zero period acceleration of 0.67 g horizontal (both directions) and 0.69 g vertical. Soil-structure interaction was considered in the site specific analysis. The seismic cask stability analyses are fully described in Section 8.2.1.

Inertia loads produced by the seismic event are less than the 45 g loads due to the postulated HI-STORM vertical drop and non-mechanistic tip over events as discussed in Section 8.2.6. Stresses in the canister due to the seismic event are bounded by those analyzed for the 45 g deceleration load from the hypothetical end drop and side drop events discussed in HI-STORM SAR Section 3.4.4.3.1. As discussed in HI-STORM SAR Appendix 3.B, shell and concrete stresses in the storage cask resulting from the seismic shear and moment forces are evaluated and determined to be acceptable.

Even though the storage cask will not tip over during an earthquake, the cask is conservatively analyzed for a hypothetical cask tip over event in HI-STORM SAR Section 11.2.3. Both the cask and canister are shown to withstand this non-credible hypothetical event without loss of integrity.

Therefore, the HI-STORM storage system design meets the PFSF design criteria requirements in Section 3.2.10 for seismic design.

I. Explosion Overpressure

Explosion overpressure loads are addressed in HI-STORM SAR Section 11.2.11. Regulatory Guide 1.91 (Reference 9) requires a detailed review of the system for overpressures that exceed 1 psi. The HI-STORM storage system is analyzed and designed for accident external pressures up to 60 psig. As shown in Section 8.2.4, the PFSF is not subject to explosions that are in excess of 1 psig. Since the PFSF will not see explosion pressures that exceed 1 psig, the HI-STORM design meets the PFSF design criteria in Section 3.2.7 for explosion accident loads as required per 10 CFR 72.122(c).

J. Fire

Fire loads are addressed in HI-STORM SAR Section 11.2.4. The HI-STORM storage system was analyzed for a fire of 200 gallons of combustible fuel encircling the cask, resulting in temperatures up to 1,475° F and lasting for a period of 15 minutes. Nonetheless, the analysis also evaluated the temperatures of the system for a fire duration of 10 hours. The results of the analysis show that the intense heat from the fire only partially penetrated the concrete cask wall and that the majority of the concrete experienced only minor temperature increases. The cask transporter will contain up to 50 gallons of fuel and therefore would have less fire consequences than the HI-STORM analysis. As discussed in Section 8.2.5, a storage cask is postulated to be involved in a diesel fuel fire, involving up to 50 gallons of diesel fuel spilled from the fuel tank of the cask transporter, which is calculated to burn for 3.6 minutes. This fire would not damage the storage cask concrete, and would have a negligible effect on canister and fuel temperatures. Therefore, the HI-STORM design meets the PFSF design criteria in Section 3.2.6 for accident-level thermal loads as required per 10 CFR 72.122(c).

4.2.1.5.2 Thermal Design

Thermal performance for the HI-STORM storage system is addressed in HI-STORM SAR Chapter 4. The HI-STORM system is designed for long-term storage of spent fuel and safe thermal performance during onsite loading, unloading, and transfer operations. The HI-STORM system is also designed to minimize internal stresses from thermal expansion caused by axial and radial temperature gradients.

The HI-STORM system is designed to transfer decay heat from the spent fuel assemblies to the environment. The canister design, which includes the high structural integrity all-welded honeycomb basket structure, allows conductive heat transfer away from the canister internal region to the canister shell. The design incorporates top and bottom plenums, with interconnected downcomer paths, to accomplish corrective heat transfer. The canister is pressurized with helium, which assists in conducting heat from fuel rods to the basket and from the basket to the canister shell. Gaps exist between the basket and the canister shell to permit unrestrained axial and radial thermal expansion of the basket without contacting the shell, minimizing internal stresses. The stainless steel basket conducts heat from the individual spaces for storing fuel assemblies out to the canister shell.

The HI-STORM storage cask design provides for an annular space between the canister shell and the inner steel liner of the storage cask for airflow up the annulus. Air enters the four inlet ducts at the bottom of the storage cask, flows upward through the annulus removing heat from the canister shell and inner cask liner by convection, and exits the four outlet ducts at the top of the cask.

The thermal analysis, discussed in HI-STORM SAR Chapter 4, was performed using the ANSYS finite element modeling package (Reference 10) and an additional code discussed in the HI-STORM SAR. The thermal analysis considers the removal of decay heat from the stored spent fuel assemblies to the environment by the three modes of heat transfer: conduction, convection, and radiation. The HI-STORM PWR canister (MPC-24) and BWR canister (MPC-68) were modeled to determine the temperature distribution under long term normal storage conditions, assuming the canisters are loaded with design basis PWR and BWR fuel assemblies. Decay heat generation rates, specified in HI-STORM SAR Table 2.1.6, are 1.177 kW for a design basis PWR fuel assembly (28.25 kW per MPC-24 canister) and 0.399 kW for a design basis BWR fuel assembly (27.13 kW per MPC-68 canister). Design basis decay heat generation rates for failed and stainless steel clad fuel assemblies are considerably lower, 0.115 kW for a failed BWR assembly (design basis failed fuel assembly), 0.662 kW for a stainless steel clad PWR assembly, and 0.079 kW for a stainless steel clad BWR assembly (HI-STORM SAR Tables 2.1.7 and 2.1.8). The analysis assumed HI-STORM storage casks are in an array, subjected to an 80° F daily average ambient temperature, with solar radiation. The results of this analysis are presented in Table 4.2-3 for MPC-24 and MPC-68 canisters. The results indicate that temperatures of all components are within maximum allowable temperatures.

Holtec considered stainless steel clad fuels in the thermal analysis, as discussed in HI-STORM SAR Section 4.3.1. Stainless steel cladding is less conductive than zircaloy clad fuel and the net thermal resistance of a basket full of stainless steel clad fuel is greater, which would result in higher cladding temperatures for stainless steel fuel assemblies having the same decay heat generation rate as zircaloy clad fuel. However, the design basis decay heat for stainless steel clad fuel is significantly lower than that of zircaloy clad fuel, as noted previously, and the allowable temperature limit for stainless steel cladding is considerably higher than for zircaloy cladding. Holtec determined that the reduction in heat duty is much more pronounced than the nominal increase in the resistance to heat transfer, and concluded that the peak cladding temperature for stainless steel clad fuel will be bounded by the results for zircaloy clad fuel and a separate analysis for stainless steel clad fuel was not required.

HI-STORM SAR Section 11.1.2 evaluates temperatures of the HI-STORM storage system for a maximum off-normal daily average ambient temperature of 100° F, an increase of 20° F from the normal conditions of storage discussed above. The maximum off-normal temperatures were calculated by adding 20° F to the maximum normal temperatures from the highest component temperature for MPC-24 and MPC-68. All the maximum off-normal temperatures are below the normal condition temperature limits except the canister shell temperature for MPC-24 (452° F). However, the off-normal high ambient temperature is of a short duration, and the resultant temperatures were evaluated against the accident condition temperature limits. The accident condition temperature limit for the canister shell is 775° F (HI-STORM SAR Table 2.2.3). Therefore, all components are within allowable temperatures for the 100° F ambient temperature condition.

It is recognized that the PFSF site design ambient temperature of 110° F exceeds the 100° F maximum daily average ambient temperature analyzed for the HI-STORM system. The 100° F condition represents a maximum daily average temperature over a period of several days and nights required for the system to reach thermal equilibrium. While ambient temperatures at the PFSF during the day could exceed 100° F, the daily average for several consecutive days would not exceed this temperature. As shown in Section 2.3.1.2, the maximum average daily ambient temperature for cities in Utah nearest the site is 93.2° F. Therefore, it is considered that the 100° F daily average ambient temperature will envelope worst case conditions involving high ambient temperatures that a HI-STORM storage system could experience at the PFSF.

The HI-STORM storage system was analyzed for a -40° F extreme low ambient temperature condition, as discussed in HI-STORM SAR Chapter 4. Holtec conservatively assumed zero decay heat generation from spent fuel, and no solar radiation, resulting in all storage system components reaching the -40° F temperature. As stated in the HI-STORM SAR, all HI-STORM materials of construction will satisfactorily perform their intended function in the storage mode at this minimum temperature condition. The PFSF site low ambient temperature of -35° F is bounded by the temperature used for the HI-STORM storage system. Therefore, the thermal design of the HI-STORM storage system bounds the site specific design requirements.

4.2.1.5.3 Shielding Design

Shielding design and performance for the HI-STORM storage system is addressed in HI-STORM SAR Chapter 5. The HI-STORM storage system is designed to maintain radiation exposure as low as is reasonably achievable (ALARA) in accordance with 10 CFR 72.126(a). The concrete storage cask is designed to limit the average external contact dose rates (gamma and neutron) to 35 mrem/hr on the sides, 10 mrem/hr on top, and 50 mrem/hr at the air inlets and outlets based on HI-STORM design basis fuel.

The storage cask is a massive structure designed to provide gamma and neutron shielding of the spent fuel assemblies stored within the canister. Radiation shielding is provided by the 2 inch thick steel inner liner and shield plate, the 26.75 inch thick concrete shell, and the 0.75 inch thick steel outer shell. Axial shielding at the top is provided by the steel canister lid and the storage cask lid. The storage cask lid consists of an approximately 10 inches of concrete sandwiched in a steel shell, with a 4 inch thick steel top plate. The configuration of the inlet and outlet ducts prevents a direct radiation streaming path from the canister to outside the cask.

The design dose rates allow limited personnel access during canister closure operations. HI-STORM SAR Section 5.1.1 provides calculated dose rates on contact and at 1 meter for the top and side surfaces of the HI-STORM storage cask for design PWR and BWR fuel, which shows that the above design criteria are met by the HI-STORM storage system. Maximum dose rates on contact from a storage cask, calculated for design basis fuels, are shown to be approximately 29 mrem/hr on the side, 7 mrem/hr on top, 32 mrem/hr at the top vents, and 50 mrem/hr at the bottom vents.

Section 3.3.5 presents the radiological requirements for the PFSF. The requirements originate from 10 CFR 72.104, which requires that the annual dose equivalent to any real individual located beyond the OCA boundary not exceed 25 mrem to the whole body, and from 10 CFR 20.1301, which requires that the hourly dose to any member of the public in any unrestricted area not exceed 2 mrem as a result of exposure to radiation from the PFSF. As discussed in Chapter 7, the HI-STORM storage system shielding design achieves compliance with these requirements for the PFSF array, assumed to consist of 4,000 HI-STORM storage casks, configured as shown in the detail on Figure 1.2-1.

4.2.1.5.4 Criticality Design

Criticality of the HI-STORM storage system is addressed in HI-STORM SAR Chapter 6. The HI-STORM storage system is designed to maintain the spent fuel subcritical in accordance with 10 CFR 72.124(a) and (b), with canister materials and geometry. The primary criteria for the prevention of criticality is that k_{eff} remain below 0.95 for all normal, off-normal, and accident conditions.

Criticality safety of the HI-STORM system depends on the following three principal design parameters:

- An administrative limit on the maximum average enrichment acceptable for storage in the canister,
- The inherent geometry of the fuel basket designs within the canister, including the flux-traps (water gaps for loading fuel into submerged canisters), where present, and
- The incorporation of fixed neutron absorbing panels (Boral) in the fuel basket structure to assist in control of reactivity (applicable only while the canister is submerged in a nuclear plant spent fuel pool or for shipping requirements).

The criticality analyses performed for the HI-STORM system assumes only fresh fuel with no credit for burnup as a conservative bounding condition. The HI-STORM system is dry (no moderator) and the reactivity is very low (k_{eff} <0.40). At the PFSF, the fuel will always be in a dry, inert gas environment, sealed within a welded canister, and no credible accident results in water entering the canister. However, the analysis was based on a flooded system during fuel loading operations, which is limiting from a criticality standpoint, and this moderated condition determines the design. The criticality analysis assume no credit for a boron concentration in the fuel pool water during fuel loading, and both the PWR and BWR canisters are designed to assure the k_{eff} meets the design criteria when a canister is filled with unborated water.

The results of the analyses of different fuel types are shown in HI-STORM SAR Table 6.2.2 for MPC-24, and Table 6.2.4 for MPC-68, with results summarized for the PWR and BWR design basis fuels in Table 6.1.1. The results confirm that the maximum reactivities of the canisters are below the design criteria (k_{eff} <0.95) for fuels with specified maximum allowable enrichments, considering calculational uncertainties. Based on these results, the maximum allowable enrichments are specified in HI-STORM SAR Table 2.1.3 for PWR fuels and Table 2.1.4 for BWR fuels.

Stainless steel clad PWR and BWR fuel assemblies were analyzed assuming 4.0 percent enrichment. The stainless steel clad fuel assemblies showed lower reactivity than zircaloy clad fuel assemblies at 4.0 percent enrichment, and storage of stainless steel clad fuel with enrichment equal to or less than 4.0 percent was determined to be acceptable.

Accident conditions have also been considered and no credible accidents have been identified that would result in exceeding the regulatory limit on reactivity. Hypothesizing arrays of HI-STORM storage systems under flooded conditions, Holtec determined that the physical separation between overpacks due to the large diameter and cask pitch and the concrete and steel radiation shields are each adequate to preclude any significant neutronic coupling between storage systems.

HI-STORM SAR Section 6.4 discusses the results of criticality analyses on canisters storing failed fuel in a Holtec failed fuel container. Analyses were performed for three possible scenarios, assuming 3.0 percent enrichment, though the maximum enrichment of the failed fuel allowed to be stored in the MPC-68 canister is 2.7 percent. The scenarios are:

1. Lost or missing fuel rods, calculated for various numbers of missing rods in order to determine the maximum reactivity.

2. Fuel assembly broken with the upper segments falling into the lower segment creating a close-packed array. For conservatism, the array was assumed to retain the same length as the original fuel assemblies.

3. Fuel pellets lost from the assembly and forming powdered fuel dispersed through a volume equivalent to the height of the original fuel, with the flow channel and cladding material assumed to disappear.

Results of the analyses confirm that, in all cases, the maximum reactivity of the HI-STORM design base failed fuel in the most adverse post-accident condition will remain well below the regulatory limit. Therefore, the HI-STORM storage system meets the PFSF design criteria in Section 3.3.4 for criticality safety.

Since criticality control is ensured by the canister basket design, criticality monitoring addressed by 10 CFR 72.124(c) is not applicable for the PFSF.

4.2.1.5.5 Confinement Design

Confinement design for the HI-STORM storage system is addressed in HI-STORM SAR Chapter 7. The confinement vessel of the HI-STORM storage system is the canister, which provides confinement of all radionuclides under normal, off-normal, and accident conditions in accordance with 10 CFR 72.122(h). The canister consists of the canister shell, a bottom base plate, the canister lid, and the canister closure ring, which form a totally welded vessel for the storage of spent fuel assemblies. The canister requires no valves, gaskets, or mechanical seals for confinement. All components of the confinement system are classified as Important to Safety.

The canister is a totally seal-welded pressure vessel designed to meet the stress criteria of ASME BPVC Section III (Reference 11), Subsection NB. No bolts or fasteners are used for closure. All closure welds are examined using the liquid penetrant method and helium leak tested to ensure their integrity. Two penetrations are provided in the canister lid for draining, vacuum drying, and backfilling during loading operations. Following loading operations, vent and drain port cover plates are welded to the canister lid. A closure ring, which covers the penetration cover plates and welds is welded to the canister lid providing redundant closure of the canister vessel. The loading and welding operations are performed at the originating power plant, ensuring total confinement of the canister upon arrival to the PFSF. There are no confinement boundary penetrations required for canister monitoring or maintenance during storage.

The confinement features of the HI-STORM storage system meet the PFSF design criteria in Section 3.3.2 for confinement barriers and systems.

4.2.2 TranStor Storage System Components

The TranStor storage system is comprised of metal canisters, concrete storage casks, and associated transfer equipment. The following sections provide an analysis of the TranStor storage system canister and storage cask design relative to the storage requirements of the PFSF. Types and characteristics of fuels to be stored, site environmental conditions, support structures, and support systems are shown to be within the design criteria envelope of the TranStor SAR, thus ensuring no unanalyzed safety conditions for storage using the TranStor storage system exist at the PFSF. The TranStor canister transfer equipment, including the metal transfer cask, is described in Section 4.7.4.

4.2.2.1 Design Specifications

The design, fabrication, and construction specifications used for the TranStor storage system components are identified in the TranStor SAR Section 2.2.7 and are summarized as follows:

- Metal canister -
  - Shell (pressure boundary) — ASME BPVC Section III Subsection NC
  - Internals — ASME BPVC Section III, Subsection NG
- Concrete storage cask - ANSI/ANS 57.9, ACI-349

4.2.2.2 System Layout

The TranStor storage system consists of a metal canister placed inside of a vertical concrete storage cask. Each canister holds up to 24 PWR or 61 BWR spent fuel assemblies in an internal basket.

4.2.2.2.1 Plans and Sections

The TranStor storage components are illustrated in Figure 4.2-4. The storage canister is shown in Figure 4.2-5 and the concrete storage cask in Figure 4.2-6.

4.2.2.2.2 Confinement Features

The TranStor canister is the primary confinement boundary for the TranStor storage system. The confinement features of the canister are a canister shell, an inner shield lid, and outer structural lid, welded to the canister shell. The confinement features of the spent fuel canister are further discussed in Section 4.2.2.5.5.

4.2.2.3 Function

The TranStor storage system is used to safely store spent nuclear fuel under dry storage conditions. The system maintains confinement, prevents criticality, provides for passive cooling by natural convection, and provides shielding under all normal, off-normal, and accident conditions that may occur during storage or handling operations at the PFSF.

4.2.2.4 Components

The major components of the TranStor storage system that are classified as Important to Safety are a sealed metal canister and a concrete storage cask.

The canister (called a basket in the TranStor SAR) is a cylindrical steel vessel consisting of a shell assembly, bottom plate, internal structure, shield lid, and structural lid. The shell and welded lids provide the confinement boundary, some shielding, and lifting provisions for the canister. The internal structure assembly provides support for the fuel assemblies and serves to conduct heat from the fuel assemblies out to the canister shell. The basket is designed to accommodate PWR and BWR intact fuel, failed fuel, and MOX fuel. Flux traps and poison plates located within the basket are provided for criticality control. Canister shell components are fabricated from stainless steel. The internal structure is fabricated from carbon steel. The canisters vary in length depending on the length of the fuel assemblies to be stored. The longest canister has a cavity length of 180 inches.

The TranStor concrete storage cask is a reinforced concrete cylinder with an internal cavity and thick concrete and steel bottom. The storage cask provides structural support, shielding, and natural convection cooling for the canister. The internal cavity is formed by a thick cylindrical steel liner. Reinforcing steel in the body is located to provide adequate strength for the design loading conditions specified in the TranStor SAR. The steel and 4,000 psi concrete walls are 31 inches thick to limit side radiation doses. The air flow path is formed by two large air inlet channels at the bottom of the cask, air inlet ducts, a gap between the basket and storage cask interior, and four air outlet ducts near the top of the cask. The cask cover provides additional shielding to reduce skyshine radiation and protects the canister from the environment and tornado missiles.

The physical characteristics of the canister and storage cask are listed in Tables 4.2-4 and 4.2-5, respectively.

4.2.2.5 Design Bases and Safety Assurance

The design bases for the TranStor storage system are detailed in the TranStor SAR. Structural, thermal, shielding, criticality, and confinement design are applicable to the TranStor storage system and are addressed in the following sections.

4.2.2.5.1 Structural Design

The structural evaluation for the TranStor storage system is contained in TranStor SAR Chapter 3. Analysis of the storage system components has been performed for normal, off-normal, and accident conditions. Structural analyses reflect the system configurations during various stages of loading, handling, and moving and have been performed for enveloping conditions representing the most conservative storage conditions.

The following verifies that the PFSF site specific criteria are enveloped by the TranStor storage system design.

A. Dead and Live Loads

The dead load of the storage cask includes the weight of the concrete cask and the metal canister loaded with spent fuel. As identified in TranStor SAR Table 2.1-1, the dead load of the storage cask is calculated assuming the heaviest PWR assembly (B&W 15 x 15 fuel assembly type, wt = 1680 lb) and the heaviest BWR assembly (GE 8 x 8 fuel assembly type, wt = 700 lb). The dead loads of the canister and the storage cask are shown in TranStor SAR Sections 3.4.4.1.2 and 3.4.4.2.1. These loads are considered in the design of the canister and storage cask and are within applicable code allowables and therefore meet the PFSF design criteria in Section 3.2.1 for dead loads.

The storage cask is subjected to two live loads, both of which act on the top of the storage cask: snow loads and the transfer cask weight (during transfer operations) with a fully loaded canister. The TranStor SAR uses a conservative worst case ground snow load of 100 psf per TranStor SAR Section 2.2.4, which exceeds the PFSF site snow load of 10 psf applicable to this geographic location. The live load capacity of the cask from the weight of a transfer cask loaded with fuel assemblies is shown in TranStor SAR Section 3.4.4.2.2 to be adequate. Therefore, the live loads used in the TranStor analysis bound the PFSF design criteria specified in Section 3.2.2 and 3.2.3 for live loads and snow loads.

B. Internal and External Pressure

The stresses resulting from the internal pressure in the canister are discussed in TranStor SAR Section 3.4.4.1.3. The helium backfill pressure is selected so that the canister will be at a slight vacuum during storage. The normal operating internal pressure is taken as -10 psig, which bounds potential heat loads and ambient conditions. The stresses resulting from the internal and external pressure loads were shown to be within code allowables and therefore meet the PFSF design criteria in Section 3.2.4 for internal and external pressures.

C. Thermal Loads

The normal thermal loads for the canister are described in TranStor SAR Section 3.4.4.1.1. The largest resulting thermal stress calculated by SNC is conservatively used in all load combinations. This stress results from the worst case temperature gradient across the canister at an ambient condition of -40° F. As shown in SAR Table 3.6-1, the design winter condition at the PFSF is -35° F. Therefore, the analysis encompasses the site specific conditions. Similarly, design summer and normal ambient temperatures fall within the other cases analyzed. Section 8.1.2 and TranStor SAR Chapter 4.0 contain a more detailed description of the thermal load evaluation.

Conservatively, the off-normal thermal stresses in the storage cask resulting from the worst case temperature gradient are used in all load combinations. This occurs when all inlet cooling vents are blocked at normal ambient conditions. The ambient temperatures assumed in the TranStor analysis bound the PFSF specific environmental conditions contained in Section 3.2.6 for thermal loads.

D. Handling Loads

Handling loads for normal conditions are contained in TranStor SAR Section 3.4.4.1.4 and for off-normal conditions in TranStor SAR Section 11.1.5. The normal handling decelerations for the canister were assumed to be 0.5 g in all directions. This value is expected to encompass all normal handling operations at the PFSF. The maximum analyzed off-normal handling load is conservatively calculated to be 17.5 g, generated by a 2 fps horizontal impact from a crane handling operation. Since the maximum trolley speed for the overhead crane at the PFSF is 60 fpm (1 fps), the canister will not reach the 2 fps analyzed impact load. Therefore, the TranStor analysis bounds the site specific criteria.

E. Cask Drop and Tipover

Cask drop loads are addressed in TranStor SAR Section 12.2.2.8 and cask tipover loads are addressed in TranStor SAR Section 11.2.10. The storage cask and canister are capable of withstanding accidental drops up to 80 inches without breaching the containment boundary, preventing removal of fuel assemblies, causing a criticality accident, or causing a structural failure of the concrete cask so it cannot maintain its shielding function. The vendor does not consider drop heights below 18 inches to be a concern. There are no operations at the PFSF where a storage cask would be raised above the 18 inch drop height. The cask transporter, used to move storage casks from the Canister Transfer Building to the storage pad, lifts the cask about 4 inches above the concrete. The transporter is designed to mechanically limit the heights below 10 inches. Therefore, the cask drop in the TranStor analysis bounds the PFSF design criteria in Section 3.2.7 for accident drop loads.

Cask tipover, resulting from tornado winds (with a concurrent tornado-generated missile strike) or earthquake, are evaluated and the cask is capable of remaining stable during these events. Therefore, cask tipover in the TranStor analysis bounds the PFSF design criteria in Section 3.2.7 for non-credible hypothetical tipover event loads.

