CHAPTER 8

ACCIDENT ANALYSES

8.0 ANALYSIS OF DESIGN EVENTS

The purpose of this section is to evaluate the safety of the H. B. Robinson (HBR) Independent Spent Fuel Storage Installation (ISFSI). The safety evaluation is accomplished by analyzing the response of the various components of the ISFSI to normal and off-normal conditions and a range of credible and hypothetical accident conditions.

In accordance with NRC Regulatory Guide 3.48, design events identified by ANSI/ANS 57.7-1981 are used in the safety evaluation of the ISFSI. In ANSI/ANS 57.7-1981, four categories of design events are defined. Design events of the first and second type are addressed in Section 8.1, and design events of the third and fourth type are addressed in Section 8.2 of this report.

Many of the design events in the above four categories have been addressed in the NUTECH Horizontal Modular Storage (NUHOMS) System Topical Report (Reference 8.1) using enveloping criteria. Whenever the site specific load is enveloped by that of the NUHOMS Topical Report, it will be noted and will reference the appropriate section of the Topical Report. Additional site specific analysis which has not been covered in the NUHOMS Topical Report will be discussed in detail in the following sections.

As discussed in Section 3.2 of this Safety Analysis Report (SAR), some design features of the HBR ISFSI are unique and differ from those of the NUHOMS generic concept. In particular, the HSM has a rear access penetration, whereas the generic concept is without any rear access. However, as discussed earlier the methodology of the structural evaluation of the HSM under the above categories of design events as utilized by the referenced report is such that it will conservatively envelop any modular stacking arrangement. Hence, the stress evaluation and the analytical results presented in Chapter 8 of the referenced report for the NUHOMS modules are fully applicable to the site specific HSM.

Some design features of the HBR DSC are also different than those of the NUHOMS generic concept. Specifically the DSC is designed to withstand inertia forces associated with cask drop accidents in which the drop height is significantly higher than the soft drop criteria established earlier in this report. Because of these design features, additional structural evaluation of the DSC is required. The method of analysis, however, for many of the design event cases is the same as the methodology utilized in the NUHOMS Topical Report. For these cases the appropriate sections of the referenced report containing the applicable methodology will be referenced. In other cases where a new methodology is utilized, such as the drop accident case, the analytical approach will be presented. In either case the resulting DSC stress evaluation will be tabulated and reported throughout this chapter.

The design of the DSC support assembly for the HBR ISFSI is identical to the NUHOMS generic concept and as such the stress evaluation presented in the referenced report is fully applicable to this component.

Since a foundation design was not included in the NUHOMS Topical Report, Section 8.3 is included in this Safety Analysis Report (SAR) to describe the foundation design and analysis using the four categories described above.

As described earlier in this report two of the DSCs will be instrumented for the purpose of collecting data. Section 8.4 of this report addresses the safety features of the instrument penetration.

8.1 NORMAL AND OFF-NORMAL OPERATIONS

Design events of the first type consist of a set of events that occur regularly in the course of normal operation of the ISFSI. These events are addressed in Section 8.1.1 of this report. Design events of the second type consist of events that might occur with moderate frequency (on the order of once during any calendar year of operation). These off-normal events are addressed in Section 8.1.2 of this report.

8.1.1 NORMAL OPERATION ANALYSIS

The loads associated with the normal operating condition of the ISFSI are as follows: dead weight loads, design basis internal pressure loads, design basis operating temperature loads, operation handling loads, and design basis live loads. The structural components effected by these loads are the dry shielded canister (DSC), DSC internals, horizontal storage module (HSM), DSC support assembly and the foundation. The following paragraphs discuss these loads and compare them to the generic assumptions reported in Section 8.1.1 of the NUHOMS Topical Report (Reference 8.1).

a) Dead Weight Loads - Dead weight analysis contained in Chapter 8 of the NUHOMS Topical Report for the HSM and the DSC support assembly envelops the Robinson ISFSI analysis. Hence, the analysis of dead weight in the Topical Report is applicable to the HBR ISFSI analysis for these components.

The DSC component weights are tabulated in Table 8.1-1. The dead weight analysis of the DSC shell is based on the same analytical approach specified in Section 8.1.1.2, Page 8.1-17 of the referenced report. Furthermore, since the total weight of the DSC is approximately the same as that of the NUHOMS generic DSC, the resulting DSC shell stresses are the same. For the dead weight analysis of the spacer disk the results of the finite element analysis reported in Section 8.1.1.3, page 8.1-32 of the referenced report can be directly ratioed for the effect of the weight redistribution and the change in the spacer disk thickness. The site specific spacer disks are 2 inch thick compared to the 1.25 inch of the NUHOMS spacers. Also, the maximum total weight distributed on one spacer is 2034 pounds compared to the 1834 pounds for the NUHOMS. Based on these differences the maximum resulting stress reported in Table 8.1-7 of the referenced report can be ratioed by the relation:

$$S_{SP} = (S_{NU}) \left(\frac{W_{SP}}{W_{NU}}\right) \left(\frac{t_{NU}}{t_{SP}}\right)$$

Where:

S_{sp} = ksi, the site specific spacer disk membrane stress

S_{NU} = 1.58 ksi, the NUHOMS spacer disk membrane stress

W_{sp} = 2,034 lb, weight per site specif. spacer disk

W_{NU} = 1,823 lb, weight per NUHOMS spacer disk

t_{NU} = 1.25 in, NUHOMS spacer disk thickness

t_{sp} = 2.0 in, site specific spacer disk thickness

Therefore

S_{sp} = 1.10 ksi

The results of the above analyses are tabulated in Table 8.1-2 of this report. The stresses caused by the weight of other components of the DSC and its internals are insignificant and do not warrant extra analysis.

b) Design Basis Internal Pressure Loads - The HBR DSCs are operated with 0.0 psig pressure. However, the DSC is designed for 25.0 psig operating pressure at off-normal conditions. This pressure is the same as that specified in the referenced report. Since the HBR DSC has the same shell thickness as the NUHOMS, the resulting primary membrane stress will remain uneffected. However, for the secondary stresses at the discontinuities the analysis reported in Section 8.1.1.2, Pages 8.1-21 through 8.1-24 of the referenced report is reworked to incorporate the change in the effective thickness of the cover plates. The NUHOMS analysis is based on an effective thickness of 1.5 inch, whereas the minimum available cover plate thickness of the site specific DSC is 1.75 inch. With all other conditions and assumptions being identical, the analysis yields a maximum secondary membrane plus bending stress of 7.64 ksi.

For the bending stress on the cover plate itself, the result of the analysis contained in Pages 8.1-24 and 8.1-25 of the referenced report is multiplied by the square of the ratio of the thicknesses. In this manner, the maximum bending stress on the 1.75 inch thick cover plate is 3.27 ksi.

The results of the above pressure analysis of the DSC and comparison against code allowables are contained in Table 8.1-2 of this report. The maximum DSC internal pressure under accident conditions is 39.7 psig, which is the same as that specified in the NUHOMS Topical Report.

c) Design Basis Operating Temperature Loads - The extreme range of ambient temperature at the Robinson site is -5°F to 105°F. For the NUHOMS Topical Report design, a range of -40°F to 125°F was assumed. Consequently the thermal analyses of the HSM and the DSC support assembly reported in Sections 8.1.4 through 8.1.5 of the NUHOMS Topical Report conservatively envelopes those of the HBR ISFSI.

The DSC thermal analysis contained in Section 8.1.1.2 of the referenced report conservatively envelopes the site specific DSC thermal analysis. This is due to the fact that the maximum shell bending stress reported in that report is based on the generic assumption that no gaps exist between the spacer disk and the inside cavity of the DSC (Section 8.1.1.2, Pages 8.1-26 through 8.1-28). The HBR DSC, however allows for a nominal radial gap of 0.13 inch. This amount of gap is larger than the differential thermal expansion of the disk. Other thermal stress evaluations of the NUHOMS canister, such as the shell stress evaluation due to temperature variation in circumferential direction, and due to dissimilar material, indicated stresses far below the 20.9 ksi obtained for the case discussed above. Hence, for the sake of conservatism and in order to envelope the actual state of thermal stress in the HBR DSC, the thermal stress obtained from the differential expansion of the spacer disk will be reported herein and is tabulated in Table 8.1.2 of this report.