The non-credible hypothetical cask tipover analysis in the TranStor SAR is based on a storage pad that is conservatively assumed to be rigid when cask crushing is considered. However, to determine the forces on the cask and canister due to impact, the assumption is reversed and the cask is assumed to be rigid. In this case, the storage pad is considered to be a yielding surface and the pad target hardness is calculated in accordance with EPRI NP-7551 (Reference 12). The TranStor SAR calculates the impact load from a storage cask tipover as being 17 g. For conservatism, the maximum bounding value for any drop height is calculated to be 19.8 g. Using PFSF site-specific concrete and soil parameters, and applying the same target hardness methodology used by SNC, an acceleration of 16.2 g was calculated to result from a horizontal drop of a TranStor storage cask on to a PFSF storage pad from any drop height.

F. Tornado Winds and Missiles

Tornado wind and tornado generated missile loads are addressed in TranStor SAR Sections 2.2.2 and 11.2.3. The TranStor storage cask is designed for tornado winds and tornado-generated missiles, which include a design basis tornado in accordance with Regulatory Guide 1.76 (Reference 4) for Intensity Region I and postulated tornado-generated missiles in accordance with NUREG-0800 (Reference 5) for Spectrum I missiles. The PFSF is located in Tornado Intensity Region III per Regulatory Guide 1.76, which has less severe tornado conditions than Region I. The postulated missile loads used in the TranStor analysis are the same as in the PFSF design criteria. Since the TranStor tornado wind loads exceed the PFSF design criteria and tornado-generated missile loads are the same as the PFSF design criteria described in Section 3.2.8, the TranStor design meets the PFSF design criteria.

G. Flood

Flood loads are addressed in TranStor SAR Section 11.2.4. The TranStor system is designed to withstand a flood up to a depth of 20-ft and a stream velocity of 24.6 fps without overturning the cask. The PFSF is above probable maximum flood conditions, therefore, the TranStor design meets the PFSF design criteria in Section 3.2.9 for flood conditions.

H. Earthquake

Earthquake loads are addressed in the TranStor SAR Sections 2.2.5 and 11.2.5. The TranStor SAR shows that the storage system will withstand the imposed loads and not tip over when subjected to a generic seismic event. A generic seismic event was defined for the TranStor system using response spectra curves from Regulatory Guide 1.60 (Reference 6) with a zero period acceleration of 0.75 g horizontal (both directions) and 0.50 g vertical. The cask vendor also performed a site specific analysis and determined the storage cask will withstand the imposed loads and not tip over when subjected to the site specific seismic event. The site specific seismic event is defined by site specific response spectra curves with a zero period acceleration of 0.67 g horizontal (both directions) and 0.69 g vertical. Soil-structure interaction was considered in the site specific analysis. The seismic cask stability analyses are described in Section 8.2.1.

Since the cask is demonstrated to remain standing during an earthquake, the stresses in the basket can be evaluated by comparison to the off-normal handling analysis. The seismic accelerations are well bounded by the 17.5 g load used for the basket design during the off-normal handling event. Therefore, no additional evaluation of basket stresses is required.

Even though the storage cask will not tip over during an earthquake, the storage cask is conservatively analyzed for a hypothetical cask tip over event in TranStor SAR Section 11.2.10. The analysis shows that tip over results in deceleration that would not cause any critical damage to the storage cask or fuel basket.

Therefore, the TranStor storage system design meets the PFSF design criteria requirements in Section 3.2.10 for seismic design.

I. Explosion Overpressure

Explosion overpressure loads are addressed in TranStor SAR Section 11.2.8. Regulatory Guide 1.91 (Reference 9) requires a detailed review of the system for overpressures that exceed 1 psi. The TranStor storage system is analyzed and designed to withstand an explosion that could result in overturning or sliding the storage cask. The minimum pressure on the cask to produce this force was an overpressure of 5.4 psig. As shown in Section 8.2.4, the PFSF is not subject to explosions that are in excess of 1 psig. Since the PFSF will not see explosion pressures that exceed 1 psig, the TranStor design meets the PFSF design criteria in Section 3.2.7 for explosion accident loads as required per 10 CFR 72.122(c).

J. Fire

Fire is addressed in TranStor SAR Section 2.3.6. The TranStor storage system materials and location at the PFSF safely protects the spent fuel from fires in accordance with 10 CFR 72.122(c). The storage cask is highly resistant to the effects of fire. The thick concrete walls of the storage cask are capable of protecting the basket. Although the exposed layer of concrete may lose a portion of its strength, it would not disintegrate from an exposure to flame temperatures on the order of 1,500° F as specified in 10 CFR 71. In addition, any fire would be required to burn for a long time (days) before much of the wall thickness would be affected. The cask materials and limited use of combustibles at the site minimizes the effects of fire on the storage system. As discussed in Section 8.2.5, a storage cask is postulated to be involved in a diesel fuel fire, involving up to 50 gallons of diesel fuel spilled from the fuel tank of the cask transporter, which is calculated to burn for 3.6 minutes. This fire would not damage the storage cask concrete, and would have a negligible effect on canister and fuel temperatures. Therefore, the TranStor design meets the PFSF design criteria in Section 3.2.6 for accident-level thermal loads as required per 10 CFR 72.122(c).

4.2.2.5.2 Thermal Design

Thermal performance for the TranStor storage system is addressed in TranStor SAR Chapter 4. The TranStor system is designed to transfer decay heat from the spent fuel assemblies to the environment. Heat generated in the fuel assemblies is transferred to the surrounding inert atmosphere and the basket sleeves by free convection and radiation. It is further conducted through the sleeves towards the exterior of the basket assembly where it conducts, convects, and radiates through the cover gas to the canister shell wall. Heat is then convected to the air in the annulus between the canister shell and the storage cask internal liner, and radiated from the canister shell to the cask liner. Cooling air enters the inlet ducts at the bottom of the TranStor storage cask, flows up the annulus by passive convection, and exits at the top of the storage cask. A small amount of heat is conducted through the concrete to the outer surfaces of the storage cask, then convected to the air.

As discussed in TranStor SAR Chapter 4, several basic models were utilized for the thermal evaluation of the TranStor storage system.

These include:

- Air flow and temperature
- Storage cask body and canister exterior heat transfer
- PWR canister interior heat transfer
- BWR canister interior heat transfer

The ANSYS finite element code was used for calculating storage cask and canister temperatures. The design basis canister heat load of 26 kW was assumed in all the thermal analyses, corresponding to 1.083 kW per PWR fuel assembly and 0.426 kW per BWR fuel assembly. Results of the thermal analyses determined that the TranStor system operates well within thermal design limits. Therefore, no degradation due to temperature effects on materials or components is expected. The analyses results represent maximum temperatures, since the heat source from the fuel assemblies decays with time. While allowable temperatures for the TranStor construction materials do not change, the fuel temperature limits decrease with time. However, SNC notes in TranStor SAR Chapter 4 that the heat load decays faster than the corresponding maximum allowable cladding temperatures, and margins between actual and allowable fuel cladding temperatures increase with time.

Off-normal and accident cases are described in TranStor SAR Chapter 11. The following steady state conditions have been analyzed:

1. Normal condition, average ambient temperature = 75° F, no solar radiation.
2. Off-normal condition, ambient temperature = 100° F, solar radiation.
3. Off-normal condition, ambient temperature = -40° F, no solar radiation.
4. Off-normal condition, ambient temperature = 75° F, no solar radiation, 1/2 of air inlets blocked.
5. Accident condition, ambient temperature = 125° F, solar radiation.

6. Accident condition, ambient temperature = 75° F, no solar radiation, all air inlets blocked.

The TranStor thermal analysis performed for the concrete storage cask verifies that material temperature limits are not exceeded for normal, off-normal, and accident conditions. The TranStor thermal analysis verifies that fuel cladding allowable temperature limits are not exceeded. The minimum temperatures for the TranStor system correspond to the coldest environmental conditions of -40° F and no heat load in the cask. However, even at these extreme conditions the components are above their minimum material temperature limits. The TranStor cask does not employ any temperature-sensitive features such as gaskets, packing, or O-rings.

The results of the thermal analysis for normal, off-normal, and accident conditions is shown in TranStor SAR Table 4.1-1. These results are summarized in Table 4.2-6.

The PFSF site ambient temperatures of -35° F to110° F to are bounded by temperatures used for the TranStor storage system. The heat generation of the fuel to be stored at the PFSF is bounded by the heat generation of the TranStor design basis fuel. Therefore, the thermal design of the TranStor storage system bounds the site specific design requirements.

4.2.2.5.3 Shielding Design

Shielding for the TranStor storage system is addressed in TranStor SAR Chapter 5. The TranStor storage system is designed to maintain ALARA radiation exposure in accordance with 10 CFR 72.126(a). The concrete storage cask is designed to limit the average external dose rate (gamma and neutron) one meter from the cask to less than 15 mrem/hr on the sides (30 mrem/hr for stainless steel clad fuel) and 200 mrem/hr on top at the cover lid centerline based on TranStor design basis fuel. The design dose rates allow limited personnel access during canister closure operations.

Radiation shielding of the TranStor storage system is provided by the 0.75 inch thick steel canister shell, the 2 inch thick steel storage cask liner, and the 29 inch thick reinforced concrete cask wall. Axial shielding at the top is provided primarily by the steel canister shield and structural lids, which have a combined thickness of 11 inches. The 0.75 inch thick steel storage cask lid also provides axial shielding. The inlet and outlet ducts are configured to prevent direct radiation streaming from the spent fuel assemblies to the outside of the cask.

TranStor SAR Section 5.1 provides calculated dose rates on contact and at 1 meter for the top and side surfaces of the TranStor storage cask for design PWR and BWR fuel, which show that the above criteria are met by the TranStor Storage System. Maximum dose rates for TranStor design basis fuels are shown to be approximately 19 mrem/hr on contact with the side and 10 mrem/hr at 1 meter from the side of the TranStor storage cask; 157 mrem/hr on contact with the center of the lid and 135 mrem/hr at 1 meter from the top of the cask; and 7.5 mrem/hr on contact with the top vent and 14 mrem/hr on contact with the bottom vent.

Section 3.3.5 presents the radiological requirements for the PFSF. The requirements originate from 10 CFR 72.104, which requires that the annual dose equivalent to any real individual located beyond the OCA boundary not exceed 25 mrem to the whole body, and from 10 CFR 20.1301, which requires that the hourly dose to any member of the public in any unrestricted area not exceed 2 mrem as a result of exposure to radiation from the PFSF. As discussed in Chapter 7, the TranStor storage system shielding design achieves compliance with this requirement for the PFSF array, assumed to consist of 4,000 TranStor storage casks, configured as shown in the detail on Figure 1.2-1.

4.2.2.5.4 Criticality Design

Criticality of the TranStor storage system is addressed in TranStor SAR Chapter 6. The TranStor storage system controls criticality, in accordance with 10 CFR 72.124(a) and (b), with canister materials and geometry. The primary criteria for the prevention of criticality is that k_{eff} remain below 0.95 for all normal, off-normal, and accident conditions.

Criticality control with the basket inside the TranStor PWR canister is achieved using flux traps and poison plates enabling the system to maintain a k_{eff} below 0.95 for all conditions. Poison plates are included in each of the sleeves adjacent to other fuel assemblies and are only applicable when the canister is submerged in a nuclear plant spent fuel pool or for shipping requirements.

Different loading schemes are available with the PWR and BWR baskets to maximize the transportable fuel enrichment in the TranStor storage system, as discussed in TranStor SAR Chapter 6. The PWR basket, normally loaded with 24 PWR fuel assemblies, can alternatively be loaded with 20 fuel assemblies, leaving the four center sleeves of the basket vacant. The absence of the four center assemblies creates a significant negative reactivity effect that enables the canister to store higher enriched fuels.

Similarly, different loading schemes are available for the BWR basket, normally loaded with 61 fuel assemblies. One scheme involves a partially loaded 60-assembly basket, with the center sleeve vacant. Another loading scheme involves a partially loaded 52-assembly basket, with the nine center sleeves left vacant. The 52-assembly BWR basket configuration is used primarily to satisfy thermal considerations, as opposed to achieving higher allowable initial enrichments. Therefore, criticality calculations to establish higher allowable enrichments for the 52-assembly basket were not performed.

The maximum allowable enrichments for the 60-assembly basket apply for the 52-assembly basket as well.

The detailed criticality evaluation of the TranStor storage system is presented in the TranStor shipping SAR (Reference 13). The effects of variations in moderator density were evaluated using the most reactive PWR (WE 15X15) and BWR (GE 8X8 R) fuel assemblies. The PWR cases assumed an enrichment of 4.1 percent and the BWR cases assumed an enrichment of 3.6 percent, the maximum allowable enrichment for the WE 15X15 and GE 8X8 R assemblies, respectively. The maximum calculated k_{eff} values for TranStor canisters loaded with these fuel types are close to 0.95, as shown in TranStor shipping SAR Tables 6.4-1 through 6.4-4.

Criticality analyses were performed to determine the maximum allowable enrichment level for each PWR and BWR fuel assembly type. For each analysis the optimum basket configurations were assumed, along with the optimum cask internal and external moderator densities. For each assembly type, the maximum enrichment that yields final k_{eff} values under 0.95 was determined. Analyses were performed on all four basket configurations (24 and 20 assembly PWR baskets and 61 and 60 assembly BWR baskets), and the results presented in TranStor shipping SAR Tables 6.4-5 through 6.4-8. The results demonstrate that k_{eff} is less than the 0.95 regulatory limit for each fuel type/enrichment allowed to be stored in the TranStor storage system.

TranStor SAR Tables 12.2-2 and 12.2-3 identify maximum allowable enrichments for various fuel types for 24 and 20 assembly PWR baskets. As shown in these tables, all PWR fuel assembly types with an enrichment at or below 4.1 percent can be safely stored in the 24 assembly basket, and all PWR fuel assembly types with an enrichment at or below 4.4 percent can be safely stored in the 20 assembly basket, with higher enrichments permitted for certain specified fuel types. TranStor SAR Tables 12.2-4 and 12.2-5 identify maximum allowable enrichments for various fuel types for 61 and 60 assembly BWR baskets. As shown in these tables, all BWR fuel assemblies with an enrichment at or below 3.5 percent can be safely stored in the 61 assembly basket, and all BWR fuel assembly types with an enrichment at or below 3.7 percent can be safely stored in the 60-assembly basket, with higher enrichments permitted for certain specified fuel types.

As discussed in TranStor SAR Section 6.2, stainless steel cladding has a much higher thermal neutron absorption cross-section than Zircaloy cladding. The stainless steel clad version of a given assembly type will be much less reactive for a given enrichment level than the Zircaloy clad version of the same fuel assembly type. Thus, the enrichment limits stated for each assembly type in TranStor SAR Tables 12.2-2 through 12.2-5 apply for the stainless steel clad versions of those assembly types.

The TranStor canister containing the PWR basket can store up to 4 partial or failed PWR fuel assemblies that are placed in cans inside the four larger sleeves in the corners of the basket. Similarly, the BWR basket can store up to 8 canistered failed BWR fuel assemblies.

The TranStor canister can store four specific WE 14X14 MOX fuel assemblies into the TranStor PWR basket. Calculations show that these assemblies are significantly less reactive than WE 14X14 UO_2-fueled assemblies with the maximum allowable enrichment levels.

Since criticality control is ensured by the canister basket design, criticality monitoring addressed by 10 CFR 72.124(c) is not applicable for the PFSF.

4.2.2.5.5 Confinement Design

Confinement for the TranStor storage system is addressed in TranStor SAR Chapter 7. The confinement boundaries of the TranStor storage system provide a redundant confinement boundary to the fuel cladding, in accordance with 10 CFR 72.122(h), and consist of the canister shell, bottom plate, inner shield lid, and the outer structural lid.

The canister is designed, constructed, and inspected in accordance with ASME III (Reference 11), Section NC. Since the TranStor canister is a totally sealed (welded) container, no leakage of the confinement boundary will occur. However, each canister is hydrostatically leak tested per ASME III, Section NC, to ensure there is no leakage. Nondestructive examination (NDE) of the welds consists of radiographic, magnetic particle, or liquid penetrant examinations as required by ASME III. An exception to ASME III NDE requirements is taken for the structural lid, shield lid, and vent and drain access lid welds that are inspected by dye penetrant but not radiographed. NDE is evaluated in accordance with ASME III, Section NC-5300. Analysis of the welds show that under normal and accident conditions stress levels are well below the maximum ASME III, Section NC allowables.

Monitoring requirements for the confinement boundaries are not required since there are no mechanical seals.

The canister is filled with helium to ensure that the canister internals are contained within a non-reactive, inert environment to protect the fuel cladding.

The confinement features of the TranStor storage system meet the requirements of the PFSF design criteria in Section 3.3.2 for confinement barriers and systems.

4.2.3 Cask Storage Pads

The design criteria for the cask storage pads are described in Chapter 3. The analysis methods and resulting design of the pads are described below.

4.2.3.1 Design Specifications

The design of the cask storage pads is in accordance with ANSI/ANS-57.9 (Reference 14) and ACI 349 (Reference 15) as identified in Chapter 3.

The cask storage pads are independent structural units constructed of reinforced concrete. Each pad is 30 ft wide by 64 ft long and 3 ft thick. The size of the pad is based on a center to center spacing of 15 ft for the storage casks. The ends of the storage pad are provided with an additional 2 ft in length to support both tracks of the cask transporter on the pad. The pads are nearly flush with grade for direct access by the cask transporter. Each cask storage pad is capable of supporting 8 loaded HI-STORM or TranStor storage casks.

An independent modular pad design was chosen to simplify the pad analysis (i.e. minimize the number of cask placement combinations) and to minimize the effects of thermal expansion. The modular pad design also provides for ease of construction by limiting the number of concrete pad construction and/or expansion joints required and allows for staged construction of the facility.

The cask storage pad design is based on a maximum loaded storage cask weight of 356,500 lbs. This maximum weight is associated with the HI-STORM storage cask loaded with an MPC-32 (32 fuel assembly capacity PWR canister) and envelopes the maximum loaded weight of both the TranStor and HI-STORM concrete storage casks proposed for use at the PFSF. The TranStor storage cask has a maximum loaded weight of 309,130 lb. as shown on TranStor SAR Table 3.2-1. The HI-STORM storage cask has a maximum loaded weight of 356,521 lb. (MPC-32) as shown on HI-STORM SAR Table 3.2.1. The Holtec MPC-32 has the maximum weight of all of the HI-STORM series canisters and is conservatively used in the design, even though it is not proposed for use at the PFSF. The HI-STORM canisters proposed for use at the PFSF are the MPC-24 and the MPC-68 with maximum weights of 346,495 lb. and 353,796 lb., respectively, when in the HI-STORM storage cask, both of which are bounded by the weight of the MPC-32, when in the HI-STORM storage cask.

The cask storage pad design also considers the weight of the loaded concrete storage casks in combination with the seismic loads due to the Design Earthquake (DE) for the site.

4.2.3.2 Plans and Sections

The site plan, which shows the locations of the concrete storage pads, is shown in Figure 1.2-1. A typical concrete storage pad plan, cross section, and details are shown in Figure 4.2-7.

4.2.3.3 Function

The function of the cask storage pads is to provide a level and stable surface for placement and storage of the TranStor and HI-STORM concrete storage casks containing the spent fuel canisters.

4.2.3.4 Components

The components of the cask storage pads consist of the materials of construction, which include concrete with a minimum 28-day compressive strength of 4,000 psi and reinforcing steel with a minimum yield strength of 60,000 psi.

4.2.3.5 Design Bases and Safety Assurance

The design bases for the cask storage pads are identified in Chapter 3.

The cask storage pads are classified as being Important to Safety in order to provide the appropriate level of quality assurance in the design and construction. This provides for the safety assurance that the cask storage pads will perform their intended function.

4.2.3.5.1 Storage Pad Analysis

The reinforced concrete pads were analyzed and designed in accordance with nuclear industry standard structural analysis and design methods (Reference 16). The static and dynamic analyses for evaluating the concrete pad response displacements and internal stresses have used standard finite element analysis computer programs CECSAP (Reference 17) and SASSI (Reference 18) computer codes.

Static analyses have been performed for the dead load and design live (storage cask) loads using the CECSAP computer program. Dynamic analyses have been performed for the DE loading also using the CECSAP computer program. In addition, a separate dynamic analysis was performed using the SASSI computer program to more rigorously account for the effect of soil-structure interaction. These static and dynamic analyses confirm the structural adequacy of the reinforced concrete storage pad for supporting the storage casks when subjected to the design loading conditions. The results of the pad dynamic analysis using SASSI confirmed validity and indicated conservatism of the corresponding results using CECSAP.

The structural analyses of the pad used a three-dimensional flat-shell finite element model for the concrete pad. The finite element model mesh developed for the pad is shown in Figure 4.2-8. A total of 264 flat-shell finite elements have been used to model the concrete pad. Gross uncracked stiffnesses have been used for the model. The finite element mesh was developed with the consideration that it would produce reasonably refined distribution of internal forces and moments. Also, the nodal points of the mesh coincided with the locations of the static and dynamic loadings associated with one to eight casks to be applied on the pad. These loadings are lumped to four points on the outer circular perimeter of each cask corresponding to the four quadrants of the cask. Various cask loading patterns were considered to determine the maximum pad internal stresses.

To represent the soil support condition of the pads for the long-term static (i.e. dead and live) load conditions, vertical boundary soil springs tributary to each node of the pad finite element model were used in the CECSAP static finite element model. The spring stiffness values for the static loading cases were developed from the modulus of subgrade reaction (20 kips/ft^3) of the supporting soil medium (Reference 19). For the short-term DE dynamic loading condition, three-component (two horizontal and one vertical) boundary soil springs and dashpots representing the dynamic soil stiffnesses and radial damping characteristics of the supporting soil medium were used to connect to each node of the pad model. The soil spring stiffness (and its associated soil mass), and radial damping coefficient tributary to each node were derived from the lumped soil spring stiffness, mass, and damping coefficient values based on the procedure in ASCE-4 (Reference 20). For the dynamic analysis using the SASSI computer program, the soil support to the pad was represented by three-component (two horizontal and one vertical) complex-valued dynamic soil impedance functions that are connected to each node of the pad finite element model. The soil impedance functions were computed numerically within the SASSI computer program based on the free-field profile and dynamic properties of the soil layers underlying the pad.

The pad structural analyses included both static and dynamic analyses. The static analysis evaluated the pad response stresses due to the dead and (cask) live loads. The dynamic analysis evaluated the pad response due to the DE loadings. The pad responses obtained from these analyses were then combined to give the combined maximum response values in accordance with the applicable load combinations. The combined response values were then used for checking the structural adequacy of the concrete pad and the soil bearing and sliding stabilities. The static and dynamic pad analyses performed for the pad are separately described below.

A. Static Analysis

The static pad analysis, using the CECSAP finite element model for the pad, was conducted for the dead load equal to the gravitational dead weight of the pad and the live load of the casks. The live loads from three loading patterns of 2, 4, and 8 fully-loaded casks were considered. The weight of one fully-loaded cask considered was 356.5 kips. To simulate the condition of one fully-loaded cask being transported onto the pad, one additional cask loading pattern consisting of 7 fully-loaded casks and one fully-loaded cask being lifted by a cask transporter on the pad having a weight of 135 kips (Reference 21) was also considered. For conservatism, a dynamic impact factor equal to 1.0 was used for the load of one fully-loaded cask plus the transporter to account for any dynamic effect that may arise during transporting of the cask. From the analysis results obtained, the worst-case cask-loading pattern that produces the highest pad internal stresses is that of four casks on the pad and the worst-case loading that produces the largest soil bearing pressure is that of 7 casks plus one cask being carried by a transporter. The maximum response results obtained from the static analyses are summarized in Table 4.2-7.

B. Dynamic Analysis

The dynamic analysis was performed to determine the pad response stresses under the design earthquake loading. The global seismic time-history response analysis was performed utilizing a series of cask-pad-soil interaction models representing the dynamic characteristics of one to eight casks supported on the pad, which is, supported on the site soil. To account for uncertainties in the frictional resistance to horizontal movements of casks on pad, the friction coefficient between the cask-base and the concrete-pad considered in these analyses was varied from a lower-bound value of 0.2 to an upper-bound value of 0.8. The case with the lower-bound friction results in an upper-bound estimate on the sliding displacements of casks on the pad and a lower-bound estimate on the cask dynamic forces acting on the pad; whereas, the upper-bound friction case results in a lower-bound estimate on the sliding displacements but an upper-bound estimate on the cask dynamic forces acting on the pad. Thus, for the purpose of determining the upper-bound seismic stresses in the pad, the cask dynamic force time histories resulting from the upper-bound friction case were conservatively used as the dynamic forcing function inputs to the pad. These dynamic forcing function inputs were provided by the Holtec site specific cask stability analysis for the HI-STORM storage cask (Reference 7). The HI-STORM storage cask weight and center of gravity loadings bound those of the TranStor storage cask. For the pad analysis, these dynamic forcing time histories were evaluated for each cask at four points that are equally-spaced along the circular outer perimeter of the cask base. At each point, a set of three-component (two horizontal and one vertical) dynamic forcing time histories was evaluated which represent the lumped dynamic reaction forces of the pad to the cask within the four quadrants of each circular cask-base area.