For the thermal expansion evaluation of the DSC internals, the evaluation reported in Section 8.1.1.3, Pages 8.1-33 and 8.1-34 of the referenced report is also fully applicable. This is due to the fact that the gap existing between the top of the fuel region and the bottom of the HBR DSC lead plug is the same as that reported in the referenced report.

d) Operation Handling Loads - The handling loads on the DSC, DSC support assembly, and the HSM are based on the maximum capacity of the hydraulic ram of 22000 pounds. This capacity is the same as that specified in the NUHOMS Topical Report. Therefore, the handling load analysis of the Topical Report, Section 8.1.1, covers the site specific design. Since the ram mounting plate assembly at the rear access of the HSM is site specific, the loading from the ram on this assembly was investigated. The ram loads are transferred to the wall through the embedded pipe and plate which have welded stud anchors. The 22000 pound loading was found to have a negligible effect on the HSM rear wall. The net effect of the tornado-generated missile impact considered in the topical report is to load the side wall with over 1000 kips. The much narrower end wall, during operational loading, is easily enveloped by the previous analysis. The results of the operational handling load analysis of 22000 pounds are tabulated in Table 8.1-2 of this report.

e) Design Basis Live Loads - The maximum snow load (or other live loads) for the Robinson site as derived from the Updated FSAR (Reference 8.2) is bounded by the NUHOMS Topical Report which assumes a live load of 200 psf.

8.1.2 OFF-NORMAL OPERATION ANALYSIS

This section describes the design basis off-normal events associated with the operation of the HBR ISFSI. The events which are considered here are expected to occur on a moderate frequency.

8.1.2.1 Transport

Off-normal events associated with the transport operation of the DSC may occur due to malfunctioning of the auxiliary components (i.e., crane, transporter ram, etc.), or by misalignment of the DSC with respect to the HSM. Malfunctioning of the auxiliary components does not relate to the safe functioning of the DSC and can be rectified without any impact to the operation of the system. As described in Section 1.3.1.7 of this report the only time the cask crane is operating without the redundant yoke is during the cask lowering on the skid assembly. A postulated malfunction or more specifically a yoke failure during this operation is considered as part of the cask drop accident which is reported in Section 8.2.4 of this report. The DSC and the ram grappling assembly are designed to the maximum ram capacity loading of 22,000 pounds. Hence, any off-normal event such as misalignment or ram malfunctioning will not cause any damage to any component of the ISFSI. The misalignment of the DSC may also cause jamming or binding of the canister casing. The analysis of the DSC under assumed jamming and binding conditions is covered in Section 8.1.2 of the NUHOMS Topical Report (Reference 8.1), and is applicable to Robinson ISFSI operation.

All auxiliary components used during the transport operation (i.e., the cask positioning skid, the cask tie-down system, the cradle support, the saddle and the transporter) are designed to withstand the inertia forces associated with transport shock loadings. The DSC and the cask are designed for the postulated drop accident. The inertia forces of a drop accident is significantly greater than the transport shock forces and, hence, inertia forces associated with transportation shock for these components are enveloped by the 8 ft drop accident.

8.1.2.2 Air Flow Blockage

Another off-normal event that may occur is the possibility of air inlet blockage. Because the air inlets are close to the ground, there is a chance that they could become blocked with blowing paper, dirt, snow or other debris. Due to the height of the air outlets, their separation and since hot air is blowing out of the exits, it is less likely that both the exits would become blocked. Furthermore, blockage of one exit alone would not be as severe as blockage of both inlets. Therefore, this off-normal event is defined as complete blockage of the HSM inlets. Blockage of all inlets and outlets is considered highly unlikely and is presented in Section 8.2 of this SAR and in Section 8.2 of the NUHOMS Topical Report.

The blockage of the air inlets has been addressed in the NUHOMS Topical Report in Section 8.1.2. The results of this analysis indicate that the rise in temperature and pressure in various components of the storage system is well within the acceptance limits. The blockage of the air inlets would be discovered during the normal surveillance of the modules. As the analysis shows, excessive temperatures are not reached and, hence, if the blockage were to occur just after one inspection and not be discovered until 24 hours later, no threat to the public health and safety would result. Once detected, the air inlets will be cleared of the blockage.

8.1.3 RADIOLOGICAL IMPACT FROM OFF-NORMAL OPERATIONS

Based on the off-normal operations described in Section 8.1.2, there is no additional radiological impact from the ISFSI beyond what is described in Chapter 7.

TABLE 8.1-1

DRY SHIELDED CANISTER AND HORIZONTAL STORAGE MODULE COMPONENT WEIGHTS

COMPONENT DESCRIPTION	CALCULATED WEIGHT (Pounds)
1. Dry Shielded Canister:	
Casing	2849
Top Grapple Assembly	49
Top Cover Plate	357
Top Lead Casing	617
Top Lead Plug	1307
Top Ring Plate	60
Bottom Cover Plate	605
Bottom Lead Casing	152
Bottom Lead Plug	1555
Total	7551
2. Canister Internals:	
Spacer Disks	1591
4 x 2 1/2" Ø Support Rods	897
7 x Boral Tubes	918
Total	3406
3. 15 x 15 PWR Spent Fuel Assembly	9975
Total Three Loaded Canisters Weight	62796
4. 3 Canister Support Assemblies	4725
5. 3-Bay Reinforced Concrete Module	800770
6. 3 x 2" Steel Door	12528
7. 6 x Shielding Blocks	10556
Total (3 Bay HSM Weight Loaded)	892236

TABLE 8.1-2

MAXIMUM DRY STORAGE CANISTER
SHELL STRESSES FOR NORMAL OPERATING LOADS

DCS COMPONENTS	LOAD TYPE / STRESS TYPE	STRESS (ksi) (1)				ASME CODE ALLOWABLES (ksi) (2)
		DEAD WEIGHT	DESIGN BASIS PRESSURE	DESIGN BASIS TEMPERATURE	OPERATION HANDLING (3)	
Canister Shell	Primary Membrane	0.21	0.91	7.4	0.38	18.7
	Local Primary Membrane	N/A	1.38	7.4	N/A	28.05
	Primary Membrane + Secondary Bending	11.55	7.64	20.90	10.99	56.10
Cover Plate	Primary Membrane	N/A	N/A	N/A	N/A	18.70
	Primary Membrane + Bending	N/A	3.27	0.45	13.36	28.05
Spacer Disk	Primary Membrane	1.10	N/A	N/A	N/A	18.70

Notes:

1. Values shown are maximums irrespective of location.
2. Allowable stresses are conservatively taken at 400EF.
3. Values are based on ram capacity load of 22,000 lb.

8.2 ACCIDENT ANALYSIS

This section addresses design events of the third and fourth types specified by ANSI/ANS 57.7-1981 and any other credible accident that could affect safe operation of the H. B. Robinson ISFSI. The postulated accidents are:

- Loss of air outlet shielding blocks
- Tornado and tornado generated missiles
- Earthquake
- Eight foot drop
- Lightning
- Blockage of air inlets and outlets
- Accident pressurization of the DSC
- Fire
- Leakage of the DSC
- Load Combination
- Train Derailment

In the following paragraphs, the accident analyses for various components of the ISFSI are described. When the accident loads or conditions are the same as (or enveloped by) those addressed in the NUHOMS Topical Report (Reference 8.1), reference will be made to the appropriate section of that report.

8.2.1 LOSS OF AIR OUTLET SHIELDING

This postulated accident assumes the loss of both air outlet shielding blocks from the top of the horizontal storage module. All other components of the ISFSI are assumed to be in normal condition. The air outlet shielding blocks are designed to remain in place and remain completely functional for all postulated accidents except tornado generated missiles. There are no structural or thermal consequences to the ISFSI as a result of the loss of the shielding blocks; however, there are radiological consequences which have been addressed and analyzed in the NUHOMS Topical Report, Section 8.2.1. The resulting increase in air scattered (sky shine) doses or direct radiation as reported in the Topical Report are within 10CFR100 dose limits.

Recovery

To recover from a lost or damaged shielding block caused by a tornado projectile, one of the spare blocks is transferred to the HSM. After the shield block is transferred to the HSM, a crane is used to lift the block into position. The block is then bolted in place. The entire remounting operation should take less than 30 minutes, during which a mechanic will be on the HSM roof for approximately 15 minutes. During this time he will receive less than 50 mrem. The dose to the crane operator and the mechanic on the ground while putting the shield block in place will be approximately 20 mrem each (assuming an average distance of 15 ft from the center of the module roof). Note: The times listed are only to provide estimates of radiation dose to workers. There are no commitments to ensure the shield blocks would be replaced within 30 minutes.