In evaluating the pad dynamic stresses due to the dynamic forces of the casks acting on the pad, the finite element dynamic model of the pad-soil system (using CECSAP) was used and the dynamic force time histories of the casks were applied on the pad as nodal forcing functions. To reasonably bound the various cask loading patterns, the same 2, 4, and 8 cask loading configurations as considered in the static analyses were also considered in the dynamic response analysis. The maximum values of the pad response shear forces and bending moments resulting from the analysis were then evaluated and used for checking the structural adequacy of the pad design. The maximum values of the three-component (two horizontal and one vertical) soil-spring reaction forces were also evaluated and used for checking the bearing and sliding stabilities of the soil supporting the pad. The results of the maximum dynamic response values obtained from the dynamic analysis described above are summarized in Table 4.2-8. Based on the analysis results obtained, the worst-case cask-loading pattern that produces the maximum dynamic pad internal stresses and soil pressures is that of two casks and the worst-case loading that produces the largest seismic horizontal soil reaction forces is that of 8 casks.

To provide a comparison and an assessment of the accuracy and conservatism of the dynamic analysis results from the CECSAP pad-soil system model, a dynamic analysis using a finite element model using the SASSI computer program was also performed for a selected dynamic loading case. The dynamic response results obtained from this SASSI analysis was compared with the corresponding results obtained the CECSAP analysis. This comparison indicates that the CECSAP analysis results are closely comparable to the corresponding SASSI analysis results and that the CECSAP results are conservative relative to the corresponding SASSI results by a margin of greater than 20 percent.

4.2.3.5.2 Storage Pad Design

The storage pad design is a 3 ft thick reinforced concrete slab with #10 longitudinal and transverse horizontal reinforcing bars spaced at 12 inches on center each way at the top face and #10 longitudinal and transverse horizontal reinforcing bars spaced at 6 inches on center each way at the bottom face of the pad. The top and bottom face horizontal reinforcements are tied through the thickness of the pad by #7 vertical shear reinforcing bars spaced at 12 inches on center each way in two ways uniformly distributed over the entire pad. The concrete has a minimum 28-day compressive strength of 4,000 psi and the reinforcing steel has a minimum yield strength of 60,000 psi. The design provides an ultimate static moment capacity of 338 k-ft/ft, an ultimate dynamic (impulse or impactive) moment capacity of 423 k-ft/ft, and a corresponding ultimate static and dynamic shear capacity of 123 k/ft and 135 k/ft, respectively. The maximum bending moment and shear force demands associated with the normal loading condition (1.4D + 1.7L + 1.7H) are 145.4 k-ft/ft and 19.2 k/ft, respectively; the maximum bending moment and shear force demands associated with the accident-level loading condition (D + L + H + E) are 383.3 k-ft/ft and 111.1 k/ft. Therefore, the storage pad as designed provides adequate strength for accommodating the design loading conditions.

Soil pressures beneath the storage pad were also verified to be within the acceptance criteria for all loading conditions. Actual soil bearing pressures were calculated beneath the pad and compared to the allowable soil bearing pressures identified in Section 2.6.1.12 for both static and dynamic load combinations. The maximum static soil pressure was calculated to be 2.12 ksf, 2.31 ksf, and 2.02 ksf for the pad dead load plus 2 casks, 4 casks, and 8 casks, respectively. A worst case static soil pressure was determined for a loading condition consisting of 7 casks plus 1 cask on the transporter with a dynamic impact factor of 1.0. This case resulted in a maximum soil bearing pressure of 3.50 ksf. All of the static load cases were within the allowable soil bearing pressure of 4.0 ksf. The maximum dynamic soil pressure, which includes earthquake loadings, was also calculated for the pad dead load plus 2 casks, 4 casks, and 8 casks. The resulting soil pressure distribution was converted to an average soil pressure over an effective pad width and compared to the allowable dynamic soil pressure. All of the dynamic load cases were below the minimum allowable dynamic soil bearing pressure.

4.2.3.5.3 Storage Pad Settlement

The relationship of major foundations to subsurface materials is contained in Section 2.6.16. Storage pad soil bearing capacity and settlement analysis is described in Section 2.6.1.12.1.

The in-situ soil is suitable for supporting the cask storage pads, but settlements are expected to occur. Analyses were performed to calculate the estimated settlement of the storage pads from the weight of the pad with 8 fully loaded casks in place. The nominal soil bearing pressure for this case is approximately 1.9 ksf and the total estimated settlement of the pad is approximately 3.3 inches.

In order to accommodate the total estimated settlement, the storage pads will be constructed 3.5 inches above adjacent finished grade. Exposed edges of the pad will be chamfered and the crushed rock surface materials will be feathered to meet the edges of the raised pads for transporter access.

Foundation preparation for the storage pad consists of the necessary soil excavation and placement of a 4 inch concrete mud mat on the insitu soil to preclude excessive disturbance of the existing soil and its natural cohesive structure. The bottom of the mud mat and the bottom of the cask storage pad are below the specified local frost depth of 30 inches below grade in accordance with the Geotechnical section of the Storage Facility Design Criteria (Reference 22).

Uniform downward settlement has no adverse effect on either the pad or the casks, it only lowers the final elevation of the storage pad. The storage pads will be constructed 3.5 inches above the surrounding grade to allow for settlements and yet maintain the surface drainage scheme at the site. The first pads constructed and loaded will be monitored for settlements to confirm the calculated settlements and make future adjustments, if necessary. The temporary uniform differential settlement of the pad from partial cask placements causes no loss of structural integrity to the pad. The storage pad is not susceptible to subsurface failures associated with liquefaction since the site is not subject to liquefaction.

4.2.3.5.4 Cask Stability

Cask stability ensures the storage casks will not tip over or slide excessively during a seismic event. Both the HI-STORM SAR and TranStor SAR contain a generic cask stability analysis for a selected upper bound ISFSI Design Earthquake. However, the generic analyses do not consider soil-structure interaction, which can amplify seismic accelerations. Consequently, a site-specific cask stability analysis has been performed by both Holtec and SNC that demonstrates the storage casks will not tip over or slide excessively during a Design Earthquake. The cask stability analyses are described in detail in Section 8.2.1. The cask storage pad is designed for the loads generated from the site-specific cask stability analyses and will provide the required support for the storage casks.

4.3 AUXILIARY SYSTEMS

4.3.1 Ventilation and Offgas Systems

The canister-based storage technologies use a sealed (welded) canister design that precludes the need for ventilation or off-gas systems. No canisters will be opened at the site, therefore no ventilation system is required.

4.3.2 Electrical Systems

4.3.2.1 Major Components and Operating Characteristics

Normal electrical power is provided at the PFSF by an existing 12.5 kV offsite distribution power line, which runs parallel to Skull Valley Road. A new line will provide power from the 12.5 kV distribution power line to a 480 volt site transformer. Normal power is provided to the PFSF for lighting, general utilities, security system, HVAC loads, crane loads, and miscellaneous equipment.

Emergency backup power is provided at the PFSF by a 480 volt diesel-generator. The emergency power supply is limited to the security system, emergency lighting loads, storage cask temperature monitoring system, and the site communications system. The diesel generator fuel supply is sized to provide continuous operation for a minimum 24 hour period. The diesel generator is located in the Security and Health Physics Building. A battery charger is provided with automatic and manual charge control to maintain fully charged diesel generator starting batteries when the unit is stopped.

An Uninterruptible Power Source (UPS) is utilized to support the security loads until the diesel starts and comes up to speed. The UPS system is a 120 volt, single phase system with integral batteries and battery charger. The UPS system is designed for a minimum of 1 hour operation without replacing or recharging batteries. The UPS system is located in the Security and Health Physics Building.

4.3.2.2 Safety Considerations and Controls

In the event of a loss of offsite power, the UPS system is designed to automatically switch over to the battery source without loss of output voltage. When the diesel generator comes up to speed, the UPS automatically switches back to its normal source (which is then from the diesel generator) without loss of output voltage or battery recharge.

The diesel generator is provided with starting batteries maintained to supply sufficient capacity to consecutively crank the engine a minimum of five times. When the diesel generator starts, an automatic transfer switch transfers the security, emergency, and temperature monitoring loads to the generator when the diesel comes up to speed. Transfer back to normal offsite power takes place after the normal power is restored for a minimum of 30 minutes.

Electrical power is not classified as Important to Safety since the storage systems do not require electrical power for operation. In addition the cranes and operating equipment have been designed to maintain adequate safety provisions for handling spent fuel canisters in the event of a loss of power as discussed in Section 8.1.1.

4.3.3 Air Supply Systems

An air supply system is provided at the PFSF in the Canister Transfer Building and Operation and Maintenance Building for maintenance purposes. There are no SSCs classified as being Important to Safety that require compressed air for operation.

4.3.4 Steam Supply and Distribution System

A steam supply system is not provided at the PFSF. There are no SSCs classified as being Important to Safety that require steam for operation.

4.3.5 Water Supply System

A water supply system is provided at the PFSF for normal facility services and operation and maintenance functions. There are no safety related SSCs classified as being Important to Safety that require water for operation.

4.3.6 Sewage Treatment System

A sewage (septic) system is provided at the PFSF for normal facility services.

4.3.7 Communications and Alarm Systems

The communication systems consist of normal telephone service in all the buildings, a site public address system, and a short-wave radio system for security. The communication systems provide a means to contact the local law enforcement authorities for security purposes and for emergency responses on site in the event of an "ALERT", with notifications and follow-up communications.

In the event of an emergency, facility personnel and visitors on site are notified by an announcement over the onsite communications system (intercom). Offsite emergency response personnel are notified by means of personal pagers and/or using the notification list of telephone numbers located in the Emergency Plan implementing procedures. Alarms at the PFSF are only used on area radiation monitors to notify nearby personnel of doses that exceed the alarm setpoint.

Portable two-way radios are used by security personnel to maintain continuous communications with the Security and Health Physics Building while on patrol. The communication system is in accordance with proposed rule 10 CFR 73.51 (Reference 23).

4.3.8 Fire Protection System

4.3.8.1 Design Basis

Fires that could affect SSCs classified as Important to Safety are postulated to result from diesel fuel sources originating from the cask transporter or shipping cask transport vehicles (heavy haul tractor/trailer or railroad locomotive). SSCs affected include the storage casks in the yard and the shipping and storage system components and cranes in the Canister Transfer Building. Scenarios for a fire in both locations considering fire location, intensity, and duration have been analyzed in Section 8.2.5. The analysis determined that the fires will not compromise the safety provisions of the SSCs.

No other major fire fuel sources are located in areas near SSCs classified as Important to Safety. The Canister Transfer Building is constructed of noncombustible materials and is designed to limit the potential effects from a diesel fuel fire with curbs, raised thresholds, and sloped floors located to contain spilled diesel fuel away from SSCs.

The Canister Transfer Building is designed with a fire detection system and a fire suppression system to aid in the mitigation of fires. Portable fire extinguishers are located in the building and yard areas to facilitate fire suppression. The fire detection system is designed in accordance with NFPA 72E (Reference 24). The fire suppression system consists of a sprinkler system designed, installed, and tested in accordance with the Uniform Building Code (Reference 25) and NFPA 13 (Reference 26) and 13A (Reference 27). The fire pumps and water supply tanks are provided in accordance with NFPA 20 (Reference 28) and NFPA 22 (Reference 29) respectively. The portable fire extinguishers are provided in accordance with NFPA 10 (Reference 30).

4.3.8.2 System Description

A sprinkler type fire suppression system is provided in the Canister Transfer Building to mitigate potential fires. The sprinkler system is supplied water by fire pumps located outside of the RA. Water for the pumps is supplied by a primary and a backup water tank. One pump is powered by an electric motor, the other by a diesel engine in the event of a loss of electrical power.

Fire hydrants are located near the buildings to support fire suppression of the buildings. The PFSF is served by at least one fire truck located at the site and on truck located at the Goshute Village 3.5 miles from the site to suppress fires that may occur around the site such as brush fires.

The fire detection system consists of photo-sensitive smoke detectors located in all the facility buildings. The smoke detectors are interconnected within each building and are connected to a central alarm panel located in the Security and Health Physics Building. Annunciation of the smoke alarms occurs within both the building where the detector is located and the central alarm panel. A trip of the fire detection system in the Canister Transfer Building will automatically set off the building's fire sprinkler system.

Smoke from a fire in the Canister Transfer Building will be removed by the building's ventilation exhaust fans.

4.3.8.3 System Evaluation

An evaluation of potential fires affecting SSCs classified as Important to Safety is shown in Section 8.2.5. The analysis concludes that these fires will not produce an unsafe condition or preclude the ability of SSCs from performing their safety related function. The sprinkler system ensures that fires that could occur in the Canister Transfer Building will be extinguished within minutes.

4.3.8.4 Inspection and Testing Requirements

Preoperational and periodic operational testing and inspection of the fire detection and fire suppression systems will be performed in accordance with requirements of Section 9.2.

4.3.8.5 Personnel Qualification and Training

Training and qualification requirements associated with the testing, inspection, and operation of the fire systems will be in accordance with the requirements of Section 9.3.

4.3.9 Maintenance System

4.3.9.1 Major Components and Operating Characteristics

The PFSF has relatively few maintenance requirements because of the passive nature of the storage system's design. Major components at the PFSF that require routine periodic maintenance include the overhead bridge crane, semi-gantry crane, transfer equipment, and fire suppression system located in the Canister Transfer Building, the rail cars or heavy haul tractor/trailer units, the cask transporters, the backup diesel generator located in the Security and Health Physics Building, and the temperature monitoring equipment, fire pumps, and fire engine.

Periodic inspection and maintenance is also required to ensure the storage cask air ducts are not blocked from snow, dirt, debris, or small animal nesting per the operation controls and limits given in Chapter 10.

4.3.9.2 Safety Considerations and Controls

Routine maintenance procedures ensure that timely maintenance is performed according to equipment manufacturer's standards. The Operations and Maintenance Building is designed to facilitate activities performed on equipment and provide a safe environment. Ladders and platforms mounted on the walls and cranes in the Canister Transfer Building are used to access the cranes for maintenance and inspection activities. PFSF procedures prevent maintenance of the cranes or transfer equipment near casks loaded with spent fuel to minimize personnel radiation doses. Maintenance and inspection of the temperature monitoring system at the storage casks or the storage cask air vents are controlled by PFSF procedures to ensure that the work is performed ALARA.

4.3.10 Cold Chemical Systems

There are no chemical systems required or provided at the PFSF.

4.3.11 Air Sampling Systems

Since the spent fuel is totally contained within the canisters, there is no need for air sampling systems or airborne monitors except for the hand held monitor use to analyze the air sample taken from the shipping cask prior to being opened.

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4.4 DECONTAMINATION SYSTEMS

4.4.1 Equipment Decontamination

Normally, decontamination of equipment is not required at the PFSF. Decontamination activities are performed as needed at the originating nuclear power plants prior to transferring canisters to the PFSF. Under off-normal conditions in which contamination of equipment or structures is encountered, decontamination would be performed using methods (e.g., paper wipes or rags) that only result in the generation of dry active waste.

4.4.2 Personnel Decontamination

Contamination of personnel is not expected to occur under normal conditions of operation. In accordance with the PFSLLC's policy to prevent generation of liquid radioactive waste, any necessary decontamination of personnel will be conducted using methods that only produce dry active solid radioactive waste. Decontamination methods would include wiping the contaminated area with rags or paper wipes. Provisions for personnel decontamination are contained in the Security and Health Physics Building.

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4.5 SHIPPING CASKS AND ASSOCIATED COMPONENTS

Spent fuel shipping casks are used to transport the spent fuel canisters from the originating power plants to the PFSF and later offsite. The shipping casks are designed to protect the canisters from the effects of environmental conditions, natural phenomena, and accidents in accordance with 10 CFR 71. Shipping casks are not licensed under 10 CFR 72. However, since the shipping casks are used to transport spent fuel to and from the PFSF and are part of the canister transfer process in the Canister Transfer Building, this section provides a brief summary of the shipping casks and associated components.

The shipping casks are shipped to the PFSF and shipped offsite at a later date complete with impact limiters, a shipping cradle, and tie downs. The shipping casks are shipped from the railroad mainline to the PFSF either by rail on a railroad spur or by highway. The highway shipment alternative requires the shipping casks be transferred from the rail car to a heavy haul tractor/trailer at an intermodal transfer point. During the rail to trailer transfer, the cask and shipping components remain an integral unit under 10 CFR 71 packaging requirements. At the PFSF, the shipping cask is unloaded from the rail car or heavy haul tractor/trailer and moved to a canister transfer cell where the shipping cask is opened and the canister is removed. After the canister is unloaded, the shipping cask is resealed and sent back to the power plants for reloading of another sealed canister of spent fuel.

The shipping components addressed in this section are:

- HI-STAR shipping cask system
- TranStor shipping cask system
- Shipping cask repair and maintenance area
- Skull Valley Road / Intermodal transfer point alternative
- Railroad spur alternative

The shipping casks and associated components are described below. Figures are provided to illustrate the systems and their function.

4.5.1 HI-STAR Shipping Cask System

The HI-STAR system is one of the shipping systems used to ship spent fuel from the originating power plants to the PFSF. The HI-STAR (Holtec International Storage, Transport, and Repository) is a spent fuel packaging design in compliance with DOE's design procurement specifications for multi-purpose canisters and large transportation casks. The HI-STAR system consists of the same sealed metal canister as used in the HI-STORM storage system, which is confined within a metal overpack or cask with impact limiters. Holtec submitted a SAR to the NRC in accordance with 10 CFR 71 for the HI-STAR system (Reference 3). The HI-STAR system components are shown on Figure 4.5-1. Details of the system and design parameters are addressed in the HI-STAR shipping SAR.

4.5.2 TranStor Shipping Cask System

The TranStor system is one of the shipping systems used to ship spent fuel from the originating power plants to the PFSF. The TranStor system is a multi-purpose canister system used for the safe storage and offsite shipping of spent nuclear fuel. The TranStor system includes a sealed metal canister, a shipping cask with impact limiters, a concrete storage cask, and a transfer cask. The canister is used in combination with the storage cask and the shipping cask components. Offsite shipping of spent fuel is performed using only the canister and the shipping cask components. SNC submitted a SAR to the NRC in accordance with 10 CFR 71 for the TranStor system (Reference 13). The TranStor system components are shown on Figure 4.5-2. Details of the system and design parameters are addressed in the TranStor shipping SAR.

4.5.3 Shipping Cask Repair and Maintenance

If shipping cask repair or maintenance activities are necessary, they will be conducted at the Operation and Maintenance Building or at a vendor designated location. No special contamination control measures are anticipated for repair or maintenance activities since the spent fuel is contained within a sealed canister and the shipping casks used for the PFSF do not enter any nuclear plant spent fuel pools and therefore, remain free of radioactive contamination.

Health physics surveys will be taken on all incoming canisters as normal receiving operations at the PFSF. In the event contamination above acceptance levels is discovered, the canister will be shipped back to the originating nuclear power plant for canister decontamination and/or spent fuel repackaging.

4.5.4 Skull Valley Road / Intermodal Transfer Point Alternative

4.5.4.1 Intermodal Transfer Point

Utilizing the Skull Valley Road / intermodal transfer point alternative, the shipping casks are moved by the use of roads from the rail mainline to the PFSF using intermodal transfer. An intermodal transfer point is at Timpie, which is approximately 24 miles north of the PFSF. The intermodal transfer point equipment is designed to accommodate transfer of the shipping casks from the rail car to the heavy haul tractor/trailer unit for highway shipping. The intermodal transfer point consists of a rail siding off the Union Pacific Railroad mainline, a 150 ton gantry crane, and a tractor/trailer yard area. The gantry crane is a single-failure-proof crane to preclude the accidental drop of a shipping cask even though the cask is designed to withstand such drops in accordance with 10 CFR 71. The crane is housed in a weather enclosure, which provides a clean, dry environment for transfer of the shipping cask.

The equipment at the intermodal transfer point is shown on Figure 4.5-3.

4.5.4.2 Shipping Cask Heavy Haul Tractor/Trailer

Utilizing the Skull Valley Road / intermodal transport point alternative, heavy haul transport tractor/trailers are used to transport the shipping cask from the intermodal transfer point to the PFSF. The maximum weight of a loaded shipping cask with impact limiters and shipping cradle is approximately 142 tons, which requires the use of overweight trailers. The heavy haul tractor/trailers are designed to accommodate road conditions at the intermodal transfer point, PFSF, and county highway. The unit is designed to travel at low speeds and is 12 ft wide with multiple wheel sets to provide stable transport of the shipping cask.

The unit is classified as not Important to Safety since safety of the spent fuel canister is maintained by the shipping cask. A typical heavy haul transport tractor/trailer unit is shown on Figure 4.5-4.

4.5.5 Railroad Spur Alternative

4.5.5.1 Railroad Spur

Utilizing the railroad spur alternative, the shipping casks continue on from the rail mainline to the PFSF by rail car. A rail spur would be built from the Union Pacific mainline to the PFSF. The rail spur is designed to standard railroad load, grade, and clearance requirements per the Union Pacific Railroad and industry standards to facilitate use of Union Pacific and standard railroad equipment.

4.5.5.2 Shipping Cask Rail Car

Utilizing the rail spur alternative, standard 145-ton (six axle) flatbed rail cars are used to transport shipping casks to the PFSF. The maximum weight of the shipping cask with impact limiters and shipping cradle on the rail car is approximately 142 tons as discussed in Section 4.5.4.2, which is within the allowable load for a 145 ton flatbed rail car. The Canister Transfer Building cask load/unload bays are designed with railroad tracks to facilitate rail car shipments where the shipping casks would be unloaded or loaded.

The flat bed rail cars are classified as not Important to Safety since spent fuel safety functions are maintained by the shipping cask. A typical 145 ton flat bed rail car is shown on Figure 4.5-5.

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4.6 CATHODIC PROTECTION

There are no cathodic protection systems required or provided at the PFSF. Underground piping used for the water supply and septic systems consists of non-metallic piping. Underground conduit consists of non-metallic conduit encased in concrete duct banks.

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4.7 SPENT FUEL HANDLING OPERATION SYSTEMS

The spent fuel handling systems are provided to transfer the spent fuel canisters from the shipping cask to the storage cask, and eventually back to the shipping cask for transporting offsite. During transfer operations, the spent fuel remains confined within the sealed metal canister at all times. No individual spent fuel assemblies are handled at the PFSF.

The spent fuel handling systems used to handle spent fuel at the PFSF consist of the following:

- Canister Transfer Building
- Canister transfer cranes
- HI-STORM transfer equipment
- TranStor transfer equipment
- Cask transporter

The spent fuel handling systems are designed to ensure adequate safety and to withstand the effects of site environmental conditions, natural phenomena, and accidents in accordance with 10 CFR 72.122(b) and 10 CFR 72.128(a).

The handling SSCs are designed to permit testing, inspection, and maintenance in accordance with 10 CFR 72.122(f). The acceptance test and maintenance program of the systems are specified in HI-STORM SAR Chapter 9 and TranStor SAR Chapter 9.

Regulation 10 CFR 72.122(l) requires that the storage systems be designed to allow ready retrieval of spent fuel for further processing or disposal. The canister based storage systems utilized at the PFSF accommodate this requirement. At the end of the storage period, the sealed canisters will be shipped offsite to the federal government.

Chapter 5 outlines the procedure for canister transfer from a storage cask into a shipping cask and offsite.

Retrieval of individual spent fuel assemblies from the canister before offsite shipping is not anticipated. As described earlier in this chapter, the canister is designed to withstand all normal, off-normal, and accident-level events. Nevertheless, retrieval of the spent fuel from the canister can be achieved if necessary. In the event the spent fuel assemblies require unloading prior to being shipped offsite, the canister will be shipped back to the originating nuclear power plant via a shipping cask (if the originating plant is still available) or the individual spent fuel assemblies will be transferred into a different canister as described in Section 8.2.7.4.

Each of the spent fuel handling systems are described in the following sections. Figures are provided to illustrate the major components of the systems and their function.

4.7.1 Canister Transfer Building

The Canister Transfer Building is provided for physical protection and shielding of the canisters during transfer from the transportation cask to the storage cask. The Canister Transfer Building consists of the shipping cask loading/unloading bays, canister transfer cells, a 200 ton overhead bridge crane, a 150 ton semi-gantry crane, a low level waste storage room, and personnel offices/restroom areas.

The detailed design of the Canister Transfer Building will be performed during the detailed design phase of the project. Specific building design parameters will enable detailed design after the crane vendor has completed the seismic dynamic analysis for the two cranes and the crane rail support loads are available.

No floor drains are located in the Canister Transfer Building to preclude the possibility of contamination entering the septic system. Shallow floor sumps are located in the center of each shipping cask load/unload bay to collect water from rain and snow that may run off onto the floor from a spent fuel shipment. Collected water will be sampled to ensure no contamination is present prior to removal.

4.7.1.1 Design Specifications

The building will be designed in accordance with the Principal Design Criteria contained in Chapter 3. The Canister Transfer Building is a massive reinforced concrete structure with thick walls provided for tornado-generated missile protection and radiation shielding. The building will be designed in accordance with the provisions of ACI-349 (Reference 15).

4.7.1.2 Plans and Sections

The Canister Transfer Building is shown in Figure 4.7-1.

4.7.1.3 Function

The function of the Canister Transfer Building is to assist in the canister transfer operations at the PFSF. A description of the canister transfer operations is contained in Chapter 5.

Canister Transfer Building functions include:

- Load or unload spent fuel shipping casks from the heavy haul tractor/trailers.
- Provide weather and tornado proof protection for performing the canister transfer operations.
- Provide the support structure for the single failure-proof cranes required for the transfer operations.
- Provide radiological shielding during the transfer operation.
- Store potential low-level radioactive waste from health physics surveys.
- Provide storage and laydown space for transfer and shipping equipment.
- Provide a staging area for storage casks.

4.7.1.4 Components

The major components that comprise the Canister Transfer Building are the cask loading/unloading bays, three canister transfer cells, the 200 ton overhead bridge crane, the 150 ton semi-gantry crane, crane runway girders and their supports, cask transporter bay, tornado-missile barriers, low level waste storage room, radiation shield walls and doors, equipment lay-down areas, storage cask delivery and staging platform, mechanical and electrical equipment areas, and personnel offices and restroom areas.

4.7.1.5 Design Bases and Safety Assurance

The Canister Transfer Building is classified as being Important to Safety to provide the safety assurance commensurate with canister transfer activities. The design bases for the Canister Transfer Building are described in Chapter 3.

4.7.1.5.1 Structural Design

The design of the Canister Transfer Building will be performed during the detailed design phase of the project. The building structure and components will be analyzed and designed to envelope the worst case loading conditions for all possible operating and canister transfer conditions for the design basis loads as identified in Chapter 3.

The following provides verification that the site specific and operational criteria of the PFSF are enveloped by the Canister Transfer Building analysis and design.

A. Dead Loads

The Canister Transfer Building will be designed for the self weight of the structure and all permanently attached equipment.

B. Live Load

The Canister Transfer Building will be designed for the following live loads:

- Snow and ice loads
- Bridge crane and semi-gantry crane loads
- Normal crane handling loads and transfer operations
- Normal wind load
- Concrete storage cask, transfer cask, and shipping cask loads
- Vehicle loads

Crane loads will be increased to account for lateral and longitudinal impact forces.

C. Lateral Soil Pressure

Below grade portions of the Canister Transfer Building will be designed for loads from lateral soil pressure, including loads in excess of geostatic pressures resulting from the presence of adjacent surcharges or vehicular traffic.

D. Thermal Loads

The Canister Transfer Building will be designed to accommodate the site-specific extreme temperatures. Expansion joints will be provided as required to accommodate thermally induced movements in the structure.

E. Tornado Winds and Missiles

The Canister Transfer Building will be designed to protect all SSCs housed within the building from the effects of tornado winds and tornado-generated missiles. The

Canister Transfer Building will be designed for the 240 mph wind speed and 1.5 psi pressure drop site specific design basis tornado event. The tornado wind speed will be converted to wind pressures in accordance with the provisions of ASCE-7 (Reference 31). Tornado wind and tornado pressure drop will be considered to act simultaneously. The worst case wind and pressure distribution acting on the structure as a whole and on individual building elements will be determined based on the physical size of the structure in relation to the size and characteristics of the design basis tornado. The structure will be designed to withstand the tornado wind and pressure drop by means of its static strength without the need to resort to venting of the structure.

The Canister Transfer Building will be designed to resist the effects of both horizontal and vertical impacts of the design basis tornado-generated missiles. Building components will be of sufficient strength and size to withstand the missile impact without compromising the strength and stability of the structure as a whole and to prevent penetration of the missile and spalling of the concrete face interior to the point of impact. The building layout and specifically designed labyrinths will prevent tornado missiles entering through door or ventilation openings in the walls and roof from impacting or damaging the fuel canisters, single failure proof cranes and their supports, or other SSC's housed within the building.

F. Earthquake

The Canister Transfer Building will be designed for the Design Earthquake loads for the site. The structure will be modeled and analyzed using three-dimensional modal seismic analysis. The dead loads from the bridge and semi-gantry cranes will be located so as to produce the highest design loads and member stresses within the structure. Lifted loads from the cranes will not be included in the seismic analysis.

G. Fire

The postulated fire accident for the Canister Transfer Building is discussed in SAR Section 8.2.5. Since the Canister Transfer Building will be equipped with fire detection and suppression systems and be constructed of reinforced concrete, which has both a high thermal inertia and is inherently noncombustible, the postulated fire accident will have no effect on the structural strength or stability of the Canister Transfer Building structure as required per 10 CFR 72.122(c).

4.7.1.5.2 Shielding Design

The Canister Transfer Building is designed to provide radiological shielding during the transfer operations. A portion of the building is divided into canister transfer cells where the transfer operations are performed. The cells are surrounded by concrete shield walls that are designed to limit the radiation doses from the canister transfer operations to personnel outside of the cell to 2 mrem/hr. Large sliding doors for moving shipping and storage casks in and out of the cell are made of steel with a sandwich layer of neutron shielding. Personnel access openings into the cells are designed with a labyrinth of concrete to mitigate streaming of radiation.

A shielding analysis will be performed assuming canisters containing design basis fuel involved in canister transfer operations to determine transfer cell wall and cell door thickness requirements. The analysis will consider attenuation of the radiation doses through the shield walls and doors to locations outside the cell.

4.7.2 Canister Transfer Cranes

The Canister Transfer Building houses two cranes, a 200 ton overhead bridge crane and a 150 ton semi-gantry crane. The cranes are provided for the purpose of loading and unloading shipping casks off or on the heavy haul tractor/trailers and transferring spent fuel canisters between the shipping cask and the storage casks. The 200 ton crane can be used for both load/unload and transfer operations. The semi-gantry crane can only be used for transfer operations and provides additional crane availability because of the time requirements involved in the transfer operations.

The design of the canister transfer cranes will be performed during the detailed design phase of the project. Detailed design of the cranes will be performed by the crane vendor.

4.7.2.1 Design Specifications

The canister transfer cranes will meet the requirements of the Design Criteria contained in Chapter 3, which requires the cranes be designed in accordance with ASME NOG-1 (Reference 32) and be single-failure-proof in accordance with NUREG-0554 (Reference 33).

During the detailed design stage, design requirements will be specified that provide for the performance of testing, inspection, and maintenance activities on the cranes in accordance with 10 CFR 72.122(f). Inspection and acceptance of the cranes will be performed during fabrication, in accordance with the QA Program described in Chapter 11, to ensure that the design requirements are satisfied.

The functional parameters of the overhead bridge crane are as follows:

Capacity:	Main hoist - 200 tons (Maximum Critical Load)
	Auxiliary hoist - 30 tons
Hoist type:	Main hoist - Single-failure-proof
	Auxiliary hoist - Standard crane design
Hoist ropes:	Main hoist - Carbon steel
	Auxiliary hoist - Carbon steel
Bridge span:	65'-0"
Length of runway:	260'-0"
Top of rail elev:	59'-6" above floor slab
Bridge/trolley:	60 fpm (Maximum speed)
Motion controls:	DC hoist and traverse
Operator controls:	Radio remote and pendant

The functional parameters of the semi-gantry crane are as follows:

Capacity:	Main hoist - 150 tons (Maximum Critical Load)
	Auxiliary hoist - 25 tons
Hoist type:	Main hoist - Single-failure-proof
	Auxiliary hoist - Standard crane design
Hoist ropes:	Main hoist - Carbon steel
	Auxiliary hoist - Carbon steel
Bridge span:	35'-0"
Length of runway:	180'-0"
Top of rail elev:	48'-3" above floor slab
Bridge/trolley:	60 fpm (Maximum speed)
Motion controls:	DC hoist and traverse
Operator controls:	Radio remote and pendant

4.7.2.2 Plans and Sections

The canister transfer cranes are shown in the Canister Transfer Building arrangements in Figures 4.7-1.

4.7.2.3 Function

The function of the canister transfer cranes is to assist in the canister transfer operations at the PFSF. A description of the canister transfer operations is contained in Chapter 5.

The overhead bridge crane will perform the following activities:

- Remove the impact limiters and personnel barrier from the shipping cask and move them to a laydown area, and
- Upright and remove the shipping cask from the heavy haul trailer and move the cask into a canister transfer cell.

The overhead bridge crane or the semi-gantry crane will perform the following activities:

- Remove the lid from the shipping cask,
- Lift the transfer cask and place on top of the shipping cask, then lift the canister into the transfer cask,
- Lift the transfer cask containing the canister off the shipping cask and onto the top of the storage cask,
- Lower the canister into the storage cask, and
- Remove the transfer cask from on top of the storage cask and place the lid on top of the storage cask.

4.7.2.4 Components

The major components of the overhead bridge crane are the bridge, trolley, main hoist, and auxiliary hoist. The major components of the semi-gantry crane are the gantry frame, trolley, main hoist, and auxiliary hoist.

4.7.2.5 Design Bases and Safety Assurance

The canister transfer cranes are classified as being Important to Safety to provide the safety assurance commensurate with shipping cask and canister lifting activities. The design bases for the canister transfer cranes are described in Chapter 3. Each crane has sufficient capacity to lift the maximum lifted load the crane is designed for during transfer operations. Based on maximum weights presented by Holtec (HI-STORM SAR Tables 3.2.1 and 3.2.2, HI-STAR shipping SAR Table 7.1.1) and by SNC (TranStor SAR Table 3.2-1 and TranStor shipping SAR Table 2.2-1), the maximum lifted loads are addressed in the following Sections:

The crane operations are designed not to exceed the handling loads (live loads) assumed in the HI-STORM and TranStor SARs. The analysis assumes the off-normal handling load is generated from a 2 fps horizontal impact. The crane design parameters limit the high speed of the trolley to 60 fpm (1 fps).

4.7.2.5.1 Maximum Loads Applicable to the Overhead Bridge Crane

The weight of loaded shipping cask, impact limiters, cask support cradle, and personnel barrier is approximately 142 tons (HI-STAR system) and 138 tons (TranStor system).

The weight of loaded shipping cask and shipping cask lifting yoke is approximately 121 tons (HI-STAR system) and 118 tons (TranStor system).

The weight of loaded concrete storage cask is approximately 177 tons (HI-STORM system) and 155 tons (TranStor system).

The overhead bridge crane capacity is 200 tons, which exceeds the heaviest load of 177 tons.

4.7.2.5.2 Maximum Loads Applicable To Both Overhead Bridge Crane And Semi-Gantry Crane

The weight of transfer cask with a loaded canister and transfer cask lifting yoke is approximately 121 tons (HI-TRAC system) and 109 tons (TranStor system).

The semi-gantry crane capacity is 150 tons, which exceeds the heaviest load of 121 tons.

4.7.3 HI-STORM Transfer Equipment

The HI-STORM transfer equipment consists of a metal transfer cask (HI-TRAC), HI-TRAC lifting trunnions, shipping cask and transfer cask lift yokes, canister downloader, canister lift cleats, and HI-STORM lifting lugs.

4.7.3.1 Design Specifications

The HI-TRAC transfer cask, trunnions, lift yokes, canister downloader, canister lift cleats, and storage cask lifting lugs are designed as special lifting devices in accordance with ANSI N14.6 (Reference 34) and NUREG-0612 (Reference 35).

4.7.3.2 Plans and Sections

The transfer cask assembly is shown in Figure 4.7-2.

4.7.3.3 Function

The function of the HI-TRAC transfer cask is to provide a shielded lifting device for carrying the canister between the HI-STAR shipping cask and the HI-STORM storage cask. The function of the lifting yokes is to provide a lifting interface between the crane and the shipping cask or transfer cask. The function of the canister lift cleats is to provide a means to lift the canister. The function of the HI-STORM storage cask lifting lugs is to provide a means to lift the storage cask.

4.7.3.4 Components

4.7.3.4.1 Transfer Cask

The HI-TRAC transfer cask is a heavy-walled cylindrical vessel. The main structural function of the transfer cask is provided by carbon steel and the main neutron and gamma shielding functions are provided by water and lead, respectively. The transfer cask is a steel, lead, steel layered cylinder with a water jacket attached to the exterior. The transfer cask provides an internal cylindrical cavity of sufficient size for housing a HI-STORM canister. The top lid has additional neutron shielding to provide neutron attenuation in the vertical direction. An access hole through the HI-TRAC top lid is provided to allow the lowering or raising of the canister between the transfer cask and shipping or storage cask. A bottom lid incorporates two sliding doors that allows the opening of the HI-TRAC bottom for the canister to pass through.

Physical characteristics of the HI-TRAC transfer cask are listed in Table 4.7-1.

4.7.3.4.2 Transfer Cask Trunnions

Trunnions are located beneath the transfer cask top flange for lifting and vertical handling of the cask. The trunnions enable the HI-TRAC transfer cask to be lifted by the lifting yoke, which is connected to the crane. The trunnions are welded to the transfer cask wall. The trunnions are designed to accommodate the combined weight of the transfer cask and a fully loaded canister while meeting NUREG-0612, Section 5.1.6(3) requirements for interfacing lift points.

4.7.3.4.3 Shipping and Transfer Cask Lift Yokes

The shipping cask lift yoke is a specialty lift rig that attaches between the crane hook and the two trunnions of the HI-STAR shipping cask. The transfer cask lift yoke is a specialty lift rig that attaches between the crane hook and the two trunnions of the HI-TRAC transfer cask. The lift yokes consist of two steel hooks joined by a steel cross beam.

4.7.3.4.4 Canister Downloader

The canister downloader is a hoist unit attached to the top of the HI-TRAC transfer cask. The downloader is used to raise and lower the canister between the HI-TRAC transfer cask and the HI-STORM storage cask or HI-STAR shipping cask in a single-failure proof mode without the risk of over lifting the canister. The downloader uses a hydraulic cylinder, which extends out to the side to physically lift the canister or retracts to lower the canister.

4.7.3.4.5 Canister Lift Cleats

The canister lift cleats consists of two steel lifting attachments that are bolted onto the top of the canister. The cleats provide lifting points for the downloader hoist hook in order to lift the canister up and out of either the HI-STAR shipping cask or HI-STORM storage cask and into the HI-TRAC transfer cask.

4.7.3.4.6 HI-STORM Storage Cask Lifting Lugs

The HI-STORM storage cask is equipped with four removable lifting lugs arranged circumferentially around the cask. The lifting lugs are threaded into anchor blocks. The anchor blocks are integrally welded to the cask radial plates, which are welded to the cask inner shell, outer shell, and baseplate. The four lugs provide for direct attachment of traditional hook or ring lifting devises, which along with a specially-designed lift rig, allow lifting by the cask transporter or crane hook. The lift rig is designed to lift a fully-loaded storage cask with margins of safety specified in ANSI 14.6, if the vertical lift height is to exceed the vertical lift height requirements.

4.7.3.5 Design Bases and Safety Assurance

4.7.3.5.1 Structural Design

A. Dead and Live Loads

The HI-TRAC transfer cask with the transfer lid attached, is designed to meet Level A Subsection NF stress limits while handling the dead load of the heaviest loaded canister. The structural analysis for the HI-TRAC transfer cask is described in HI-STORM SAR Appendix 3.AD.

The transfer cask lifting trunnions are designed for a conservative total lifting load of 376,000 lb (150 percent of loaded transfer cask) using a two point lift with a minimum safety factor of 10 based on the ultimate strength. During a lift no point in the HI-TRAC body exceeds its material yield strength. The structural analysis for the HI-TRAC transfer cask trunnions is described in the HI-STORM SAR Appendix 3.E.

The shipping cask and transfer cask lift yokes are designed as a non-redundant lifting devices with a factor of safety of ten or greater on material ultimate strength and six or greater on yield and includes the dynamic load increase factor of 10 percent. The lift yokes therefore meet the NUREG-0612 requirements for single-failure-proof devices.

The canister downloader is designed as a single-failure-proof lifting device in accordance with NUREG-0612. The downloader consists of a hydraulic ram that is a non-redundant lifting device designed with the safety factors of 10 on ultimate and 6 on yield. The downloader uses two redundant sets of anti-drop cam locks to secure the load in the event of a loss of power or hydraulic pressure.

The two canister lift cleats are designed with a minimum factor of safety of three on material yield strength and five on material ultimate strength, as well as a dynamic load increase factor of 10 percent. Each cleat can totally support the weight of the canister thereby making them single-failure-proof per NUREG-0612. The cleats are connected to the canister via 4 bolts, 2 bolts per cleat.

The HI-STORM storage cask is designed to be lifted using four lifting lugs (threaded eyebolts) located on top of the cask. The lifting lugs screw into steel lifting blocks that are integrally welded to the storage cask steel. The stresses were compared with ASME III, NF allowables. The thread shear in the lifting block is compared to 10 percent of the ultimate strength of the base material in accordance with NUREG-0612. The lifting lugs have a net section stress below 10 percent of the ultimate strength of the lug material. The strength qualification analysis is described in HI-STORM SAR Appendix 3.D. No credit is assumed for the concrete except as a vehicle to transfer compressive loads. A dynamic load factor of 1.15 is applied to simulate anticipated inertia forces during a low speed lift.

B. Thermal Loads

Thermal loads induced on the HI-TRAC transfer cask are identified in HI-STORM SAR Section 3.4.4.2. The analysis was performed to demonstrate that the annulus between the inner walls of the transfer cask and the exterior of the canister would not close due to unconstrained thermal expansion of each assembly. The analysis results are shown in HI-STORM SAR Table 4.5.4. The table shows a summary of temperature differences in the basket periphery and canister shell between the top and bottom of the canister. The table indicated temperature differences between the top and bottom section of the basket periphery of approximately 238° F, and approximately 166° F between top and bottom sections of the canister shell. The temperature gradients were evaluated to determine the cask and canister thermal growths and shown to be minimal. The temperature gradients were also used to calculate thermal stresses in the canister, which were shown to be within code allowables and therefore meet the PFSF design criteria in Section 3.2.6 for thermal loads.

C. Tornado Winds and Missiles

Evaluation of the transfer cask for tornado wind or missile is not required since the canister transfer operations are conducted within the Canister Transfer Building.

D. Earthquake

The transfer cask has been evaluated for stability during a seismic event when in the stacked cask arrangement. The stacked cask arrangement occurs when the transfer cask is resting on top of the storage cask. It was concluded that in normal operations, the crane would be connected to the cask throughout the transfer operation and therefore prevent the cask from toppling during a seismic event.

E. Fire

Fires concerning the HI-TRAC transfer cask are addressed in HI-STORM SAR Section 11.2.4. The HI-TRAC was analyzed for a fire around the cask of 50 gallons of combustible fuel. The fire had a duration of less than 5 minutes. A bounding cask temperature rise of less than 16° F per minute was determined from the combined radiant and convection heat input to the cask. As a result, the fuel cladding was shown not to exceed the accident condition fuel cladding temperature limits. As shown in Section 8.2.5, the only fuel source near a loaded HI-TRAC transfer cask would be diesel fuel from the cask transporter, whose fuel tanks have a capacity of 50 gallons, which would fuel a fire for a duration of less than 5 minutes, as analyzed. In addition, it is anticipated any fires would be put out by the Canister Transfer Building sprinkler system.

The elevated temperatures from a fire could cause the pressure in the transfer cask water jacket to increase and cause the overpressure relief valve to vent steam to the atmosphere. However, this would not have any adverse affect on systems classified as Important to Safety and would vent less water and cause less disruption than the sprinkler system. Therefore the HI-TRAC design and building provisions meet the PFSF design criteria in Section 3.2.6 for accident-level thermal loads in accordance with 10 CFR 72.122(c).

4.7.3.5.2 Thermal Design

The thermal analysis for the HI-TRAC transfer cask is described in HI-STORM SAR Section 4.5.1. The analysis uses the same approach as the HI-STORM storage cask/canister thermal analysis (Section 4.2.1.5.2) and was performed using the ANSYS finite element computer code (Reference 10).

Heat generated in the fuel assemblies is transported to the shell of the canister, in the manner described in Section 4.2.1.5.2. From the outer surface of the canister, heat is transported across a total of six concentric layers, representing the air gap, the HI-TRAC inner steel shell, the lead shielding, the outer steel shell, the water jacket, and the enclosure shell from which heat is rejected to atmosphere. Heat is transferred across the air gap between the canister and the transfer cask by parallel mechanisms of conduction and radiation. Heat is transported through the cylindrical wall of the transfer cask by conduction through successive layers of steel, lead, and steel. Conduction through the water jacket occurs through both the water cavities and the steel channels.

A bounding steady-state analysis of the HI-TRAC transfer cask was performed using the least favorable canister basket thermal conductivity, the highest design basis decay heat load (28.25 kW), and assuming solar radiation. Maximum fuel cladding temperatures and temperatures in different parts of the transfer cask and canister are summarized in Table 4.7-2. Temperatures of all components are shown to be within allowable temperature limits.

The minimum ambient temperature condition required to be considered for the HI-TRAC design is specified as 0° F. Provided an antifreeze is added to the water in the transfer cask jacket, all HI-TRAC materials will satisfactorily perform their intended functions at the 0° F minimum postulated temperature condition. The minimum design temperature for the Canister Transfer Building is 40° F. Movement of the transfer cask at temperatures above 40° F eliminates the potential for approaching the minimum HI-TRAC design condition.

4.7.3.5.3 Shielding Design

The transfer cask provides shielding of the canister during transfer operations. Radial shielding is provided by steel shells that enclose a lead gamma shield with radial neutron shielding provided by 24 water-filled steel channels on the outside of the transfer cask. The bottom lid consists of a lead gamma shield and a solid neutron shield material sandwiched between steel liners. Shielding in the axial-up direction relies primarily on the canister's thick steel lid. Results of the dose rate analysis and determination of the dose rates at the bottom, sides, and top of the loaded HI-TRAC transfer cask are shown in HI-STORM SAR Section 5.1 and summarized in Table 7.3-3. Chapter 7 discusses the shielding analysis.

Temporary shielding will be provided as needed during the transfer operation as well as measures implemented to maintain ALARA doses. Doses will be maintained within occupational dose limits required in 10 CFR 20 in accordance with Section 3.3.5.2 for shielding.

4.7.4 TranStor Transfer Equipment

The TranStor transfer equipment consists of a metal transfer cask, transfer cask lifting trunnions, shipping cask and transfer cask lifting yokes, canister hoist rings, and storage cask lifting lugs.

4.7.4.1 Design Specifications

The TranStor transfer cask, trunnions, lifting yokes, and canister hoist rings are designed as special lifting devices in accordance with ANSI N14.6 (Reference 34) and NUREG-0612 (Reference 35).

4.7.4.2 Plans and Sections

The transfer cask assembly is shown in Figure 4.7-3.

4.7.4.3 Function

The function of the TranStor transfer cask is to provide a shielded lifting mechanism for transfer of the loaded canister between the shipping cask and the storage cask. The function of the lifting yokes is to provide a lifting interface between the crane and shipping cask or transfer cask. The function of the canister hoist rings is to provide a means to lift the canister. The function of the storage cask lifting lugs is to provide a means to lift the storage cask.