8.2.2 TORNADO/TORNADO GENERATED MISSILE

The most severe tornado wind loadings as specified by NUREG 0800 (Reference 8.3) and NRC Regulatory Guide 1.76 (1974) are selected as a design basis for this accident condition. The applicable design parameters of the design basis tornado (DBT) are the same as those specified in Section 3.2.1 and 3.2.2 of the NUHOMS Topical Report. The accident analysis of the ISFSI under the DBT is covered by the analysis presented in Section 8.2.2 of the referenced report. Given the fact that the HSM method of structural analysis as utilized by the referenced report conservatively envelopes any stacking arrangement of the modules, including the three modular concept at the H. B. Robinson ISFSI, the maximum moment and shear for the design basis wind pressure and missiles are also enveloped by the values given in Table 8.2-3 of this referenced report. Furthermore, the walls of the horizontal storage modules are anchored into the concrete foundation and as such, there is no possibility of overturning or sliding of the modules due to the impact of a massive high kinetic energy missile. The uplift forces generated by the impact of the massive missile and tornado wind loads are included in the foundation design presented in Section 8.3 of this report. The design and analysis of the anchorage system is also presented in Section 8.3.

The result of this accident analysis indicates that all components of the ISFSI are capable of withstanding the tornado wind loads and tornado generated missiles with the exception of the air outlet shielding blocks. The loss of the shielding blocks is addressed in Section 8.2.1 of this report.

8.2.3 EARTHQUAKE

8.2.3.1 <u>Accident Analysis</u>

As specified in Section 3.2 of this report, the maximum ground horizontal acceleration is 0.20g and the maximum ground vertical acceleration is 0.133g. The NUHOMS Topical Report assumes a value of 0.25g for maximum horizontal acceleration and 0.17g for maximum vertical acceleration. In the Topical Report, for the seismic stress analysis of various components, a multiplier of 2 is used to account for multimode excitations. Since the values of the vertical and horizontal acceleration of the referenced report are higher than the H. B. Robinson site accelerations, the seismic analysis for the HSM and the DSC support assembly presented in Section 8.2.3 of this referenced report is fully applicable and the results of these analyses envelop the site specific design. To establish the actual seismic response of the HBR DSC additional analysis is performed. However, the methodology is the same as that reported in Section 8.2.3.2, Pages 8.2-15 through 8.2-19 of the referenced report. Since the site specific design is different than that of the Topical Report, the longitudinal horizontal seismic loading on the HSM was reviewed. First of all, the DSC loads are transferred to the seismic retainer during a seismic event. The retainer is connected to the ram mounting assembly plate through tiedown bolts in the two inch cover plate. Consequently the loading is transferred to the embedded pipe and plate which are anchored into the HSM rear wall. The maximum loading of 8800 pounds generated by this event was found to have a negligible effect on the HSM rear wall.

In the referenced report, Section 8.2.3.2, the DSC shell ovaling mode was found to yield the lowest natural frequency. Since the HBR DSC shell parameters (i.e., the thickness and nominal diameter) have not been changed the lowest natural frequency remains the same at 37.2 Hz. The stresses induced on the canister casing and the basket due to the 0.20g horizontal and 0.133g vertical seismic accelerations are calculated on the basis of equivalent static method. The static stresses obtained are increased by a factor of 2.0 to account for multimode excitation. To obtain the DSC stresses due to the vertical component of the seismic load, the bending stresses calculated for the dead weight analysis can be factored directly by 0.266. The maximum stress obtained in this manner is 3.07 ksi. For the horizontal seismic analysis both the longitudinal and the transverse directions are considered. For the horizontal acceleration in the transverse direction, the method of analysis presented in Page 8.2-16 of the referenced report was employed and a bending stress intensity of 7.5 ksi was obtained. The stresses in the DSC shell and outer top plate due to the restraining action of the seismic restraint assembly under the longitudinal seismic loading was also investigated and found to have negligible effect. The shell stresses obtained for the vertical and horizontal cases were summed absolutely and a combined stress of 9.32 ksi was obtained.

Additionally, using the same methodology as that presented in Section 8.2.3.2, Page 8.2-17 of the referenced report, a margin of safety against a DSC roll over during a seismic event was established. A value of 2.5 was obtained for this margin of safety against the DSC roll over.

In summary, the ISFSI seismic analysis using site specific accelerations is enveloped by that reported in the NUHOMS Topical Report. Furthermore, the HSMs are anchored to the foundation and as such, no overturning or sliding of the modules is possible. However, the overturning effects on the foundation are included in the foundation design which is presented in Section 8.3 of this report. The anchorage design is also presented in Section 8.3 of this report.

8.2.3.2 Accident Dose Calculation

The major components of the HBR ISFSI are designed and analyzed to withstand the forces generated by the safe shutdown earthquake, hence there are no dose consequences.

8.2.4 DROP ACCIDENT

8.2.4.1 Postulated Cause of Events

As described in Section 1.3.1.7 of this report, the only time during the transfer operation that the IF-300 cask is operating without its redundant yoke is during the cask lowering into the cradle of the skid assembly. As shown in Figure 8.2-1 the maximum height that the cask is raised during this operation is 8.0 feet. Hence, the maximum height of a postulated drop accident is limited to this value. Furthermore, since the cask is always lifted from the trunnions located at the upper regions of the cask, the postulate failure of the single yoke can only cause a cask bottom end or a corner drop. Consequently, if the yoke fails during the tilting operation the cask will either land on the bottom end fins or on the side steel rings located near the upper and lower regions of the cask outer shell.

Based on the above discussion, an 8-foot drop criteria in either horizontal or vertical bottom end orientation will bound any possible drop orientation during the transfer operation, including a corner drop orientation. The skid assembly and the cask/skid/trailer tie down systems are designed to withstand the inertia forces associated with the transportation shock loads, and as such there is no possibility of a cask drop during the transport operation from the decon area to the HSM site. Even if such unlikely event occurs or the cask/skid/trailer tip over as a unit, the height of this drop condition is enveloped by the 8 foot drop height criteria.

8.2.4.2 Drop Accident Analysis

As stated earlier in Section 1.3.1.3 of this report, the IF-300 cask requires an additional extension collar and a new cask lid, in order to meet the cask cavity minimum length requirement and meet the criteria for cask lid removal in horizontal orientation. In this modified configuration the cask's impact limiters which are the radial fins attached to the cask's original head are removed. Hence, the energy absorbing properties of the cask is significantly reduced at upper regions. However, as discussed earlier the cask is always handled in upright position and no postulated failure mechanism can produce a top end drop. Additionally, the 8 feet rise of the cask is not sufficient for the cask to rotate 180 degrees in mid air to land on its head or upper corner. The remaining part of the cask impact limiters, i.e., the bottom radial fins and the ring and both ends are not altered and will provide the energy absorption mechanism needed for the vertical bottom end and the horizontal drop.

The IF-300 cask energy absorbing properties are contained in the cask Safety Analysis Report (Reference 8.4). This SAR contains extensive data concerning a 30-foot drop accident.

The latest deceleration time history development work of the IF-300 cask is contained in Appendix V-1 of the above referenced document. These particular impact time histories contain peak deceleration values, at early time of impact. These peak acceleration values are associated with the dynamic yield stress characteristic of the stainless steel fins (strain rate dependency). These time histories which envelop the previous histories reported in the referenced document, include 3 horizontal and 2 vertical drop orientations. These selected time histories were modified to reflect the 8 ft drop criteria described earlier. Since the overall geometry and the weight of the loaded cask are not significantly changed, these deceleration time histories were linearly scaled to reflect the 8 ft drop criteria. Figure 8.2-2 shows the modified deceleration time histories used in the DSC drop analyses.

Horizontal Drop

Principle structures effected by the horizontal drop are the spacer disk and the boral tubes. The boral tubes serve only as a guide for the fuel assemblies and are not considered load bearing members, except for their own weight. In the NUHOMS Topical Report, Section 8.2.9, Page 8.2-35, the stresses in the boral tube under the inertia forces of a 34g drop criteria were evaluated by a finite analysis technique. Since the boral tube design is not changed, the result of this analysis can be directly ratioed for the higher deceleration value of 54.4g. In this manner a maximum stress of 4.24 ksi is obtained.

The DSC basket is designed such that the locations of the spacer disk coincide with the fuel assembly grid strap. Therefore the weight of the fuel assemblies is directly transmitted to the disk. For the analysis of this member, the finite elements analysis reported in Section 8.2.4, pages 8.2-31 through 8.2-34 of the referenced report can be utilized directly. This is due to the fact that the overall configuration of this member has not been changed from that of the NUHOMS generic concept, with the exception of thicker disks, and the analysis is linear elastic. Consequently, the results of the referenced analysis can be factored to include the effect of the mass, thickness, length and deceleration value changes. Additionally, a factor was added to include the additional weight of the support rods in relation to the mass used in the STARDYNE Model.

$$S_{sp} = S_{nu} \left(\frac{M_{sp}}{M_{nu}}\right) \left(\frac{t_{nu}}{t_{sp}}\right) \left(\frac{g_{sp}}{g_{nu}}\right) \left(\frac{l_a}{l_u}\right) \left(\frac{M_{nsr}}{M_m}\right)$$

where:

S_{sp} = Maximum Stress, ksi

S_{nu} = 38.52 ksi (from NUHOMS)
M_{sp} = 2034 lb Mass, CP&L without rods
M_{nu} = 1818 lb Mass, NUHOMS without rods
g_{sp} = 54.4g, site deceleration value
g_{nu} = 34g, NUHOMS drop value
l_a = 26.19 in, actual cell length
l_u = 26.00 in, NUHOMS length
M_{nsr} = 1962.1 lbs Mass, NUHOMS with lids
M_m = 2133.1 lbs Mass, STARDYNE Model

therefore:

S_p = 39.93 ksi

It must be noted that this stress intensity is mainly due to the shear force developed near the imposed artificial support boundary, and as such is not representative of the actual stress of the disk. A more critical stress location of the disk is at the spacer beams adjacent to the fuel assemblies. The maximum membrane stress intensities is 23.5 ksi which is obtained by the same ratioing technique discussed above. The results of the horizontal drop analysis are contained in Table 8.2-1 of this report.

<u>Vertical Bottom End Drop</u>

The components of the DSC that are critically effected during a vertical bottom end drop are the DSC shell, the top and bottom DSC regions, the support rods and related DSC welds. The vertical drop analyses utilize both hand calculations and finite element technique. For the DSC shell and the end regions ANSYS program was employed for its axisymmetric and linear or nonliner features. Other components of the DSC are analyzed by hand calculation techniques.

As stated earlier in this report, the HBR DSC configuration is different from that of the NUHOMS generic concept. The DSC has been redesigned to fit into the IF300 cask, and also is designed to withstand a drop accident in which the height of the drop is significantly greater than the 8-foot criteria. This is done for compatibility with future shipping options.

For the DSC bottom region analysis a model consisting of 131 elements and 183 nodes was developed. The model is shown in Figure 8.2-3. Both lead and steel are modeled as 2-D, 4-node isoparametric axisymmetric finite elements (STIF42). The interface of the lead and steel is modeled with coincident nodes which are coupled in vertical direction only. In this manner, only normal forces are transmitted between the two surfaces, and the shear and friction forces are conservatively released. Both physical and symmetrical boundary conditions are imposed at appropriate locations. The material properties are conservatively taken at 400°F to envelop peak temperatures of the DSC shell. The entire weight of the basket and the fuel assemblies are included as added mass elements along the top surface of the 2 inch cover plate. The weight of the top region of the DSC and that portion of the DSC shell that is not included in the model, is also included as added mass at the appropriate location on the shell. The response of the DSC bottom region under the drop impact time history was conservatively approximated by an equivalent static analysis. The impact time history has a very short duration and essentially behaves like a very short triangular impulse. Frequency analyses performed on various DSC components indicated that the longest natural period was much greater than the duration of the impulse. Thus, the dynamic impact loads cannot produce a response that exceeds the static response, and as such the dynamic amplification factor is less than unity. Therefore, the static analysis performed is more conservative than a dynamic analysis. An acceleration value of 76.5g was imposed statically on the model. Both membrane and extreme fiber stress intensities at critical locations including the weld elements are reported in Table 8.2-1 of this report.

For the top region of the DSC, another ANSYS finite element model as shown in Figure 8.2-4 was developed. This model consists of 298 isoparametric STIF42 elements and 409 nodes. Similar assumptions and modeling technique as discussed for the bottom region model were employed. Static acceleration of 76.5g was applied to the model to obtain the membrane and bending stresses for various components and welds. The results of this analysis is also included in Table 8.2-1 of this report along with the ASME code allowables.

The 2 1/2 inch diameter steel support rods were analyzed under the postulated vertical drop. These rods extend the entire length inside cavity of the DSC. The main function of these rods is to provide resistance to axial loads for the spacer disks.

Each of the seven spacer disks is welded to these rods by means of fillet welds. One inch clearance is provided between the support rods and the top lead plug of the DSC. This clearance is provided so that thermal expansion of the components and deflection of components during accident loading conditions, such as a drop accident, will not cause interference.

The 2 1/2 inch diameter support rods are designed so that they will resist the weight of the spacer disks under the postulated drop. The most critical segment of the support rod is between the two bottom spacer disks. For this analysis, the weight imposed on a single rod at this critical location was the weight of six spacer disks divided by 4 plus the self weight of 1 rod. The axial stress at this 26 inch segment of the rod was found from the following relationship:

$S_{mx} = W \times a / A$

where: S_{mx} = Axial stress
W = 651.7 lb, total weight imposed on the rod
a = 76.5g, peak vertical deceleration
A = 4.91 in^2, cross sectional area of the rod

therefore:

S_{mx} = 10.15 ksi

The support rod material has been changed from SA304 stainless steel to SA-479 Type XM19 material which has a yield stress of 40.8 ksi at 400°F. The allowable compressive stress for this material is established by the rules of the ASME Appendix XVII, and Appendix F, which include the effect of slenderness ratio.

The results of the support rod analysis along with the compressive stress allowable are tabulated in Table 8.2-1 of this report.

The results of the horizontal and vertical drop analysis as shown in Table 8.2-1 indicate that the stresses in all components of the DSC and its internals are within the ASME acceptance limits and are capable to withstand inertia forces associated with the 8 foot drop accident condition. A corner drop accident was also considered. However the deceleration values as established by the IF-300 cask SAR are significantly lower than the values of either the horizontal or the vertical deceleration components. Therefore the stresses for corner drop analysis are bounded by the analyses presented above.

8.2.5 LIGHTNING

8.2.5.1 Postulated Cause of Events

Since the ISFSI is outdoors, there is a likelihood that lightning could strike the ISFSI. Section 2.3.1 of the HBR2 Updated FSAR (Reference 8.2) provides information on the frequency of cloud-to-ground lightning strokes (the only type of lightning stroke which poses a hazard to the ISFSI) at the site. In order to protect the ISFSI from any damage which could be caused by a lightning discharge, a lightning protection system is installed on the ISFSI. The lightning protection system is designed in accordance with NFPA No. 78-1979 Lightning Protection Code (Reference 8.5). This system will prevent any damage to the HSM and its internals. Therefore, lightning striking the HSM and causing an off-normal condition is not a credible accident.

8.2.5.2 Analysis of Effects and Consequences

Lightning protection systems have proven to be an effective means of protecting a structure and its contents from the effects of a lightning discharge. The lightning protection system does not prevent the occurrence of a lightning discharge; however, the system does intercept the lightning discharge before it can strike the HSM and provides a continuous path for the discharge to the earth. In the event of lightning striking the HSM, the air terminal located on the HSM roof slab would intercept the lightning discharge. The current will follow the low impedance path of the air terminal, conductors, and ground terminals to the earth. Since the system diverts the current, the HSM and its contents will not be damaged by the heat or mechanical forces generated by the current passing through the HSM. In addition, since the ISFSI requires no electrical system for its continuous operation, the resulting current discharge will have no effect on the operation of the ISFSI.

8.2.6 BLOCKAGE OF AIR INLETS AND OUTLETS

This accident is the complete and total blockage of the air inlets and outlets of the horizontal storage module. Since the ISFSI is located outdoors, it can be postulated that the module is totally covered by debris from such an unlikely event as a tornado. The ISFSI's design features, such as a perimeter fence and separation of air inlets and outlets, minimize the probability of such an accident occurring under normal conditions. Nevertheless, such an accident is postulated and analyzed.