4.7.4.4 Components

4.7.4.4.1 Transfer Cask

The TranStor transfer cask is a cylindrical vessel, with walls that consist of multiple layers of material. The inside and outside walls of the cylinder are steel. There is a layer of lead inside the inner wall with an adjacent layer of neutron absorbing material. The base of the transfer cask consists of movable steel plates that are hydraulically operated to permit opening and closing of the cask bottom for transfer of the canister. The steel plates travel along rails located on each side of the cask. Two steel pins in each plate are provided to prevent inadvertent opening of the plates while the canister is contained within the transfer cask. The top of the transfer cask consists of a steel ring with an inner diameter smaller than that of the canister to prevent the canister from being lifted through the top of the cask.

Physical characteristics of the TranStor transfer cask are listed in Table 4.7-3.

4.7.4.4.2 Transfer Cask Trunnions

The transfer cask is lifted from above via two trunnions located near the top of the outer shell. The trunnions are steel forgings that extend radially from the transfer cask body. Each trunnion is welded to the inner and outer steel shells of the transfer cask wall with full penetration circumferential welds. The two trunnions are capable of accommodating the combined weight of the transfer cask and a fully loaded, water filled canister (at the originating power plant) while meeting NUREG-0612, Section 5.1.6(3) requirements for interfacing lift points.

4.7.4.4.3 Shipping and Transfer Cask Lifting Yokes

The shipping cask lifting yoke is a specialty lift rig that attaches between the crane hook and the two trunnions of the shipping cask. The transfer cask lifting yoke is a specialty lift rig that attaches between the crane hook and the two trunnions of the transfer cask. The lifting yokes consist of two armed steel hooks joined by two steel beams.

4.7.4.4.4 Canister Hoist Rings

The canister hoist rings consist of eight steel rings that are threaded into the top of the canister. The rings are used to provide a lift attachment for the crane in order to lift the canister up and out of either the shipping cask or storage cask and into the transfer cask.

4.7.4.4.5 TranStor Storage Cask Lifting Attachments

The TranStor storage cask is lifted from the top by use of four lifting attachments. The lifting attachments consist of steel plates, two plates located on either side of the cask. The plates are integrally welded to the cask concrete reinforcing bars. The four plates allow for direct lifting by the cask transporter or crane hook. The lifting attachments are not Important to Safety since the cask is not allowed to be lifted more than 10 inches per the operating conditions and limits given in Chapter 10.

4.7.4.5 Design Bases and Safety Assurance

4.7.4.5.1 Structural Design

A. Dead and Live Loads

The structural analysis for the TranStor transfer cask is described in TranStor SAR Section 3.4.3.3. The transfer cask is designed to lift the required load within the allowable safety factors to provide single-failure-proof lift capability in accordance with Section 3.2. The transfer cask, including the shell, bottom plates, trunnions, and associated welds are evaluated for loading conditions imposed by the weight of the transfer cask including the weight of a loaded canister. The transfer cask lid has been evaluated for the full weight of the transfer cask should inadvertent lifting of the transfer cask by the canister occur.

Structural adequacy of the transfer cask trunnions was evaluated by modeling the trunnions as cantilevers and applying the weight of the loaded transfer cask. The resulting bending and shear stresses in the trunnions were combined to calculate the maximum principal stress and determine the corresponding safety factors.

The shipping cask and transfer cask lifting yokes are designed as a non-redundant lifting devices with a factor of safety of ten or greater on material ultimate strength and six or greater on material yield strength and includes the dynamic load increase factor of 10 percent. The lifting yokes therefore meet the NUREG-0612 requirements for a single-failure-proof device.

The canister hoist rings are designed with a minimum factor of safety of three on material yield strength and five on material ultimate strength, as well as a dynamic load increase factor of 10 percent. Eight rings provide redundant capability since only four are required, therefore the hoist rings meet the NUREG-0612 requirements for redundancy.

The TranStor storage cask is designed to be lifted using four lifting lugs, which are steel plates integrally welded to the concrete steel reinforcing. The lifting lugs are not classified as Important to Safety since the cask lift height is limited by the Technical Specifications but are designed with a minimum factor of safety of 3 on material yield strength and 5 on material ultimate strength.

B. Tornado Winds and Missiles

Evaluation of the TranStor transfer cask for tornado wind or missile is not required since protection of the transfer operation from the effects of tornado wind and tornado missiles is provided by the Canister Transfer Building structure.

C. Earthquake

The transfer cask has been evaluated for stability during a seismic event when in the stacked cask arrangement. The stacked cask arrangement occurs when the transfer cask is resting on top of the shipping or storage cask. Since the TranStor system operation requires the crane be removed from the transfer cask in order to hook to the canister for lifting, a condition would exist where the transfer cask could topple during a seismic event. Therefore, the transfer cask is designed to be secured to the cell walls with struts when in the stacked arrangement, prior to removing the crane to preclude a cask toppling accident.

D. Fire

As shown in Section 8.2.5, fires near a loaded transfer cask would have a small effect on the canister temperature because of the short duration of the fire accidents. The only fire fuel source would be diesel fuel from the cask transporter. In addition, it is anticipated any fires would be put out by the Canister Transfer Building sprinkler system. Therefore the transfer cask design and building provisions meet the PFSF design criteria in Section 3.2.6 for accident-level thermal loads in accordance with 10 CFR 72.122(c).

4.7.4.5.2 Thermal Design

The thermal analysis performed for the transfer cask is described in TranStor SAR Section 4.4.1.3. The analysis uses the same approach as the TranStor storage cask/canister thermal analysis evaluation (Section 4.2.2.5.2) and was performed with the ANSYS thermal finite element code (Reference 10). The transfer cask geometry and materials were accurately modeled in detail, while the canister is treated simply as a 26 kW cylindrical heat source, with only the canister shell modeled in detail. Heat is transferred from the canister shell to the inner steel liner of the TranStor transfer cask, then conducted through this inner liner, the lead gamma shield, the solid neutron shield material, and the steel outer liner. The major difference between this case and that of the storage cask is the absence of convective air flow along the canister exterior. For conservatism, only the steel fins were considered in determining the effective conductivity of the neutron shield region, with no credit taken for heat conduction by the neutron shield material. A key objective of this analysis was to determine the highest temperature of the canister shell, which is used for thermal evaluation of the canister internals and fuel during transfer operations.

As shown in TranStor SAR Table 4.1-1, the thermal analysis assumed 75° F average ambient air temperature and computed a canister shell temperature of 434° F, a PWR maximum cladding temperature of 757° F, and a BWR maximum cladding temperature of 816° F. The fuel cladding temperatures are well below the accident condition limit of 1,058° F, which applies to both PWR and BWR fuel assemblies, and are therefore acceptable.

The materials of the transfer cask shells, trunnions, and lifting yoke require Charpy testing that assures the nil ductility transition (NDT) temperature of not higher than -40° F. Per ANSI N14.6, the lowest service temperature (LST) for the special lifting devices is required to be 40° F above the NDT point. This results in the 0° F requirement specified in Section 10.2.1.3. The Canister Transfer Building is designed with a minimum temperature of 40° F. Movement of the transfer cask at temperatures above 40° F eliminates the potential for brittle fracture.

4.7.4.5.3 Shielding Design

The transfer cask provides shielding of the canister during transfer operations. Radial shielding consists of steel liners, which enclose a lead gamma shield and a solid neutron shield material. The bottom lid consists of steel doors. Shielding in the axial-up direction relies on the canister steel shield and structural lids. The dose rate analysis and determination of the doses at the bottom, sides, and top of the canister are shown in TranStor SAR Section 5.4.3. Chapter 7 provides a discussion of the shielding analysis. The results of the shielding analysis of the TranStor transfer cask are included in Table 7.3-4.

Temporary shielding will be provided as needed during the transfer operation as well as measures implemented to maintain ALARA doses. Doses will be maintained within occupational dose limits required in 10 CFR 20 in accordance with Section 3.3.5.2 for shielding.

4.7.5 Cask Transporter

A cask transporter is used to move the loaded storage cask between the Canister Transfer Building and the storage pad.

4.7.5.1 Design Specifications

The cask transporter is a commercial grade system that has no specific code or specification criteria.

4.7.5.2 Plans and Sections

A drawing of a typical cask transporter is shown on Figure 4.7-4.

4.7.5.3 Function

The function of the cask transporter to enable transfer of the loaded concrete casks between the canister transfer facility and the concrete storage pads.

4.7.5.4 Components

The cask transporter is a large tracked vehicle designed to straddle a concrete storage cask and lift it for transport between the Canister Transfer Building and the storage pads. The transporter lifting mechanism consists of a lift beam supported on either end by two hydraulic lift rams. The lift beam is designed with lift connections to attach to the lifting eyes in the storage cask. The transporter is controlled by a driver who is located on the back corner of the vehicle. The braking system is designed to automatically set when the vehicle operating levers are in neutral or the parking brake is set.

The transporter travels up to 2 mph, has a capacity of 200 tons, and weighs approximately 135,000 lb (Reference 21).

4.7.5.5 Design Bases and Safety Assurance

The cask transporter is classified as not Important to Safety. A failure of any cask transporter components will not result in any safety concerns since the cask would only lower 4 inches back to the ground. Drops this small are within analyzed accident conditions presented in Section 8.2.6. The transporter is designed to mechanically limit the lifting height of a canister to a maximum of 10 inches. The hydraulic lift cylinders are equipped with double locking valves and a cam locking system engages and holds the load in the event a cylinder looses holding power. Indicator lights on the operating console tell if the cams are disengaged or engaged. Markings on the lift boom and a meter on the operating console give indication of the lifted height.

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TABLE 4.1-1
(Sheet 1 of 7)

PFSF COMPLIANCE WITH GENERAL DESIGN CRITERIA (10 CFR 72, SUBPART F)

10 CFR 72 REQUIREMENT	REQUIREMENT SUMMARY	SAR SECTION WHERE COMPLIANCE IS DEMONSTRATED
72.122 (a) Quality standards	Structures, systems, and components Important to Safety must be designed, fabricated, erected, and tested to quality standards commensurate with the importance to safety of the function.	• Section 3.4 provides the QA classifications for SSCs Important to Safety. • Chapter 4 describes the design of SSCs Important to Safety. • Section 9.4.1.1.5 describes the QA procedures req'mts. • Chapter 11 shows that the QA Program is in accordance with 10 CFR 72.140.
72.122 (b) Protection against environmental conditions and natural phenomena	Structures, systems, and components Important to Safety must be designed to accommodate the effects of and be compatible with site characteristics and environmental conditions and to withstand postulated accidents.	• Sections 3.2 and 3.2.10.2.11 provide req'mts for environmental and site design criteria for SSCs Important to Safety. • Sections 4.2 and 4.7 describe the design to mitigate environmental effects. • Chapter 8 and Sections 8.2.1.1, 8.2.1.2, and 8.2.2.2 demonstrate the capability of SSCs Important to Safety to withstand postulated accidents.
72.122 (c) Protection against fires and explosions	Structures, systems, and components Important to Safety must be designed and located so that they can continue to perform their safety functions under credible fire and explosion exposure conditions.	• Section 3.3.6 provides fire and explosion protection req'mts. • Sections 4.2.1.5.1 (I) and (J), 4.2.2.5.1 (I) and (J), 4.7.3.5.1(E), and 4.7.4.5.1(D) describe the design that provides fire and explosion protection. • Sections 8.2.4.2 and 8.2.5.2 show the capability of SSCs Important to Safety to withstand postulated fire and explosion accidents.

TABLE 4.1-1
(Sheet 2 of 7)

PFSF COMPLIANCE WITH GENERAL DESIGN CRITERIA (10 CFR 72, SUBPART F)

10 CFR 72 REQUIREMENT	REQUIREMENT SUMMARY	SAR SECTION WHERE COMPLIANCE IS DEMONSTRATED
72.122 (d) Sharing of structures, systems, and components	Structures, systems, and components Important to Safety must not be shared between the PFSF and other facilities unless it is shown that such sharing will not impair the capability of either facility to perform its safety functions.	• Section 1.2 verifies that the PFSF does not share SSCs with other facilities.
72.122 (e) Proximity of sites	An ISFSI located near other nuclear facilities must be designed and operated to ensure that the cumulative effects of their combined operations will not constitute an unreasonable risk to the health and safety of the public.	• Section 7.6.2 verifies that no other nuclear facilities are located within 5 miles of the PFSF.
72.122 (f) Testing and maintenance of systems and components	Systems and components that are Important to Safety must be designed to permit inspection, maintenance, and testing.	• Sections 4.2, 4.7, 5.1.4.7, 4.7.2.1, 5.1.6.5, and 9.2.2 describe the capability of SSC's to permit inspection, maintenance, and testing.

TABLE 4.1-1
(Sheet 3 of 7)

PFSF COMPLIANCE WITH GENERAL DESIGN CRITERIA (10 CFR 72, SUBPART F)

10 CFR 72 REQUIREMENT	REQUIREMENT SUMMARY	SAR SECTION WHERE COMPLIANCE IS DEMONSTRATED
72.122 (g) Emergency capability	Structures, systems, and components Important to Safety must be designed for emergencies. The design must provide accessibility to the equipment by onsite and available offsite emergency facilities and services.	• Section 4.1.2 specifies that the PFSF is designed for accessibility. • Section 9.5 summarizes the Emergency Plan for the PFSF.
72.122 (h) Confinement barriers and systems	The spent fuel cladding must be protected during storage against degradation that leads to gross ruptures or the fuel must be otherwise confined. Ventilation systems must be provided to ensure confinement of airborne particulate. Storage confinement systems must have the capability for continuous monitoring to maintain safe storage conditions.	• Section 3.3.2 provides the requirements to ensure confinement of the spent fuel. • Sections 4.2.1.5.5 and 4.2.2.5.5 describe the confinement design features. • Section 8.2.7.2 accident analysis shows that there is no loss of confinement. • Section 8.2.10.1 shows that the fuel cladding is protected. • Sections 7.3.4 and 7.3.5 describe the continuous monitoring process.
72.122 (i) Instrumentation and control systems	Instrumentation and control systems must be provided to monitor systems that are Important to Safety over anticipated ranges for normal operation and off-normal operation.	• Section 3.3.3.2 provides the requirements to monitor systems Important to Safety. • Section 5.4.1 describes the instrumentation and control systems.

TABLE 4.1-1
(Sheet 4 of 7)

PFSF COMPLIANCE WITH GENERAL DESIGN CRITERIA (10 CFR 72, SUBPART F)

10 CFR 72 REQUIREMENT	REQUIREMENT SUMMARY	SAR SECTION WHERE COMPLIANCE IS DEMONSTRATED
72.122 (j) Control room or control area	A control room or control area, if appropriate, must be designed to permit occupancy and actions to be taken to monitor the PFSF safely under normal conditions, and to provide safe control of the PFSF under off-normal or accident conditions.	• Section 5.5 shows that a control room/area is not required. • Section 5.1 describes the operational systems that ensure safe conditions during cask storage and canister transfer. • Section 10.2.5 defines the operational controls and limits to be used for the PFSF.
72.122 (k) Utility or other services	Each utility service system must be designed to meet emergency conditions. The design of utility services and distribution systems that are Important to Safety must include redundant systems to maintain the ability to perform safety functions assuming a single failure.	• Section 4.1.2.3 verifies that the PFSF does not rely on utility systems to ensure the safe operation of the facility.
72.122 (l) Retrievability	Storage systems must be designed to allow ready retrieval of spent fuel for further processing or disposal.	• Section 3.3.7 provides the requirements for transferring and storing the canisters that contain the spent fuel and for shipping the canisters offsite. • Section 4.7 describes the capability for retrieving the spent fuel canisters.

TABLE 4.1-1
(Sheet 5 of 7)

PFSF COMPLIANCE WITH GENERAL DESIGN CRITERIA (10 CFR 72, SUBPART F)

10 CFR 72 REQUIREMENT	REQUIREMENT SUMMARY	SAR SECTION WHERE COMPLIANCE IS DEMONSTRATED
72.124 (a) Design for criticality safety	Spent fuel handling, packaging, transfer, and storage systems must be designed to be maintained subcritical.	• Section 3.3.4 provides the requirements to ensure subcriticality is maintained. • Sections 4.2.1.5.4 and 4.2.2.5.4 describe the criticality safety design.
72.124 (b) Methods of criticality control	When practicable, the design of an ISFSI must be based on favorable geometry, permanently fixed neutron absorbing materials (poisons), or both.	• Section 3.3.4 provides the requirements for the means of subcriticality control. • Sections 4.2.1.5.4 and 4.2.2.5.4 describe the components that maintain subcritical conditions.
72.124 (c) Criticality monitoring	A criticality monitoring system shall be maintained in each area where special nuclear material is handled, used, or stored which will energize clearly audible alarm signals if accidental criticality occurs.	• Sections 4.2.1.5.4 and 4.2.2.5.4 describe why criticality monitoring is not applicable for dry storage systems where the spent fuel is packaged in its stored configuration.
72.126 (a) Exposure control	Radiation protection systems must be provided for all areas and operations where onsite personnel may be exposed to radiation or airborne radioactive materials.	• Section 3.3.5 provides the radiological protection design criteria. • Sections 4.2.1.5.3 and 4.2.2.5.3 describe the components that provide shielding for exposure control. • Sections 7.1.1 and 7.1.2 describe the program features for ensuring that occupational exposures are ALARA.

TABLE 4.1-1
(Sheet 6 of 7)

PFSF COMPLIANCE WITH GENERAL DESIGN CRITERIA (10 CFR 72, SUBPART F)

10 CFR 72 REQUIREMENT	REQUIREMENT SUMMARY	SAR SECTION WHERE COMPLIANCE IS DEMONSTRATED
72.126 (b) Radiological alarm systems	Radiological alarm systems must be provided in accessible work areas as appropriate to warn operating personnel of radiation and airborne radioactive material concentrations above a given setpoint and of concentrations of radioactive material in effluents above control limits.	• Section 3.3.5 provides the requirements for radiological alarm systems. • Section 7.3.5 describes the radiological monitoring program.
72.126 (c) Effluent and direct radiation monitoring	As appropriate for the handling and storage system, a means to measure effluents must be provided. Areas containing radioactive materials must be provided with systems for measuring the direct radiation levels in and around these areas.	• Section 3.3.5 provides the requirements for effluent and direct radiological systems. • Sections 7.3.5 and 7.6.1 describe the radiological monitoring program.
72.126 (d) Effluent control	The ISFSI must be designed to provide means to limit to ALARA levels the release of radioactive materials in effluents during normal operations and control the release of radioactive materials under accident conditions.	• Section 7.1.2 describes why effuent control is not applicable at the PFSF. • Section 8.2 demonstrates that offsite exposures for postulated accident conditions are controlled such that the dose limits specified in 10 CFR 72.106 are met.

TABLE 4.1-1
(Sheet 7 of 7)

PFSF COMPLIANCE WITH GENERAL DESIGN CRITERIA (10 CFR 72, SUBPART F)

10 CFR 72 REQUIREMENT	REQUIREMENT SUMMARY	SAR SECTION WHERE COMPLIANCE IS DEMONSTRATED
72.128 (a) Spent fuel storage and handling systems	Spent fuel storage and other systems that might contain or handle radioactive materials associated with spent fuel must be designed to ensure adequate safety under normal and accident conditions.	• Section 3.3.7 provides the requirements for ensuring the safe design of the spent fuel storage and handling systems. • Sections 4.2 and 4.7 describe the design features of the storage and handling systems to provide adequate shielding, confinement, and heat removal capability. • Section 10.2.3 addresses the surveillance specifications for testing and monitoring some components Important to Safely.
72.128 (b) Waste treatment	Radioactive waste treatment facilities must be provided.	• Section 3.3.7 addresses radioactive waste provisions. • Chapter 6 addresses the generation of radioactive wastes.
72.130 Criteria for decommissioning	The ISFSI must be designed for decommissioning.	• Section 3.5 provides the requirements for decommissioning the site. • Section 9.6.3 describes the design considerations to facilitate decommissioning. • Decommissioning Plan (License Application, Appendix B) presents an overall description of the decommissioning requirements.

TABLE 4.2-1

PHYSICAL CHARACTERISTICS OF THE HI-STORM CANISTER

PARAMETER	VALUE
Outside Diameter	68.38 inches
Length, maximum	190.5 inches
Capacity	24 PWR assemblies 68 BWR assemblies
Maximum Heat Load	28.25 kW for PWR canister (MPC-24) 27.13 kW for BWR canister (MPC-68)
Material of Construction	Stainless steel (shell) Concrete in lid (neutron absorber)
Weight, maximum (loaded with spent fuel)	78,831 lb (MPC-24) 86,131 lb (MPC-68)
Internal Atmosphere	Helium

TABLE 4.2-2

PHYSICAL CHARACTERISTICS OF THE HI-STORM STORAGE CASK

PARAMETER	VALUE
Height	231.25 inches
Outside Diameter	132.5 inches
Capacity	1 loaded canister
Max. Radiation Dose[1]	
1 meter from surface:	
Side	14 mrem/hr
Top	2 mrem/hr
On contact with surface:	
Side	29 mrem/hr
Top	7 mrem/hr
Top vents	32 mrem/hr
Bottom vents	50 mrem/hr
Material of Construction	Concrete (core) Steel (liner and shell)
Weight, maximum	267,664 lb (empty) 346,495 lb (with loaded MPC-24) 353,796 lb (with loaded MPC-68)
Service Life	>100 years

1. Dose rate is based on HI-STORM design basis fuel.

TABLE 4.2-3

HI-STORM STORAGE SYSTEM STEADY STATE TEMPERATURE EVALUATION UNDER NORMAL CONDITIONS OF STORAGE

COMPONENT	MPC-24 TEMPERATURE (°F)	MPC-68 TEMPERATURE (°F)	NORMAL CONDITION TEMPERATURE LIMITS (°F)
Ambient Air	80	80	N.A.
Storage Cask Outer Shell	146	146	350
Air Outlet	205	202	N.A.
Storage Cask Inner Liner	264	264	300 *
Canister Shell	432	416	450
Helium Gas	630	625	N.A.
Fuel Cladding	632	627	716

* 300°F is Holtec's normal condition temperature limit on the concrete. The storage cask steel structure has a normal condition limit of 350°F (HI-STORM SAR Table 2.2.3).

TABLE 4.2-4

PHYSICAL CHARACTERISTICS OF THE TRANSTOR CANISTER

PARAMETER	VALUE
Outside Diameter	66 inches
Length	192.25 inches maximum
Capacity	24 PWR assemblies 61 BWR assemblies
Maximum Heat Load	26 kW
Material of Construction	Stainless steel (shell), Carbon steel (internals)
Weight, maximum (loaded with spent fuel)	76,595 lb (PWR) 84,460 lb (BWR)
Internal Atmosphere	Helium

TABLE 4.2-5

PHYSICAL CHARACTERISTICS OF THE TRANSTOR STORAGE CASK

PARAMETER	VALUE
Height	222.5 inches maximum (depending on fuel length)
Outside Diameter	136 inches
Capacity	1 loaded canister
Maximum Radiation Dose[1]	
1 Meter from surface:	
Side	10 mrem/hr
Top	135 mrem/hr
On contact with surface:	
Side	19 mrem/hr
Top	157 mrem/hr
Top vent	7.5 mrem/hr
Bottom vent	14 mrem/hr
Material of Construction	Reinforced concrete Steel (inner liner)
Weight, maximum	223,435 lb (empty) 297,055 lb (loaded with PWR canister) 309,130 lb (loaded with BWR canister)
Service Life	>50 years

1. Dose rate is based on TranStor design basis fuel

TABLE 4.2-6

SUMMARY OF TRANSTOR SYSTEM THERMAL HYDRAULICS EVALUATION (°F)

CASE	AMBIENT AIR		OUTER	INNER	CANISTER	MAX CLAD**	
	INLET	OUTLET	CONCRETE	CONCRETE	SHELL	PWR	BWR
Normal Condition Generic Limits	N/A	N/A	150	200	N/A	621	673
Steady-State Normal Condition Storage	75	171	85	188	274	613	664
Off-normal Condition Generic Limits	N/A	N/A	150	225	N/A	1058	1058
Steady-State Abnormal Cold	-40	35	-39	53	167	519	566
Steady-State Abnormal Hot	100	200	141	222	299	635	688
½ Inlet Ducts Blocked	75	189	87	201	283	621	673
Accident Level Condition Generic Limits	N/A	N/A	200	350	N/A	1058	1058
Extreme Hot Ambient Temperature	125	230	190	257	325	658	712
All Inlet Ducts Blocked	75	238	88	224	303	638	691

** Based on the highest burnup and shortest cooling time of all the fuels considered in the TranStor SAR and is therefore conservative for PFSF fuel.