There are no structural consequences under this event. The thermal consequence of this accident results from heating of the DSC and HSM due to the blockage of air flow. Section 8.2.7 of the NUHOMS Topical Report addresses this accident condition. The results of the analysis indicate that there is no structural or dose consequence if the air inlets and outlets are cleared within 48 hours. This 48 hour time limit for clearing the air inlets and outlets is specified in the HBR2 ISFSI operation and limits criteria (See Chapter 10).

8.2.7 ACCIDENT PRESSURIZATION OF DSC

Internal pressurization of the DSC results from fuel cladding failure and the subsequent release of fuel rod fill gas and free fission gas. To establish the maximum accident pressurization, it is assumed that all fuel rods in the DSC are ruptured and that the fission gas release fraction is 25%, and the original fuel rod fill pressure is 500 psig. (HBR fuel actually has a fill pressure of 300 psig.) The resulting internal pressures at HBR's maximum ambient temperature of 105^{o}F and at the minimum ambient temperature of -5^{o}F are below the accident pressures reported in Section 8.2.9 of the NUHOMS Topical Report (for temperature extremes of 125^{o}F and -40^{o}F). The limiting accident for canister pressurization is the blockage of air flow to the DSC. Under these conditions, the gas temperatures in the DSC will rise to 413^{o}C (775^{o}F) producing a DSC internal gauge pressure of 2.76 bar (39.7 psig). The canister shell stresses due to accident pressurization are enveloped by those reported in the Topical Report.

The DSC has a safety margin of greater than 3 under this accident condition and as such, there are no dose consequences.

8.2.8 FIRE

No flammable or combustible substances are stored within the ISFSI or within the ISFSI's radiation control area. Additionally, the ISFSI is constructed of non-flammable heat-resistant materials (concrete and steel). The only credible accident which could expose the ISFSI to a flammable substance would be the accidental spillage of a flammable liquid, either through human error or equipment malfunction, at the perimeter of the ISFSI. However, the sandy soil between the sides of the ISFSI's perimeter fence and the HSM, is highly porous. Most of the flammable liquid would be absorbed by the soil, greatly reducing the intensity or duration of the fire.

The only other time in which a component of the ISFSI would be exposed to a potential fire hazard would be during the DSC drying and transport operations. Throughout these operations, the DSC is located within the cavity of the GE IF-300 shipping cask.

Based on the above discussion, exposure of the ISFSI to a long or intense fire is not considered a credible accident.

8.2.9 DRY STORAGE CANISTER LEAKAGE

The DSC is designed for no leakage under any normal or credible accident conditions. The accident analyses in previous sections show that none of the events could breach the canister body. However, to show the ultimate safety of the ISFSI, a total and instantaneous leak was postulated. The postulated accident assumes that one DSC ruptured and all fuel rod claddings failed simultaneously such that 25% of all fission gases in the irradiated fuel assemblies (mainly Kr-85) are instantaneously released to the atmosphere. The dose consequences from the leaking DSC are evaluated in the NUHOMS Topical Report, Section 8.2.8, and the resulting accident dose is found to be well below the 10 CFR Part 72.68 acceptable limit of 5.0 rem.

8.2.10 LOAD COMBINATION

Normal operating and postulated accident loads associated with various components of the ISFSI are either the same as or are enveloped by those reported in the NUHOMS Topical Report, except for the DSC and the foundation. Hence, the combined effect of various accident and normal operating loads for the DSC support assembly and the HSM are enveloped by the load combination results presented in Section 8.2.10 of the Topical Report. The methodology used in combining normal operating and accident loads and their associated over load factors for various components of the ISFSI, with the exception of the foundation, is presented in the aforementioned report. Load combination procedures for the foundation are addressed in Section 8.3 of this report. The DSC analysis load combination utilizes the same methodology as in the Topical Report, but due to design differences the results are changed slightly. The results of the DSC load combination for the worst case, i.e., drop accident, are contained in Table 8.2-2 of this report. Furthermore, the DSC fatigue analysis due to normal operating pressure loads, accident pressure loads, seismic loads, seasonal temperature loads, and daily temperature cycling as presented in Section 8.2.10 of the Topical Report, envelops the HBR site specific analysis. This is because the extreme ambient temperature selected for generic design of the DSC (-40^{o}F to 125^{o}F) envelops the HBR ambient temperature range (-5^{o}F to 105^{o}F) and the HBR has a lower seismic acceleration.

Table 8.2-1

MAXIMUM DSC STRESSES FOR 8-FOOT
BOTTOM END DROP ACCIDENT

DSC COMPONENTS[2]	STRESS TYPE	STRESS (ksi)	
		CALCULATED	ALLOWABLE[1]
Canister Shell	Primary Membrane	10.11	44.88
	Primary Membrane + Bending	16.56	64.40
Bottom Cover Plate	Primary Membrane	6.09	44.88
	Primary Membrane + Bending	13.40	64.40
Top Cover Plates	Primary Membrane	2.77	44.88
	Primary Membrane + Bending	5.47	64.40
Support Ring For Top Lead Plug	Primary Membrane	1.71	44.88
	Primary Membrane + Bending	5.43	64.40
Lead	Compressive	1.65	6.80
Lead Casing	Primary Membrane	17.23	44.88
Spacer Disk	Primary Membrane	39.93	44.88
Boral Tubes	Primary Membrane + Bending	4.24	64.40
2 ½ in. diam. Support Rods	Compression	10.16	21.13[3]
¼ in. Fillet Weld	Primary	11.64	22.44
J-Weld	Primary	6.16	29.20

Notes:

1. Allowable stresses shown correspond to service Level D limits, unless noted otherwise.
2. Material properties taken at 400°F design temperature.
3. Compressive stress allowable of the support rods is based on Appendices XVII and F rules and for Level A limits.

Table 8.2-2

DSC ENVELOPING LOAD COMBINATION[1]

DSC COMPONENTS[4]	STRESS TYPE[5]	STRESS (ksi)	
		COMBINED[2]	ALLOWABLE[3]
Canister Shell	Primary Membrane	11.23	44.88
	Primary Membrane + Bending	35.75	64.40
Bottom Cover Plate	Primary Membrane	6.09	44.88
	Primary Membrane + Bending	15.91	64.40
Top Cover Plates	Primary Membrane	2.77	44.88
	Primary Membrane + Bending	8.74	64.40
Support Ring For Top Lead Plug	Primary Membrane	1.71	44.88
	Primary Membrane + Bending	5.44	64.40
Lead	Compressive	1.86	6.80
Lead Casing	Primary Membrane	17.29	44.88
Spacer Disk	Primary Membrane	41.03	44.88
Boral Tubes	Primary Membrane + Bending	4.36	64.40
2 ½ in. diam. Support Rods	Compression	10.19	21.13[6]
¼ in. Fillet Weld	Primary	11.68	22.44
J-Weld	Primary	6.18	29.20

Notes:

1. When applicable, stresses due to the drop accidents are combined with that of pressure and dead weight.
2. Stresses for each DSC components are conservatively combined irrespective of location.
3. Allowable stresses shown correspond to service Level D limits, unless noted otherwise.
4. Material properties taken at 400°F design temperature.
5. Thermal stresses need not be included under service Level D limits.
6. Compressive stress allowable of the support rods is based on Appendices XVII and F rules for Level A limits.

8.3 FOUNDATION DESIGN

To provide a means of transmitting the reaction loads of the ISFSI modules to the ground, a rectangular, flat plate type, mat foundation was selected. The mat foundation is ideally suited for the ISFSI since it spreads out the loadings and consequently reduces the soil bearing pressure and at the same time minimizes the differential settlements.

To accommodate the ISFSI modules, the front cask unloading area and the hydraulic ram area behind the modules, an overall foundation size of 28'-9" by 60'-0" was selected. The HSM foundation slab is 3 feet thick. A construction joint connects this slab to the cask unloading slab which is 2 feet thick starting from a point 5 feet from the module front. The ram mounting slab at the rear of the modules is 8 inches thick and connects to the 3 foot foundation by an expansion joint. The foundation concrete is 4000 psi normal weight concrete poured on a 4 inch mud slab. The HSM foundation and the cask unloading slab are interlaced with continuous two-way reinforcing top and bottom. Number 9 bars are used for tensile reinforcement and as dowels to anchor the HSM walls to the foundation. The ram mounting slab has a number 5 bar continuous two-way reinforcing at the bottom only. Welded wire fabric is placed at the top of the 8 inch slab.

For analysis purposes, a STARDYNE rectangular plate finite element model as shown in Figure 8.3-1 was developed. The model consists of 255 nodes and 224 plate elements. At each node, a ground support spring was added to simulate the soil elastic properties. The elastic soil spring is obtained by modifying the experimental modulus of subgrade reaction by an appropriate size factor of the foundation. The modified modulus of subgrade reaction is then multiplied by the tributary area associated with each node. The resulting values of the spring stiffnesses were used as input to the finite element model as a ground stiffness matrix. The method for finding the stiffness K is shown below (Reference 8.7):

$$K = K_V \left(\frac{B + 1}{2B}\right)^2 A$$

Where:

K_v = experimental modulus of subgrade reaction
= $100^{\#}/in^3$ (for granular soil)
B = foundation width = 28.75 feet
A = nodal tributary area (varies)

Five separate load cases were considered in the foundation design:

1) Center module loading
2) Outside module loading
3) Dead Weight + Live Load
4) Dead Weight + Tornado Wind/Impact (lengthwise)
5) Dead Weight + Tornado Wind/Impact (widthwise)

Since cask unloading and ram mounting slabs are cast in place after HSM construction, the differential settlement due to HSM dead weight will not be experienced by the cask unloading slab. Consequently, for load cases 1 and 2 the dead weight was not included. For load cases 1 and 2 the total trailer loading of 175 k, which includes the saddle, canister, cask, skid, trailer, rollers, trunnion, and cradle is applied as concentrated loads at nodal locations in the unloading areas. Since only one loading or unloading operation will occur at a time, the two load cases were evaluated independently. Load case 3 consists of the dead weight of the three modules containing the DSCs. This total 3 bay module weight of 800.8 k is added to the weight of three DSCs. The total loading is divided by the surface area in contact with the foundation to get an equivalent pressure load. Additionally, a live load of 200 psf is postulated for the HSM roof. This total load is also divided by the contact area to get a pressure loading on the foundation. These loads are applied as pressure loads on the appropriate plate elements of the STARDYNE model. Load cases 4 and 5 are the maximum uplift load combinations caused by tornado loadings in the two horizontal directions. Using a conservative wind pressure of 400 psf applied on the module walls and roof plus the reaction load of 458.2 k caused by a 3967 lb. automobile traveling at 184.8 ft./s applied to the top of the module in the same direction combined with the module dead weight, the maximum uplift forces were calculated. Live loads are excluded since they would reduce uplift loads. A simple frame model was used to calculate uplift forces as shown in Figure 8.3-2. The maximum uplift force of 38.80 k is converted to a pressure using the contact area of one wall. This yields a maximum uplift pressure of 3.1 psi which is used in the analysis. Comparison of tornado loads and HSM seismic loadings shows that tornado loads are much more severe. Consequently, seismic loads will not be included in the foundation analysis. Once the uplift forces are calculated they are applied as negative pressures on the appropriate plate elements corresponding to the HSM/foundation connection surface. Tornado wind and impact loads are evaluated for both directions.

Since an uplift force is created by the tornado loads the foundation itself will have a negative bearing or uplift along the edge of the module. The soil itself does not resist uplift. Results from load cases 4 and 5 were reviewed for the effects of the uplift along the foundation edge. Minimal uplift was experienced in low stressed areas. Therefore, results from load cases 4 and 5 are not significantly affected by the uplift since the high stressed areas are not in that vicinity.

The maximum calculated bearing stress is shown in Table 8.3-1. For sandy soils present at the bearing level of the mat foundation, allowable soil bearing pressures in the range of 3000 to 4000 pounds per square foot are recommended by the Southern Standard Building Code per the geotechnical exploration performed at the Robinson site by Law Engineering Testing Company. Since the maximum soil contact pressure produced by the HSM foundation analysis is 2210 psf the bearing strength is sufficient. For normal dead weight and live loads the bearing pressure is only 1605 psf.

The reinforcement design was based on the element bending moment results from the finite element analysis. Using the ultimate design method, the reinforcement was designed to withstand all postulated load combination bending moments with a conservative load factor of 1.7 applied to envelope all load combination factors specified in Section 9.2 of ACI 349-80. A tabulation of the results for the HSM Foundation and the cask unloading slab is presented in Table 8.3-2.

A license amendment issued on March 23, 1989, authorized construction of a five module foundation. Supporting information regarding the five module foundation is found in CP&L letters dated January 7, 1989, and February 1, 1989, and in the NRC letter dated March 23, 1989.

TABLE 8.3-1

FOUNDATION BEARING STRESS

LOAD CASE	LOAD DESCRIPTION	BEARING STRESS (KSF)
1	Center Module Loading	0.247
2	Outside Module Loading	0.463
3	Dead Weight + Live Load	1.605
4	Tornado Wind + Impact (Widthwise)	2.210
5	Tornado Wind + Impact (Lengthwise)	0.671

Note:

1. Dead weight of module not included in load cases 1 and 2.

TABLE 8.3-2

FOUNDATION SLAB
MAXIMUM BENDING MOMENTS

LOAD CASE	LOAD DESCRIPTION	SLAB THICKNESS	MAXIMUM MOMENT (K-in./in.)	ALLOWABLE MOMENT (K-in./in.)
1	Center Module Loading	2'-0"	13.8	87.0
		3'-0"	28.9	186.0
2	Outside Module Loading	2'-0"	13.1	87.0
		3'-0"	24.5	186.0
3	Dead Weight + Live Load	2'-0"	N/A	87.0
		3'-0"	46.4	186.0
4	Tornado Wind + Impact (Widthwise)	2'-0"	N/A	87.0
		3'-0"	80.1	186.0
5	Tornado Wind + Impact (Lengthwise)	2'-0"	57.6	87.0
		3'-0"	155.8	186.0

Notes:

1. Dead weight of module not included in load cases 1 and 2.

2. All moments conservatively factored by 1.7 to envelop all ACI 349 load combination factors.

The moment capacity of the sections are calculated per methods identical to the NUHOMS Topical Section 8.1.1.5, Equation 8-1-32. The 3'-0" slab with number 9 bars at 9 inches yields an ultimate strength of 186 k.in per inch section. The 2'-0" slab with number 9 bars at 12 inches yields an ultimate strength of 87 k.in per inch section. Therefore all bending moments experienced by the foundation are below ultimate capacity.

As calculated before, the maximum uplift pressure exerted by the module wall is 3.1 psi for load case 5. For a 1'-0" section of module the resulting uplift is 1.56 k/ft. section. The dowel area required can be calculated by:

$$A = \frac{(UPLIFT)\ (1.7)}{(\emptyset)\ (f_y)}$$

Where:

UPLIFT = 1.56 K
θ = 0.9 = Factor for Tension
f_y = 60 ksi

Therefore, Area A = 0.05 in^2. Conservatively 2 number 6 bars with an area of 0.88 in^2 will be used every 12 inches to prevent uplift. Keyways will be used between the module foundation interface to prevent sliding. Assuming the maximum horizontal tornado loads are shared by the walls perpendicular to load yields a maximum shear force of 24 k/ft including the load factor of 1.7. The nominal shear strength of the keyway and dowels can be found from:

$$V_n = (V_s + V_c)\ \emptyset$$

Where:

V_c = 2 F'_c b_w = concrete shear strength (k)
f'_c = 4000 psi
b_w = 9 inches
d = 12 inches
V_s = $(A_v)\ (f_y)$ = steel reinforcement shear strength (k)
A_v = .88 in^2
f_y = 60 ksi
$\emptyset$ = .85 = shear factor

Consequently, V_n = 56.49 k which exceeds the maximum factored shear force of 24 k. Thus, the module will neither slide nor overturn. Table 8.3-3 presents foundation anchor loads and capacities for load cases 4 and 5.

The 8 inch ram mounting slab was designed by hand calculations suggested by Teng (Reference 8.7) and Bowles (Reference 8.8). By applying the maximum factored spider leg loadings from the hydraulic ram a simple span is approximated by treating the soil as a uniform load and the spider leg as reaction points. A maximum factored moment of 32.3 k-in/ft is calculated. Using the ultimate strength method with number 5 bars at 12 inches, the ultimate strength of the 8 inch slab is 64.2 k-in/ft. Welded wire fabric was placed at the top of the slab as shrinkage and temperature reinforcement. Additionally all punching shear from the ram supports were found to be negligible.