TABLE 4.2-7

STATIC PAD ANALYSIS MAXIMUM RESPONSE VALUES

LOADING CONDITIONS		MAXIMUM MOMENT (k-ft/ft)	MAXIMUM SHEAR FORCE (k/ft)	MAXIMUM SOIL PRESSURE (k/ft^2)
Dead Load		0.0	0.0	0.45
Live Load	2 Casks	21.8	6.9	1.67
	4 Casks	57.1	8.4	1.86
	8 Casks	37.4	5.7	1.57
	8 Casks + Transporter	45.6	11.3	3.05

TABLE 4.2-8

DYNAMIC PAD ANALYSIS MAXIMUM RESPONSE VALUES

DESIGN EARTHQUAKE LOADING	MAXIMUM MOMENT (k-ft/ft)	MAX. SHEAR FORCE (k/ft)	MAXIMUM SOIL PRESSURE (k/ft^2)	MAX. HORIZONTAL TOTAL SOIL REACTION (kips)	
				Longitudinal	Transverse
2 Casks	344.3	76.3	3.34	670	730
4 Casks	132.6	25.2	2.10	1,195	910
8 Casks	114.0	27.7	2.80	1,330	2,030

TABLE 4.7-1

PHYSICAL CHARACTERISTICS OF THE HI-TRAC TRANSFER CASK

PARAMETER	VALUE
Inside Diameter	68.75 inches
Outside Diameter	94.625 inches
Height	199.25 inches
Materials of Construction	Steel (inner and outer shell) Lead (gamma shield) Water (neutron absorber)
Weight (empty)	151,963 lb
Maximum Working Dose Rate[1] (1 meter from surface) Side	 49 mrem/hr

1. Dose rates are based on HI-STORM design basis fuel.

Table 4.7-2

HI-TRAC TRANSFER CASK STEADY STATE TEMPERATURE EVALUATION

COMPONENT	TEMPERATURE (°F)	NORMAL CONDITION TEMPERATURE LIMITS (°F)
Ambient Air	80	N/A
Transfer Cask Outer Shell	214	N/A
Top Neutron Shield	318	-
Water Jacket Inner Surface	281	-
Transfer Cask Inner Surface	302	-
Canister Shell	447	450
Helium Gas	703	N/A
Fuel Cladding	705	716

TABLE 4.7-3

PHYSICAL CHARACTERISTICS OF THE TRANSTOR TRANSFER CASK

PARAMETER	VALUE
Inside Diameter	67 inches
Outside Diameter	86 inches
Height	204 inches maximum (depends on fuel length)
Materials of Construction	Steel (inner and outer shell) Lead (gamma shield) Polymer (neutron absorber)
Weight (empty)	126,630 lb max.
Maximum Working Dose Rate[1] (1 meter from surface) Side	 79 mrem/hr

1. Dose rates are based on TranStor design basis fuel.

FIGURE WITHHELD AS SENSITIVE
UNCLASSIFIED INFORMATION

Figure 4.1-1

CANISTER TRANSFER BUILDING

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 4.1-2

SECURITY AND HEALTH PHYSICS BUILDING

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 4.1-3

ADMINISTRATION BUILDING

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 4.1-4
OPERATIONS AND MAINTENANCE BUILDING

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

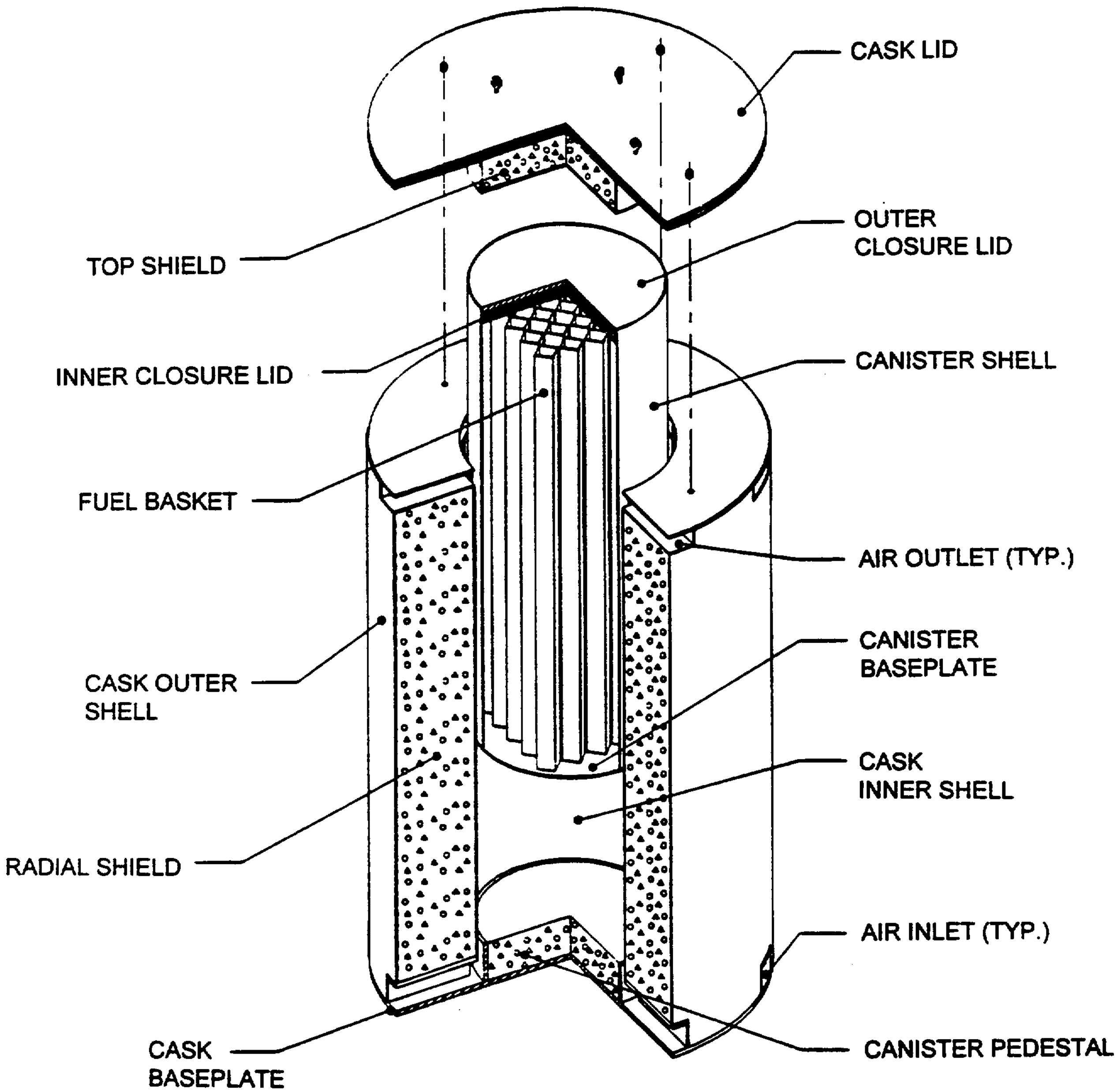
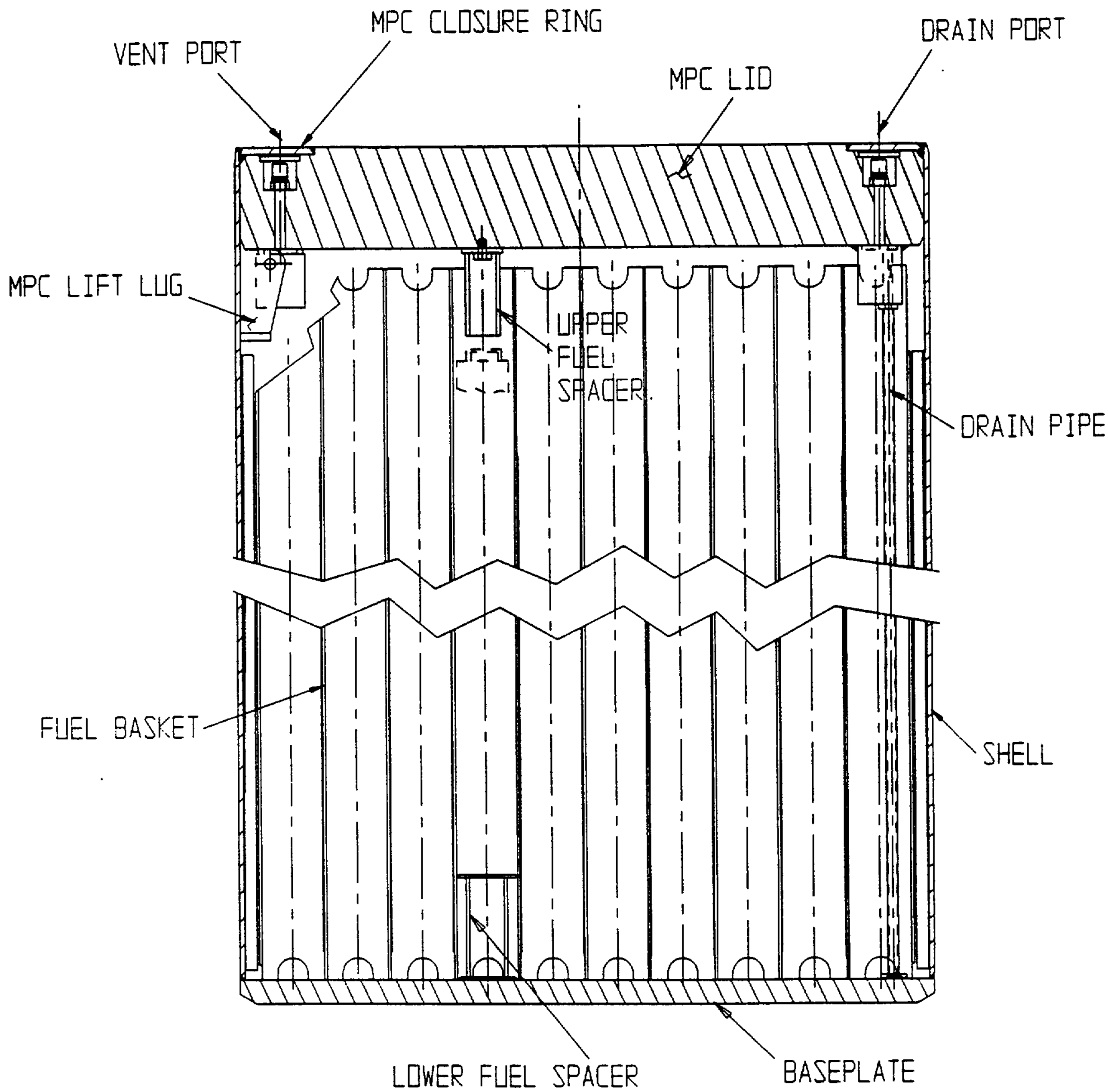


Figure 4.2-1

HI-STORM STORAGE COMPONENTS

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

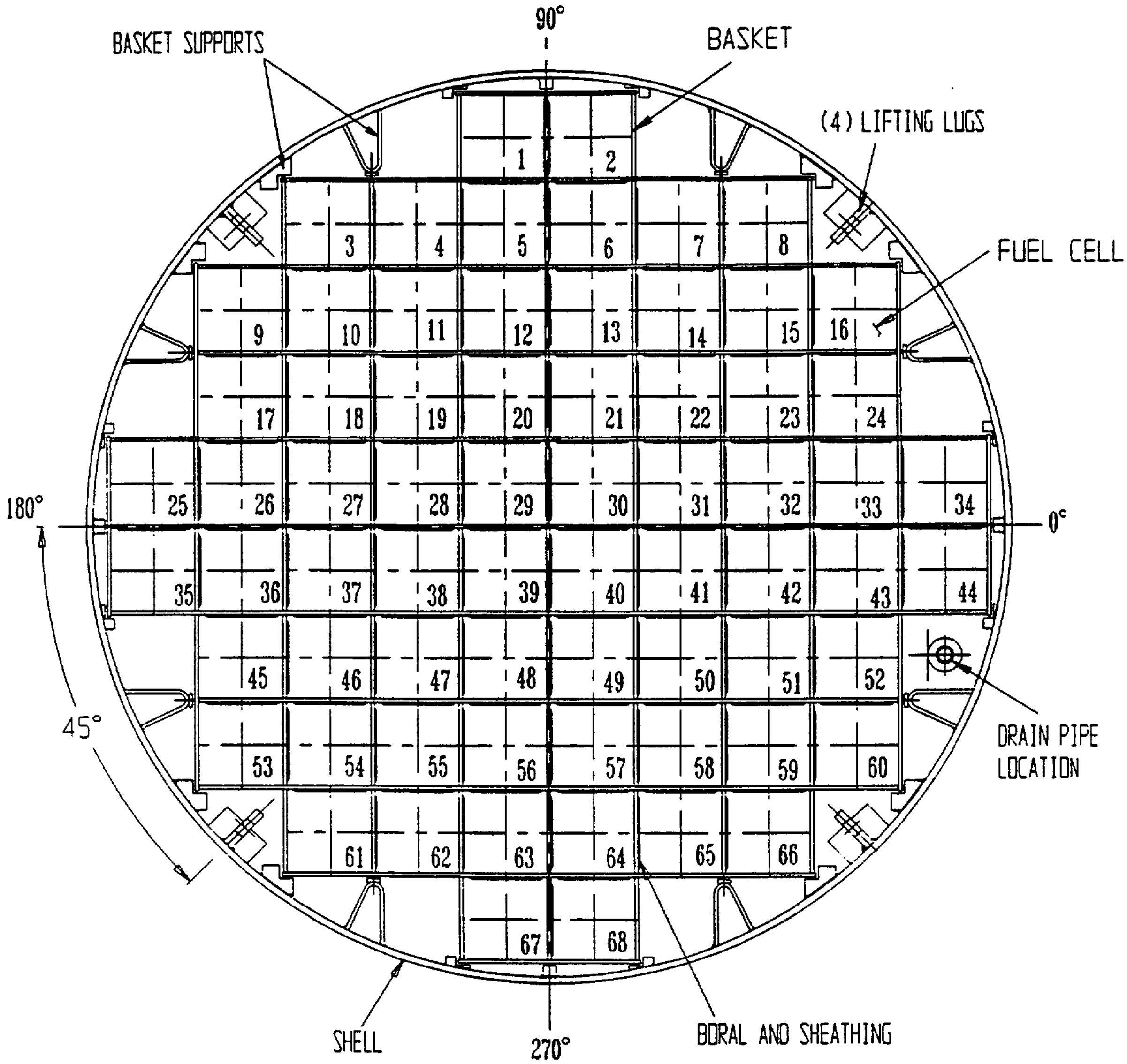


CROSS SECTION ELEVATION VIEW OF MPC

Figure 4.2-2 (Sheet 1 of 3)

HI-STORM STORAGE CANISTER

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

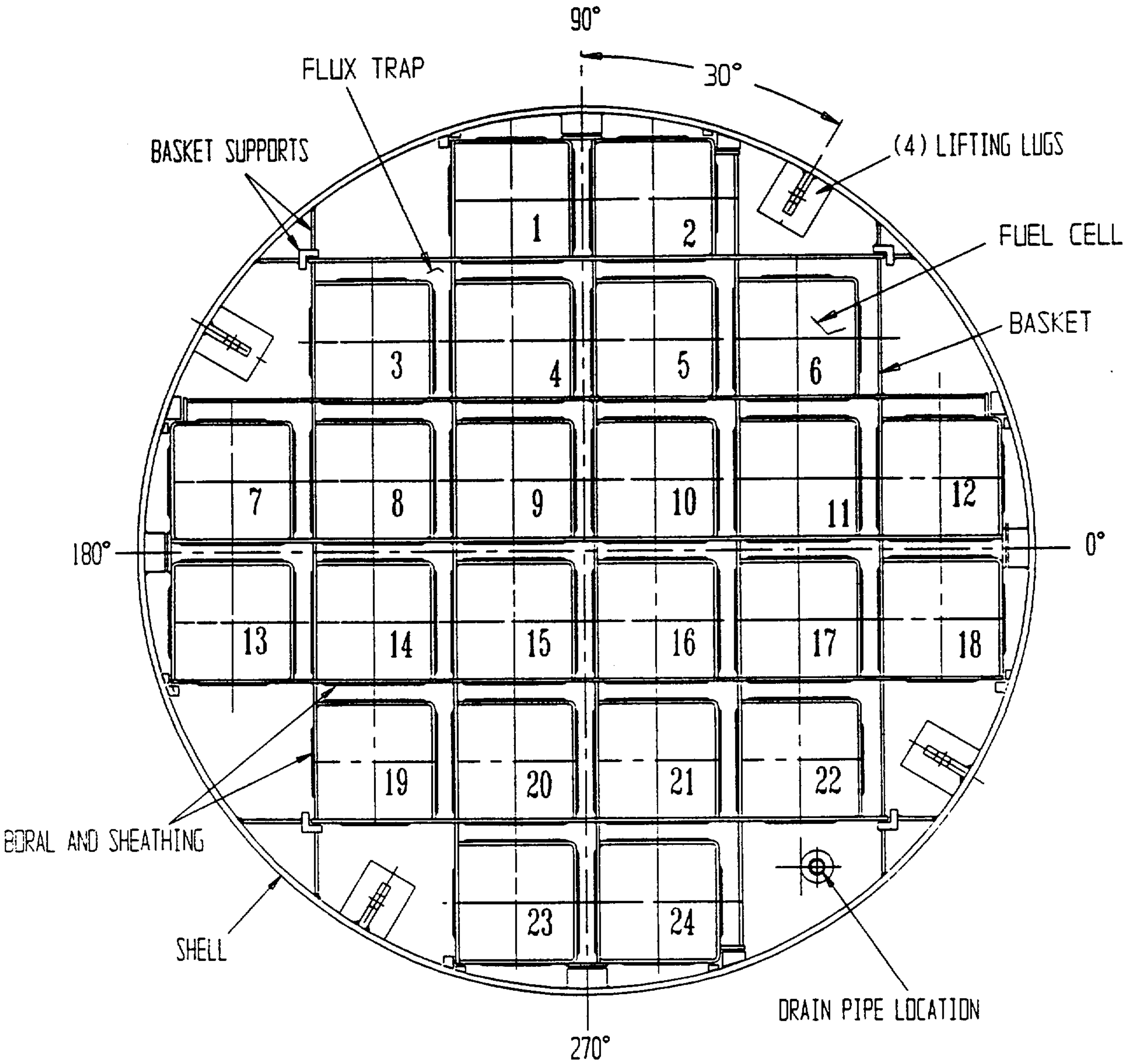


MPC-68 CROSS SECTION

Figure 4.2-2 (Sheet 2 of 3)

HI-STORM STORAGE CANISTER

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT



MPC-24 CROSS SECTION VIEW

Figure 4.2-2 (Sheet 3 of 3)

HI-STORM STORAGE CANISTER

PRIVATE FUEL STORAGE FACILITY SAFETY ANALYSIS REPORT

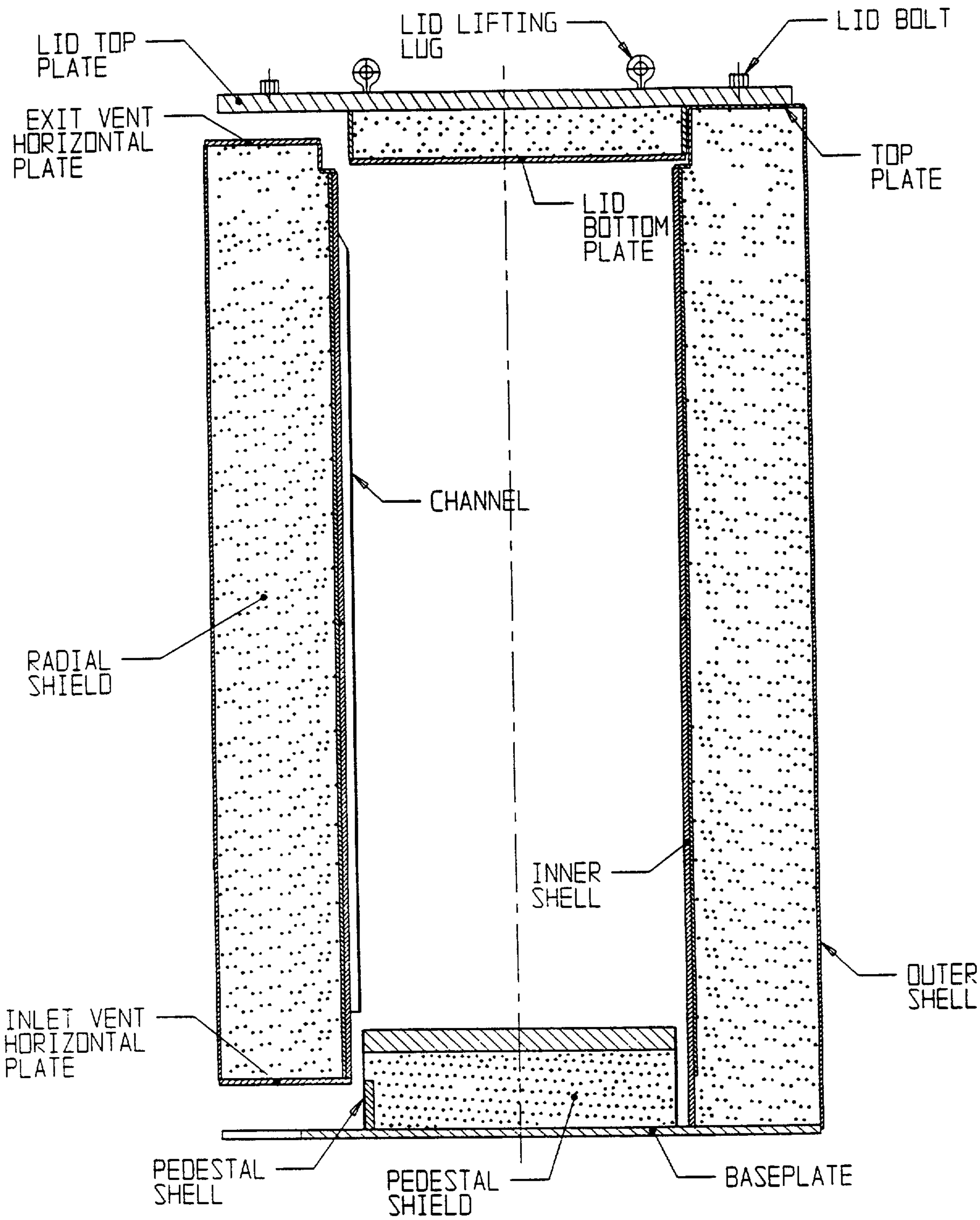


Figure 4.2-3

HI-STORM STORAGE CASK

PRIVATE FUEL STORAGE FACILITY SAFETY ANALYSIS REPORT

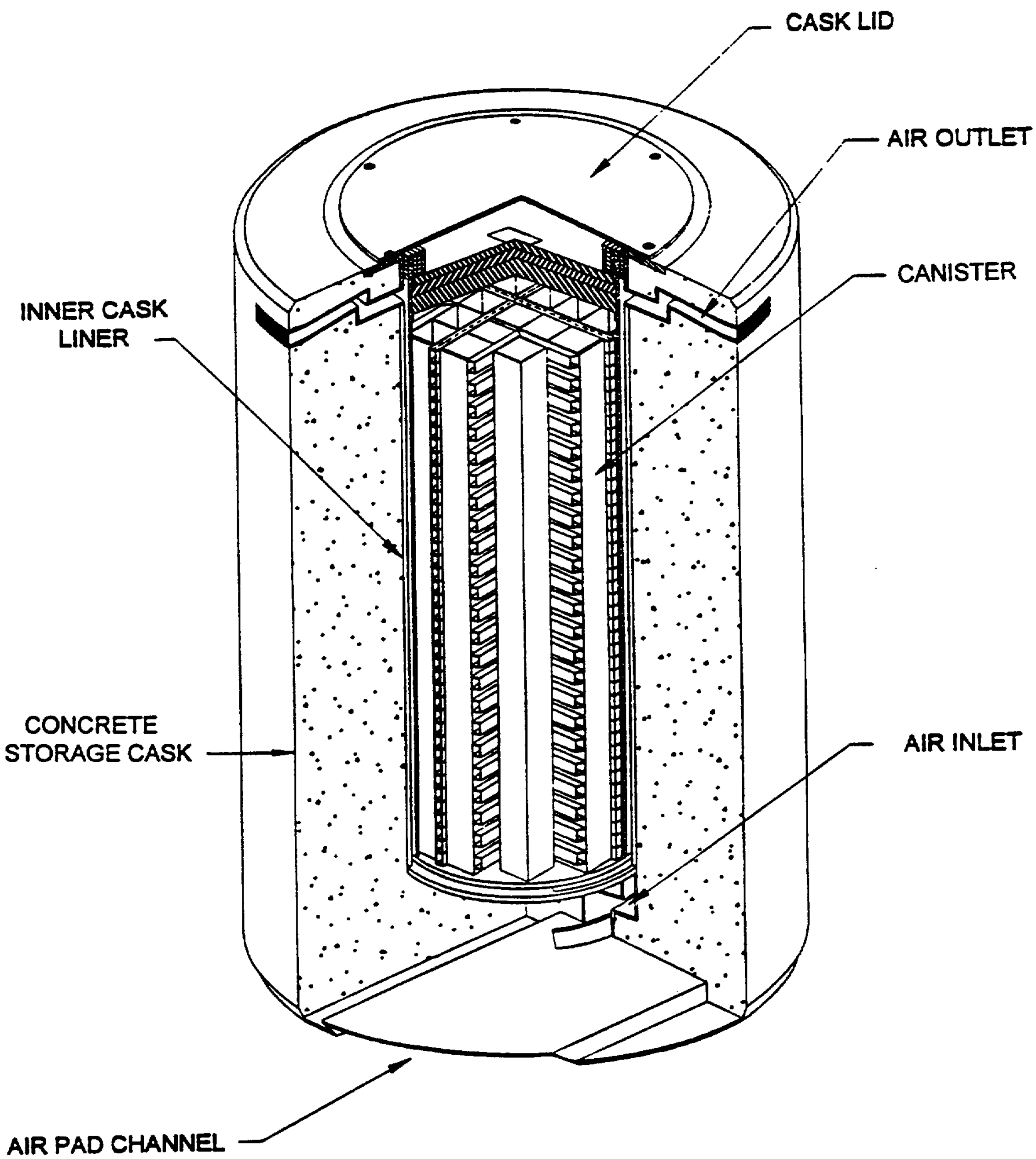
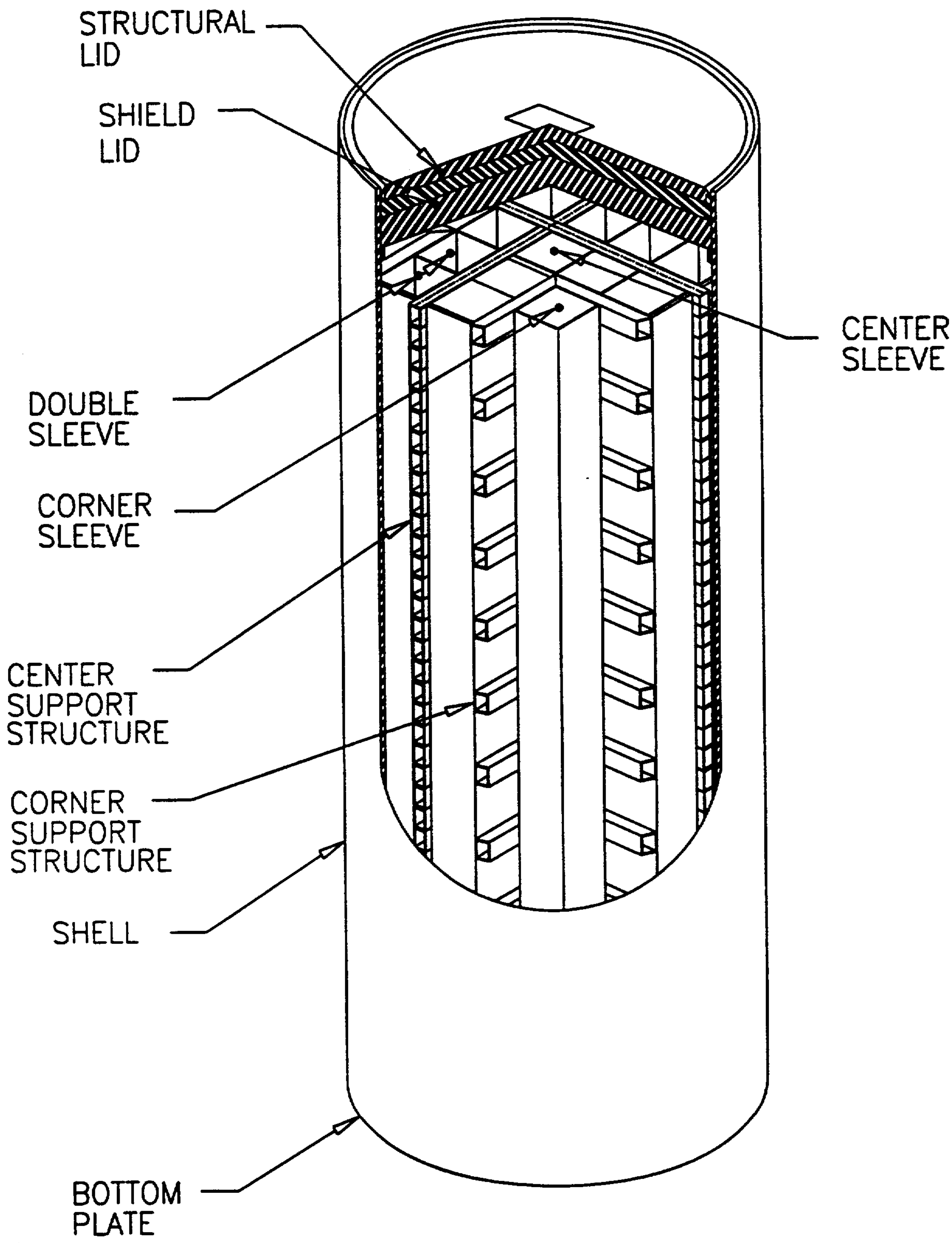


Figure 4.2-4

TRANSTOR STORAGE COMPONENTS

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

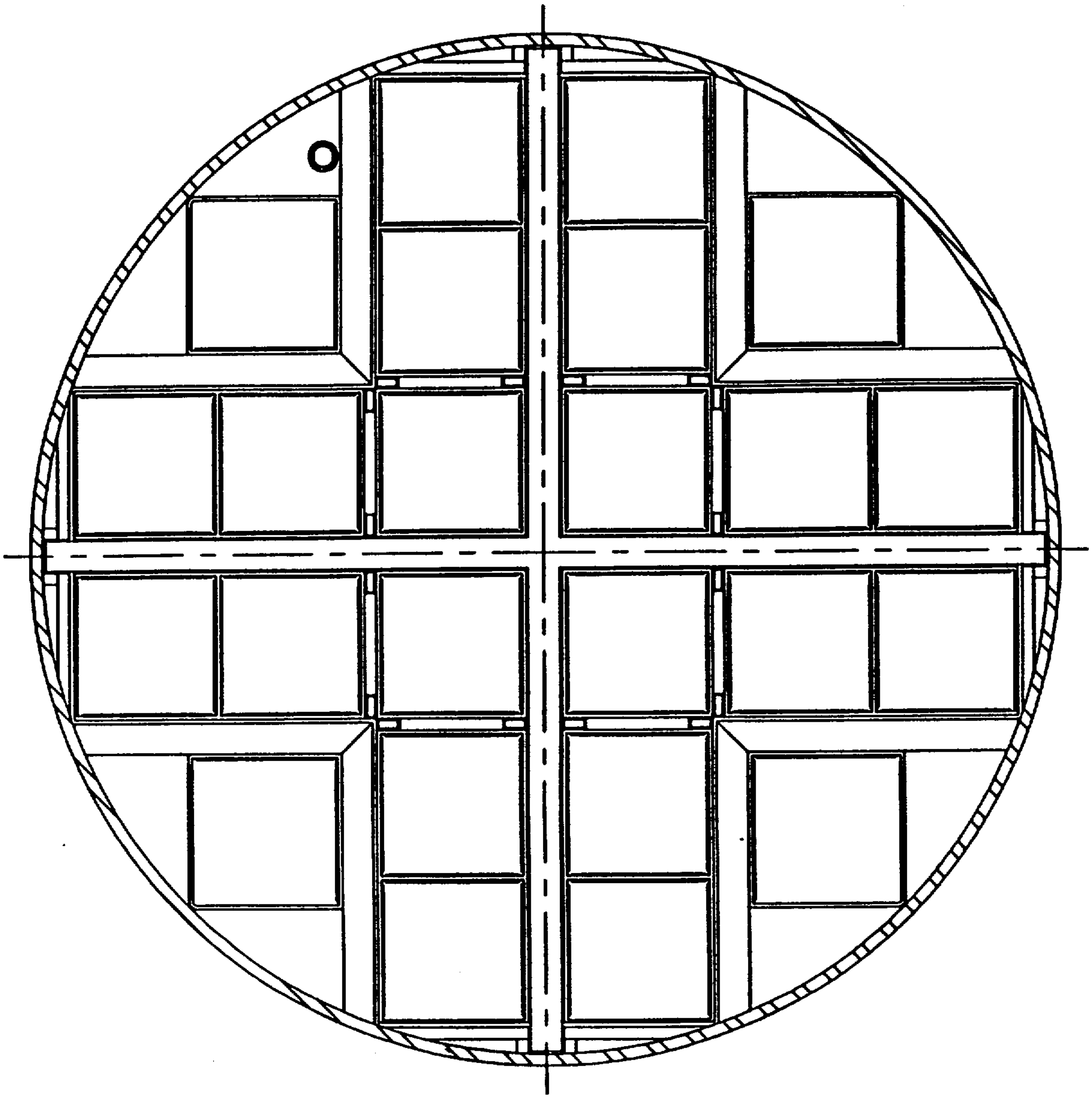


SCHEMATIC OF THE TranStor™ PWR BASKET

Figure 4.2-5 (Sheet 1 of 4)

TRANSTOR STORAGE CANISTER

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

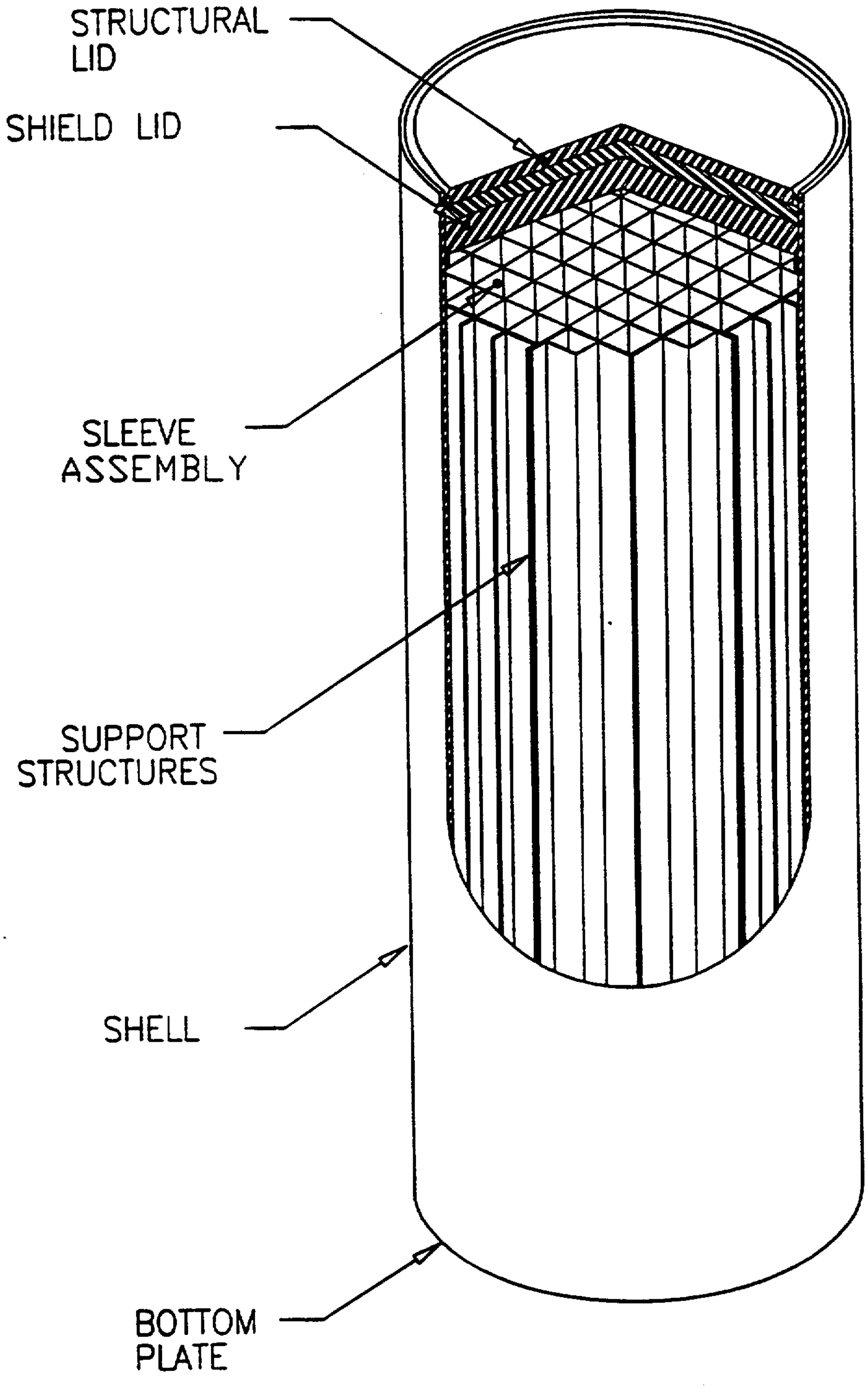


SCHEMATIC OF THE TranStor™ PWR BASKET

Figure 4.2-5 (Sheet 2 of 4)

TRANSTOR STORAGE CANISTER

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

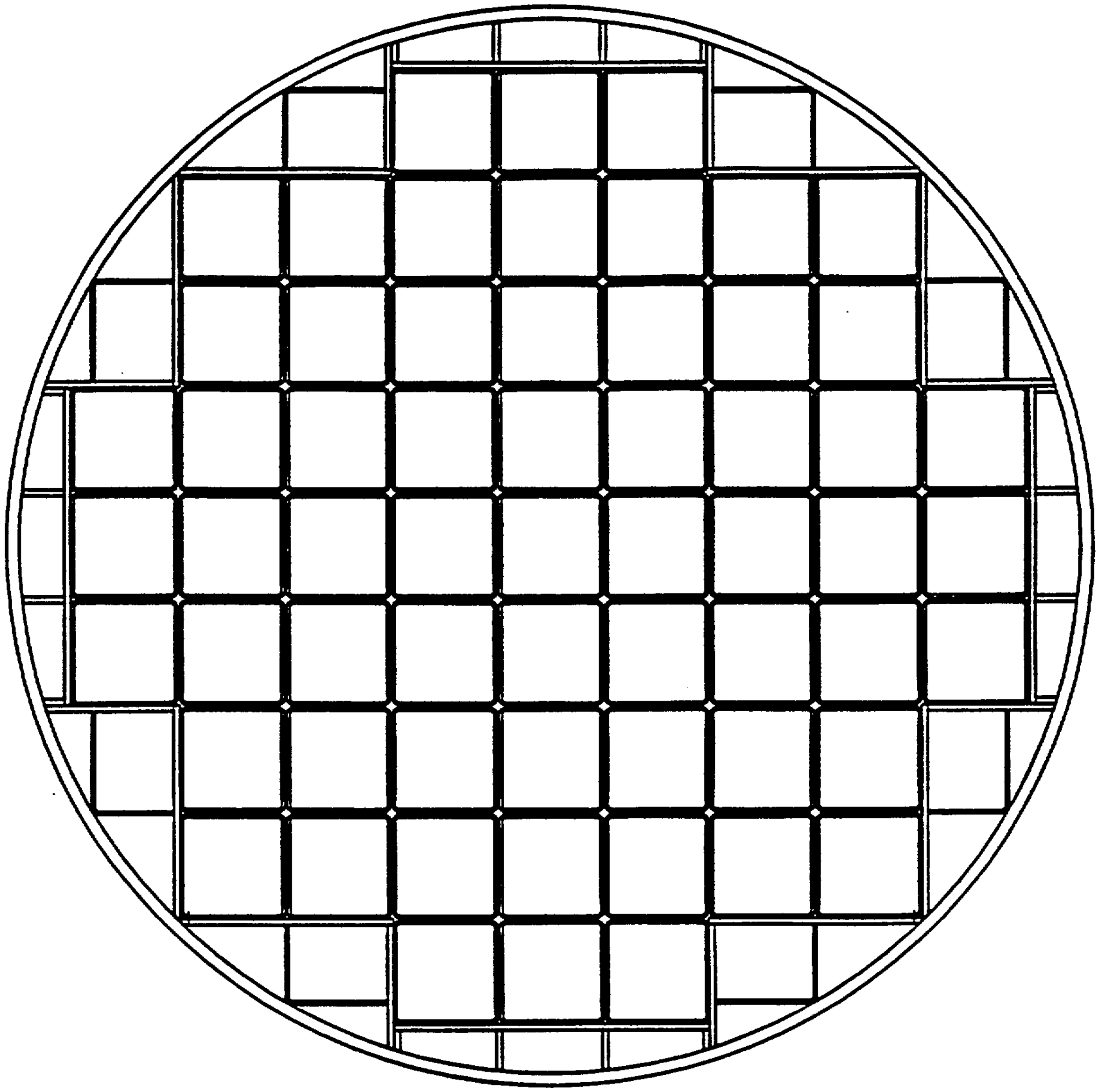


SCHEMATIC OF THE TranStor™ BWR BASKET

Figure 4.2-5 (Sheet 3 of 4)

TRANSTOR STORAGE CANISTER

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT



SCHEMATIC OF THE TranStor™ BWR BASKET

Figure 4.2-5 (Sheet 4 of 4)