Furthermore, the cask unloading slab was analyzed for bearing and punching shear due to the hydraulic cylinder. A maximum bearing stress of 2.34 ksi was calculated which is less than the allowable of 4.76 ksi calculated from ACI 349-80 Section 10.16. The maximum punching shear was also found to be under code allowables.

TABLE 8.3-3

FOUNDATION ANCHOR LOADS

LOAD CASE	DESCRIPTION	LOADING TYPE	LOAD (K/FT)	CAPACITY (K/FT)
4	Tornado Wind + Impact (Widthwise)	Shear	13.00	56.5
		Uplift	0	28.0
5	Tornado Wind + Impact (Lengthwise)	Shear	24.00	56.5
		Uplift	1.56	28.0

Notes:

1. All Shear and Uplift loads factored by 1.7 to envelop all ACI 349 load combination factors.
2. Shear capacity based on concrete keyway plus embedded dowels.
3. Uplift capacity calculated from embedded dowel area.

8.4 DSC INSTRUMENTATION PENETRATION DESIGN

Instrumentation is not required to support the operation of the ISFSI. However, for research purposes two of the DSCs at the H. B. Robinson facility have been designed to accept instrumentation. Instrumentation was included as part of an agreement between CP&L, EPRI and DOE to augment the U.S. database on LWR fuel rods in dry storage.

The DSC thermocouples were connected to an external cable by means of a specially designed feed-through. This feed-through incorporates the same redudant seal philosophy used in the DSC containment design. After the penetration plug assembly was welded to the bottom of the DSC cover plate, a sleeve was welded over the plug, forming a redundant seal. Thermocouple sheaths were brazed to the plug assembly at inner and outer penetrations. To preclude possible leakage through the aluminum oxide insulation, each end of the sheathed thermocouples was sealed with an environmentally qualified resin.

The instrumentation penetration described above was analyzed for the maximum of the three load combinations described below:

1) DW + Accident Pressure + Thermal + 8 Ft. Vertical Drop

2) DW + Accident Pressure + Thermal + 8 Ft. Horizontal Drop

3) DW + Accident Pressure + Thermal + Seismic

The dead weight of the instrumentation penetration including the sleeve, the lead, the junction box and miscellaneous fittings was approximately 11 pounds. A 1g acceleration was added on top of the peak deceleration for the 8 foot drop to account for dead weight stresses.

An accident pressure of 39.7 psi was applied to the external surface of the stainless steel tubing sleeve. Using the formula from Roark for a thick-walled vessel (Reference 8.9, Table 32, Case 1d) the maximum stresses were calculated for the accident pressure load as shown below.

$$s_1 = \frac{-qa^2}{a^2 - b^2}$$

$$s_2 = \frac{-2qa^2}{a^2 - b^2}$$

$$t_{MAX} = \frac{s_2}{2}$$

where:

S_1= longitudinal stress, psi
S_2 = circumferential stress, psi
t_{MAX} = maximum shear stress, psi
a = .8125 in., outside radius
b = .625 in., inside radius
q = 39.7 psi, accident pressure
S_1 = 97 psi
S_2 = 195 psi
t_{MAX} = 97 psi

Consequently the maximum stress intensity for the accident pressure case is 0.25 ksi.

The thermal expansion of the tubing sleeve between the 2 in. plate and the outer 1/4 in. lead casing plate was examined. After comparison of the tubing axial stiffness in relation to the 1/4 in. plate stiffness it was concluded that the sleeve is essentially free to grow since the plate is approximately 72 times as flexible as the tubing. Consequently thermal stresses are considered negligible for the penetration analysis.

The maximum seismic ground accelerations in the horizontal and vertical directions are .2g and .133g, respectively. They are enveloped by the 8 foot drop peak decelerations.

For the 8 foot drop analysis both vertical and horizontal drops were considered. The peak deceleration for the horizontal drop of 55.4g (1g added for dead weight) was applied to the junction box and tubing extending internally from the weld on the two inch plate. Assuming a cantilever type beam as shown in Figure 8.4-1, the maximum stress intensity of the tubing is 8.19 ksi which is located near the weld. Applying the horizontal drop load to the weld shows a maximum stress of 0.89 ksi. Additionally, the effect of the 2 1/4 in. lead plug pressure loading on the outside surface of the tubing was checked. Results from this analysis indicated a stress much less than the 8.19 ksi previously calculated. Therefore this was not a critical area.

The peak vertical bottom end drop deceleration of 77.5g (1g added for dead weight) was applied to the tubing penetration in the axial direction. The corresponding axial stress was 1.01 ksi, which is considerably less than the horizontal drop case. The weld stress for the vertical drop was calculated as 0.17 ksi. Consequently, the 8 foot horizontal drop load case will be used as the governing load combination.

Combining the dead weight, accident pressure and horizontal drop stresses absolutely for the tubing penetration indicates a maximum stress intensity of 8.44 ksi. The maximum calculated weld stress was 0.89 ksi. These stresses are far below allowable stresses for both components. Clearly then, the confinement integrity of the instrumented DSC will not be jeopardized.

The method for sealing the thermocouple sheaths has been changed from the originally planned sealing by metalizing the aluminum oxide insulation to the use of an environmentally qualified resin. The thermocouple system with the resin sealant has been analyzed for drop (up to 15 inches) and cooling-related accidents. In addition, the integrity of the epoxy seal was reviewed against effects of the following:

- environmental conditions (thermal, radiation) inside and outside of the DSC;

- potential changes in epoxy characteristics over time under expected environmental conditions;

- evaluation of permeation rates; and

- responses to accidents including overpressurization

Analyses have concluded that under normal operating conditions seal leakage will be insignificantly small. Also, the structural capability of the material is such that possible accidents will not compromise performance. A detailed discussion of the analyses may be found in References 8.10, 8.11, 8.12, and 8.13.

8.5 TRAIN DERAILMENT

This postulated accident was analyzed in Section 2.1.2 of Reference 8.10. The closest rail line of those lying north of the ISFSI foundation pad is approximately 33 feet distant. This line is used for temporary holding of empty coal cars and as a run through track. The maximum speed limit for trains on this track is 5 mph. The soil between the rail line and the ISFSI is very porous, which would tend to impede the motion of a derailed car even though the ISFSI site is at a somewhat lower elevation than the track. In view of the foregoing and the fact that there are no switches within 500 feet of the ISFSI location, damage to the ISFSI from train derailment is not considered credible.