TRANSTOR STORAGE CANISTER

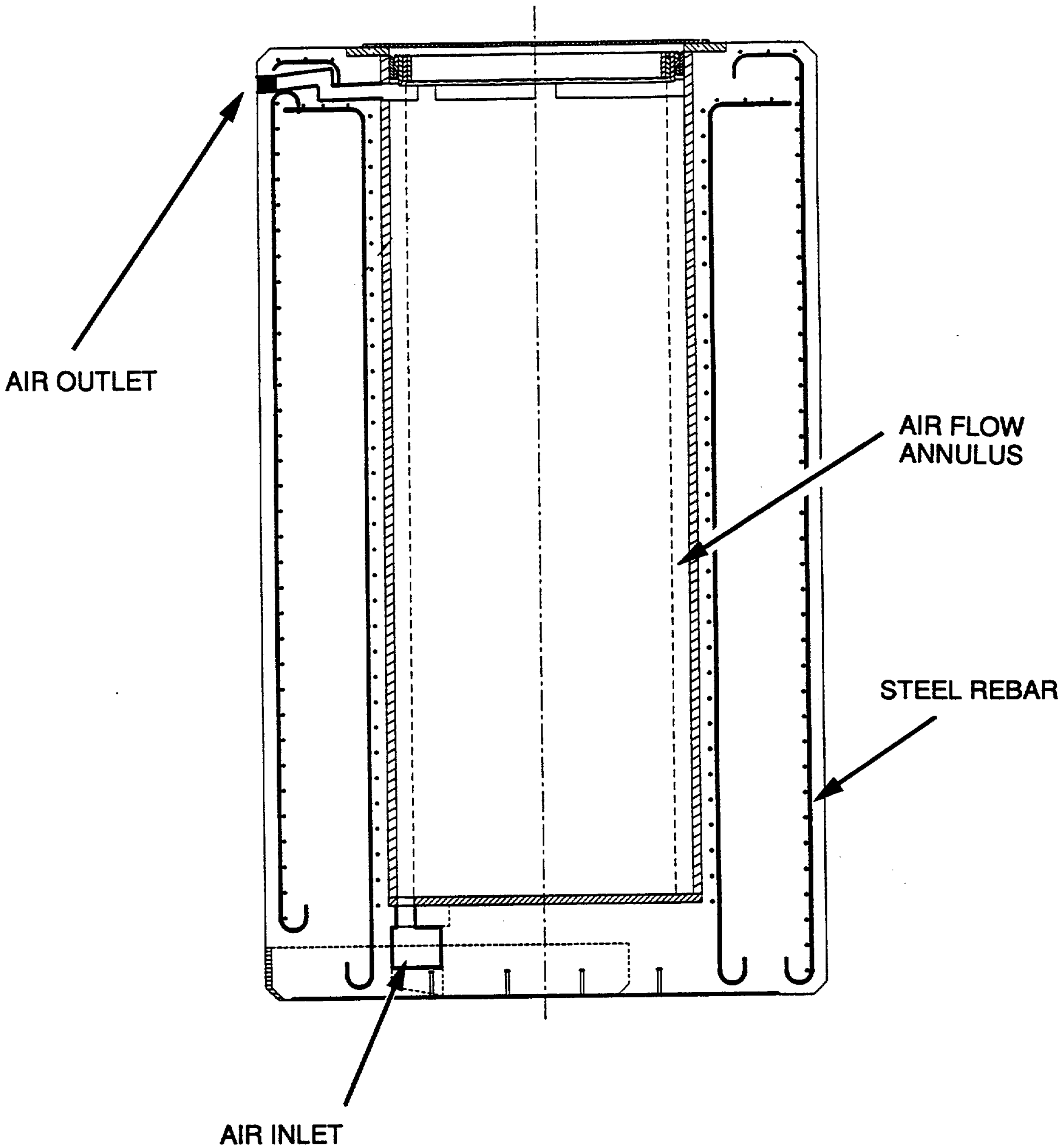


Figure 4.2-6

TRANSTOR STORAGE CASK

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 4.2-7

CASK STORAGE PADS

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

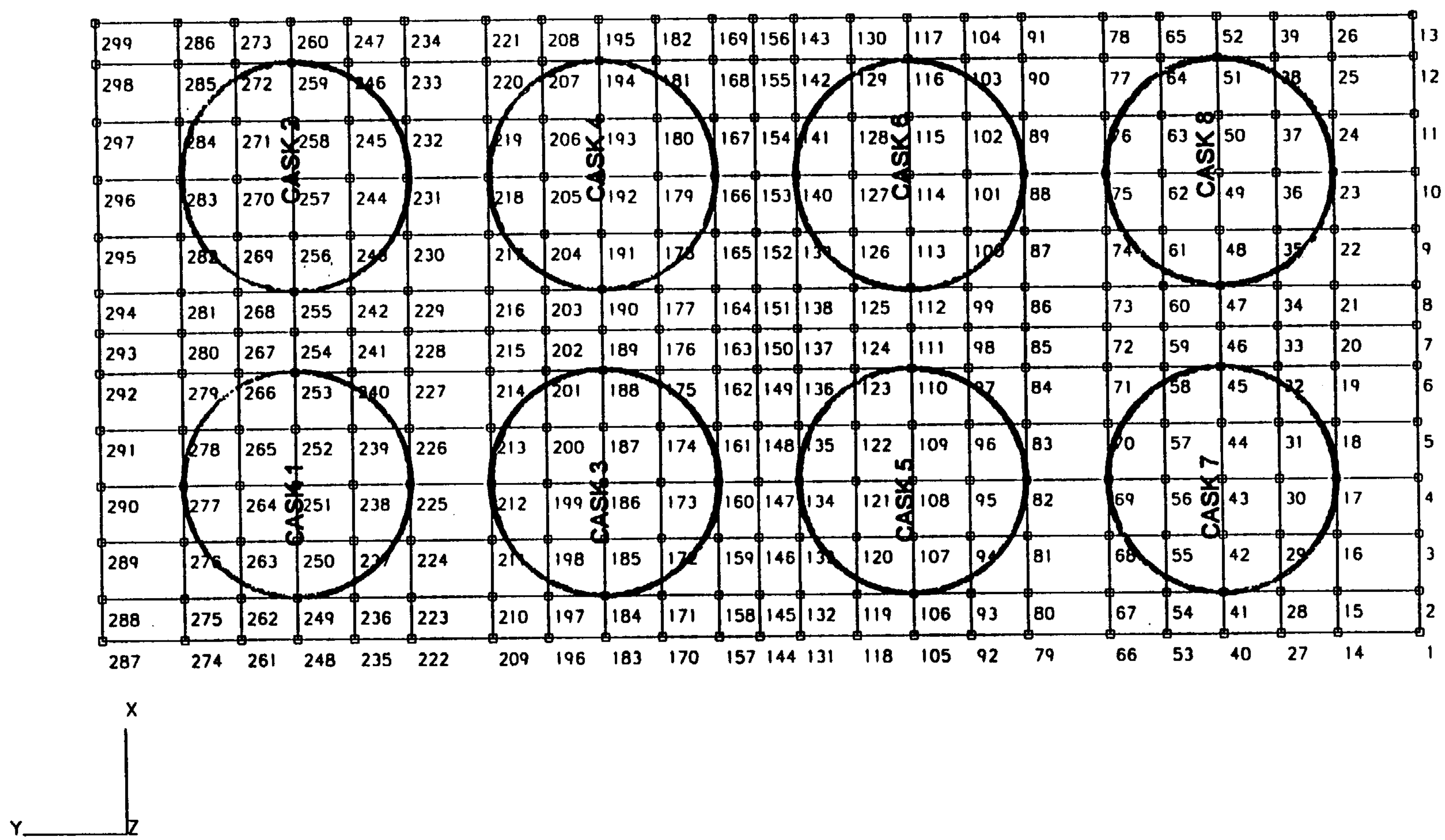


Figure 4.2-8

COMPUTER MODEL OF CASK STORAGE PAD

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

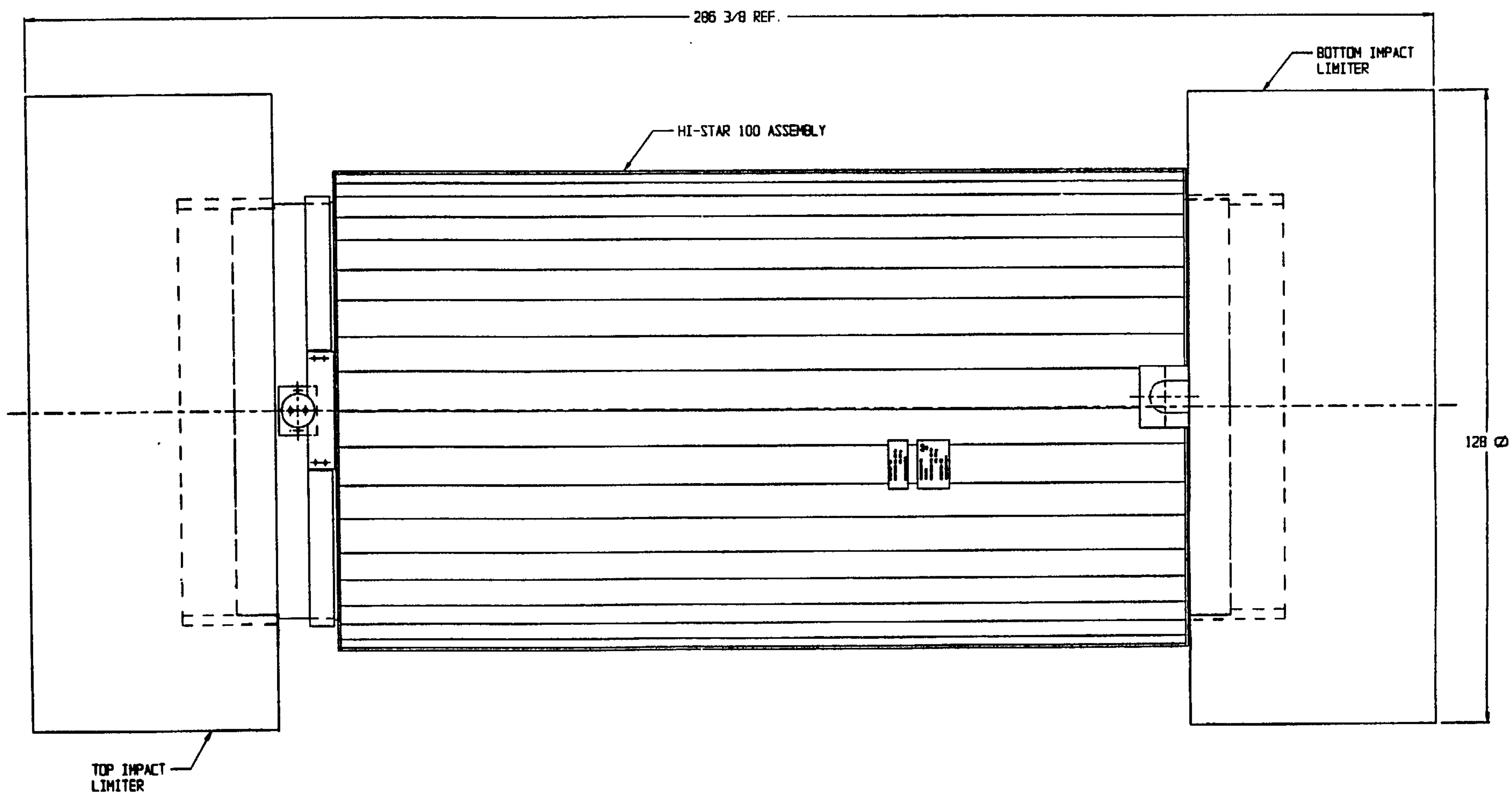


Figure 4.5-1

HI-STAR SHIPPING CASK COMPONENTS

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 4.5-2

TRANSTOR SHIPPING CASK COMPONENTS

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 4.5-3

EQUIPMENT AT THE INTERMODAL TRANSFER POINT ALTERNATIVE

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

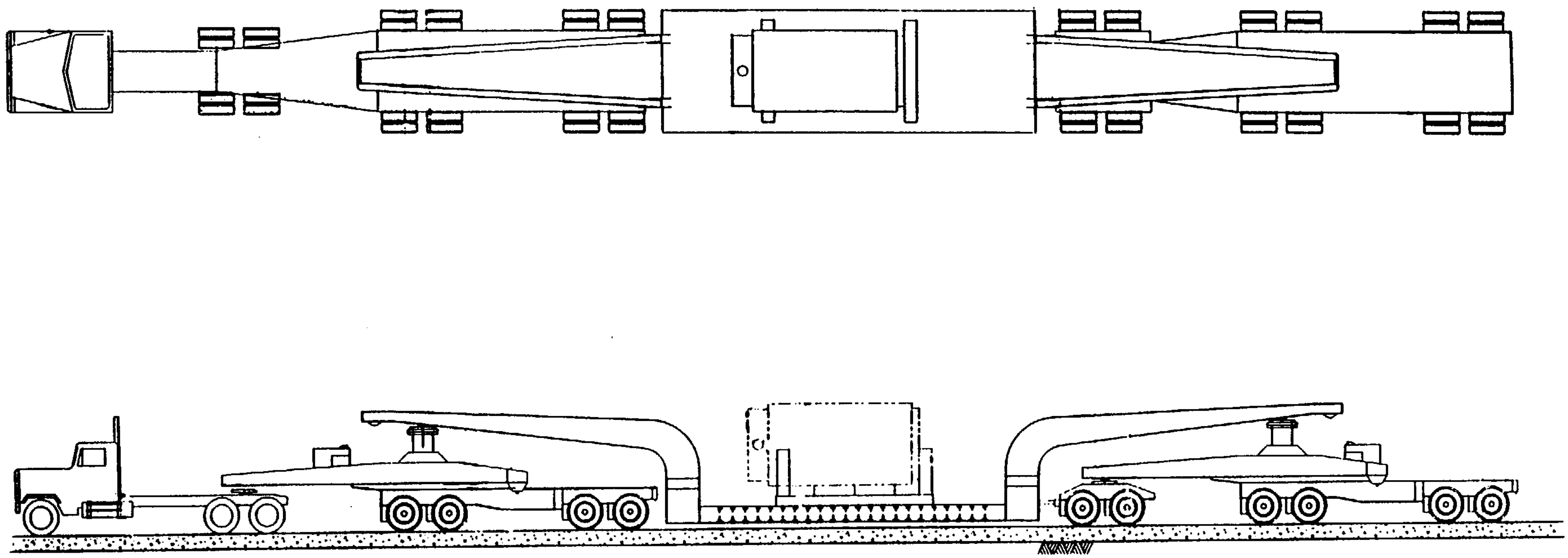


Figure 4.5-4

SHIPPING CASK HEAVY HAUL TRACTOR/TRAILER ALTERNATIVE

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

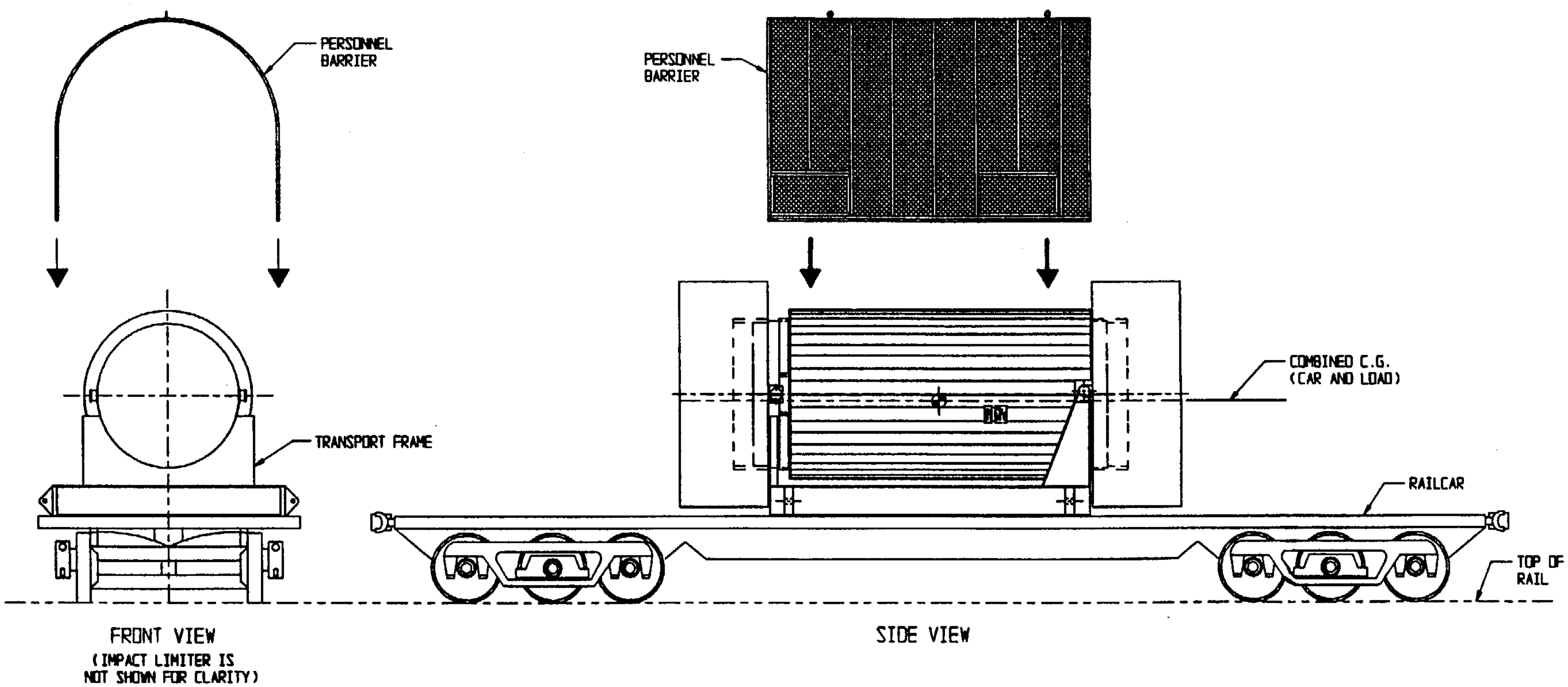


Figure 4.5-5

145 TON FLAT BED RAIL CAR ALTERNATIVE

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

FIGURE WITHHELD AS SENSITIVE
UNCLASSIFIED INFORMATION

Figure 4.7-1 (Sheet 1 of 3)

CANISTER TRANSFER BUILDING

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

FIGURE WITHHELD AS SENSITIVE
UNCLASSIFIED INFORMATION

Figure 4.7-1 (Sheet 2 of 3)
CANISTER TRANSFER BUILDING
PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 4.7-1 (Sheet 3 of 3)

CANISTER TRANSFER BUILDING

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

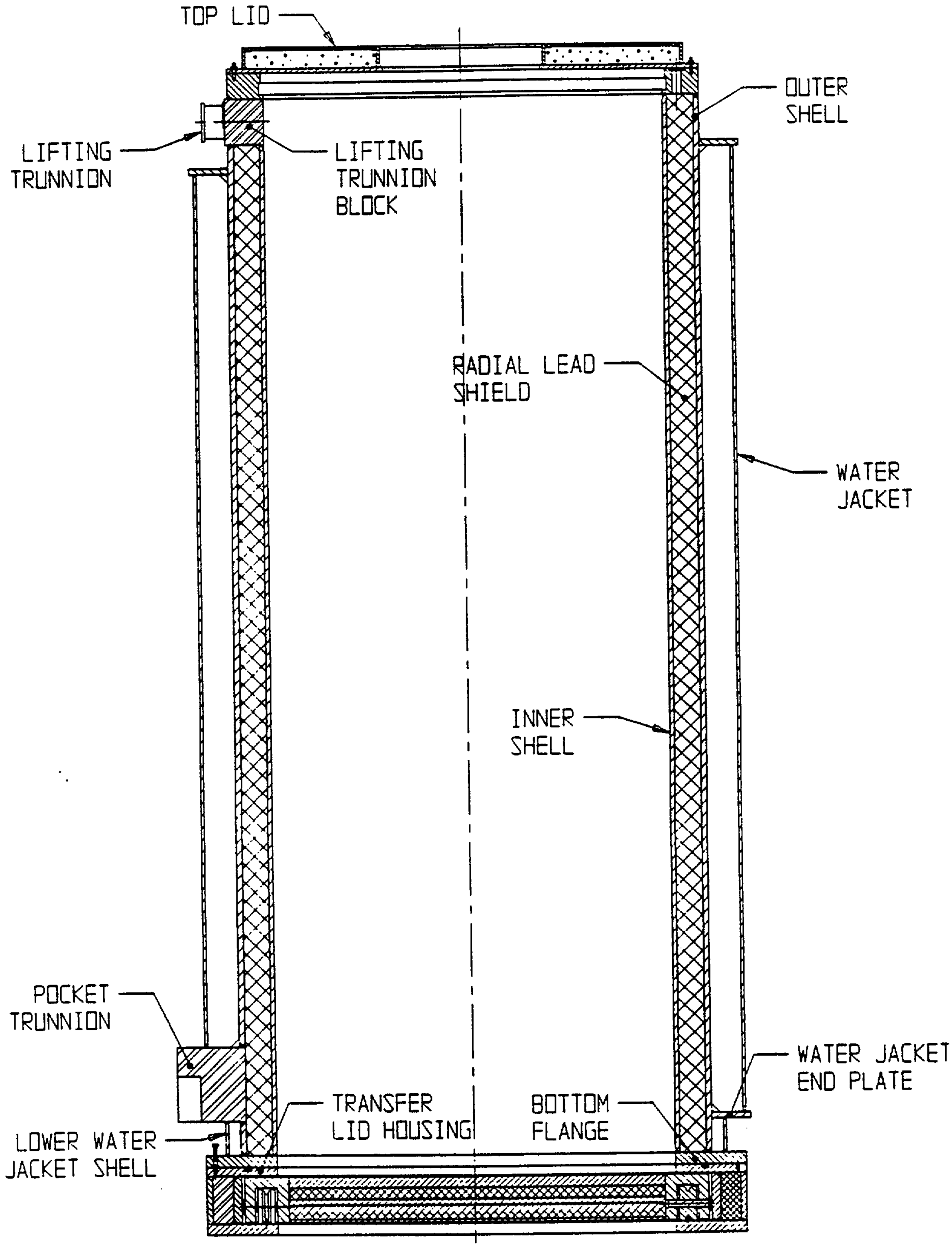


Figure 4.7-2

HI-TRAC TRANSFER CASK

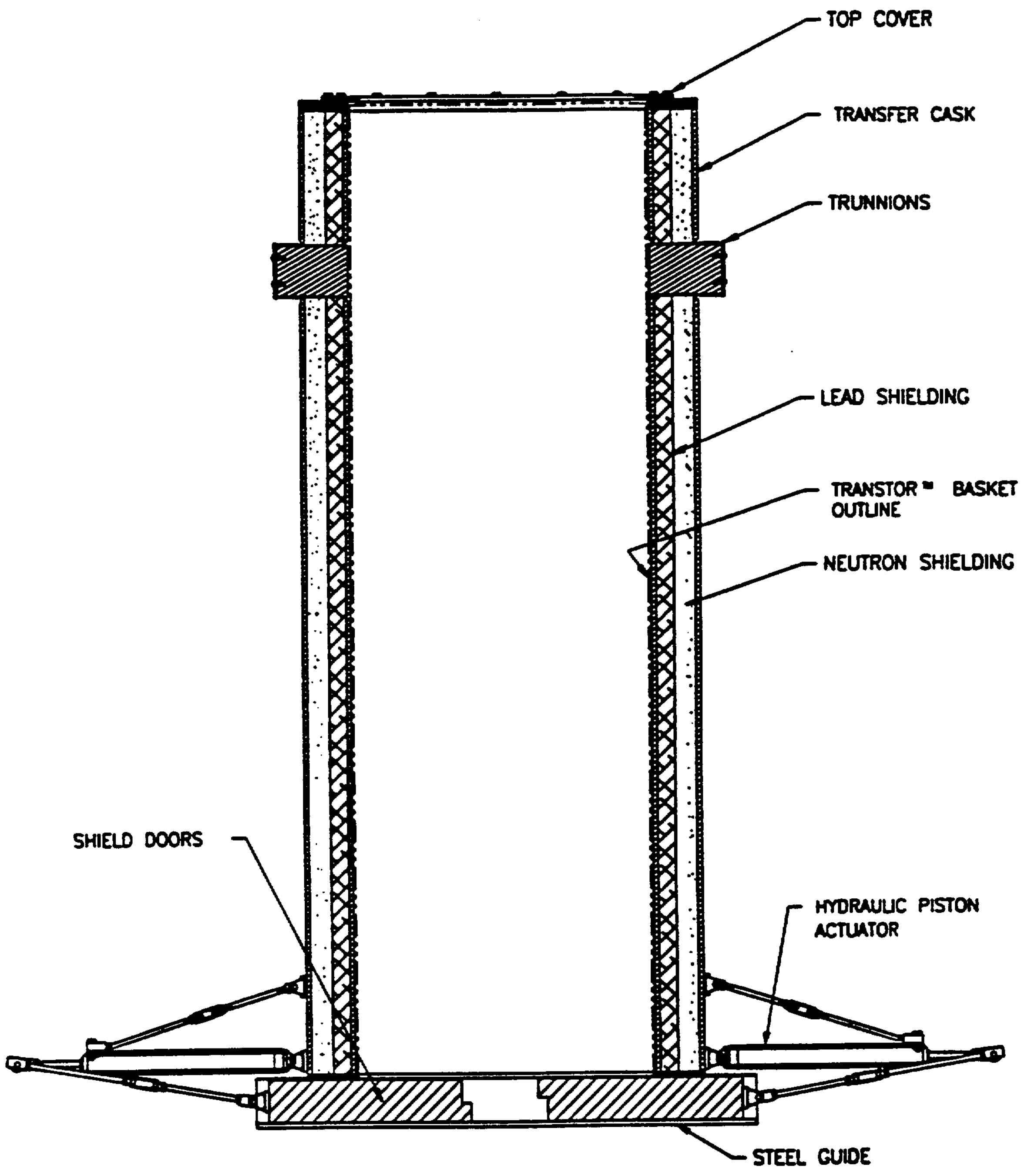


Figure 4.7-3

TRANSTOR TRANSFER CASK

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT

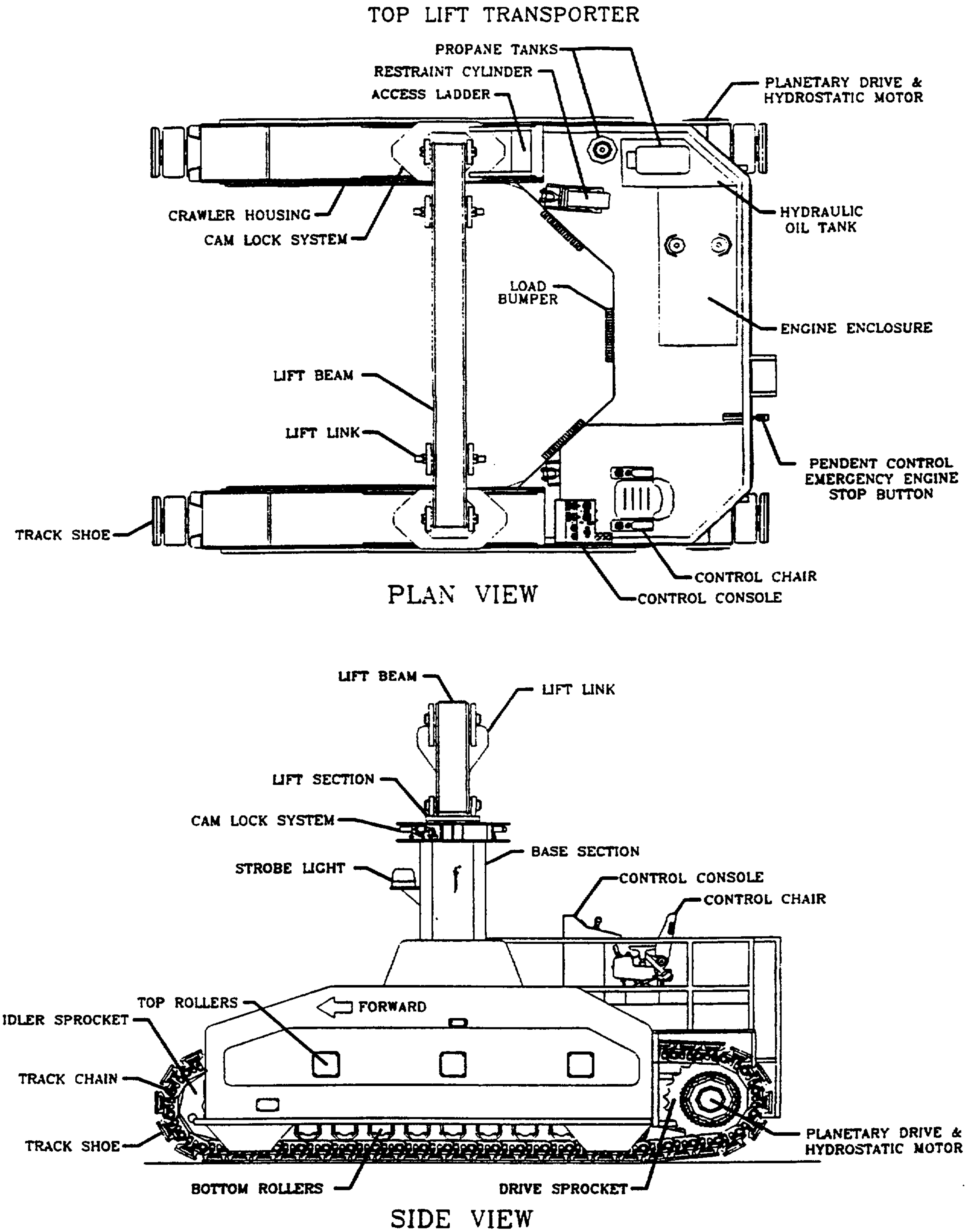


Figure 4.7-4

CASK TRANSPORTER

PRIVATE FUEL STORAGE FACILITY
SAFETY ANALYSIS REPORT