REFERENCES: CHAPTER 8

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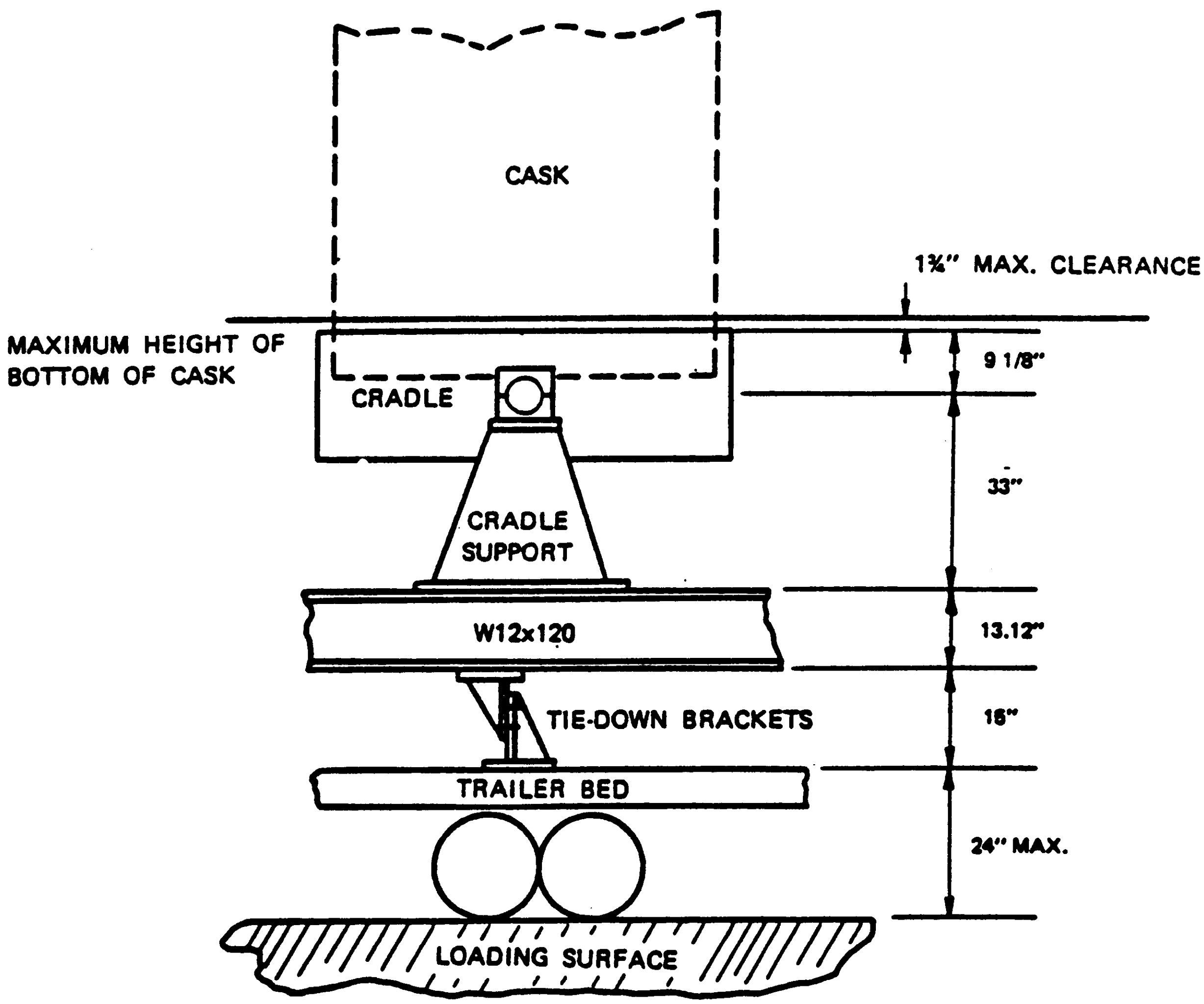

AMENDMENT 1

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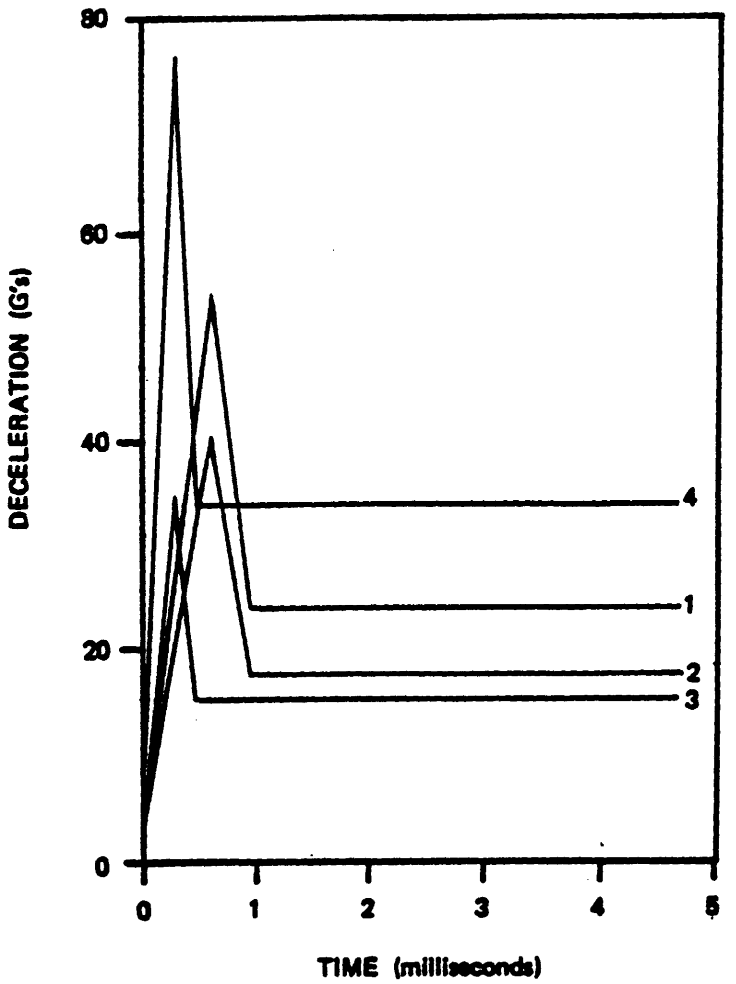
INDEPENDENT SPENT FUEL
STORAGE INSTALLATION
SAFETY ANALYSIS REPORT

CASK DROP HEIGHT CRITERIA

Figure 8.2-1

NO.	CASK ORIENTATION	PEAK G's	PLATEAU G's
1	0 DEGREES	54.4	24.3
2	45 DEGREES	40.8	18.1
3	90 DEGREES	35.5	15.7
4	BOTTOM END	76.5	33.9



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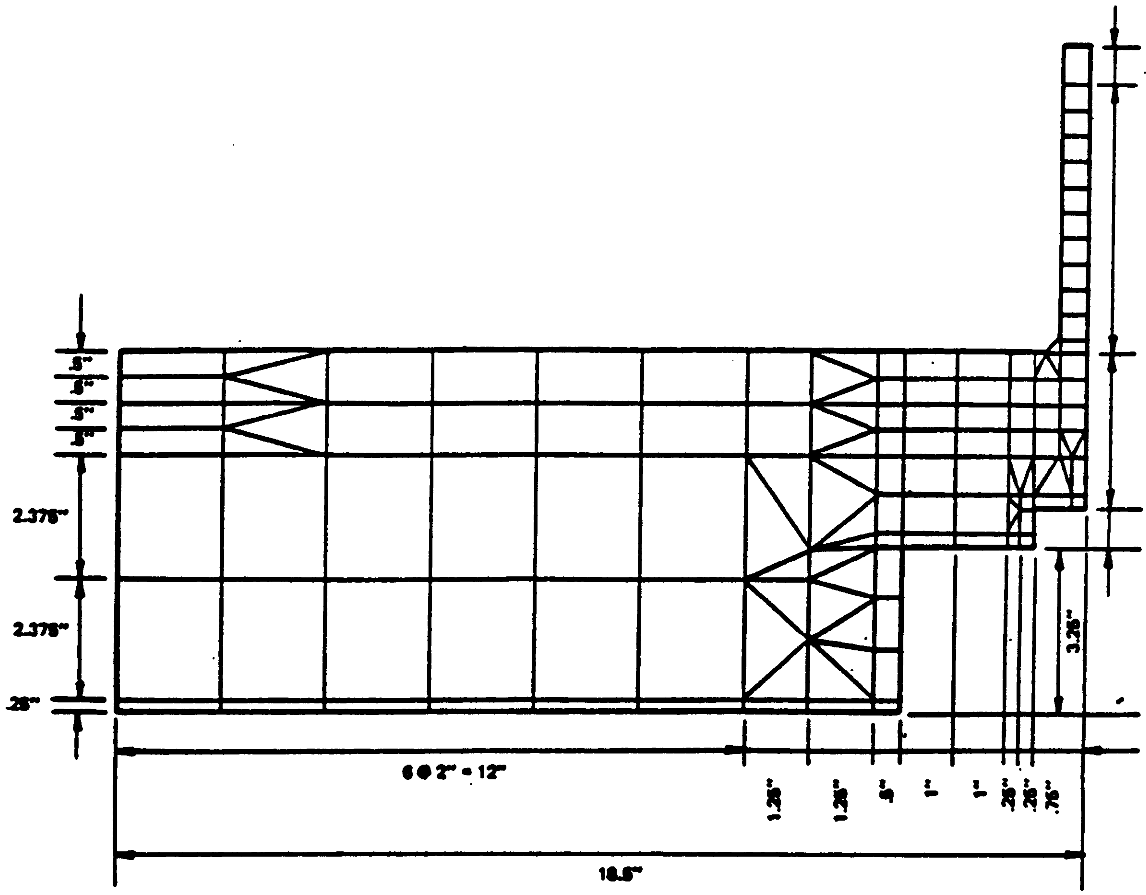
SAFETY ANALYSIS REPORT

CASK DECELERATION vs. TIME
8 FOOT DROP
Figure 8.2-2



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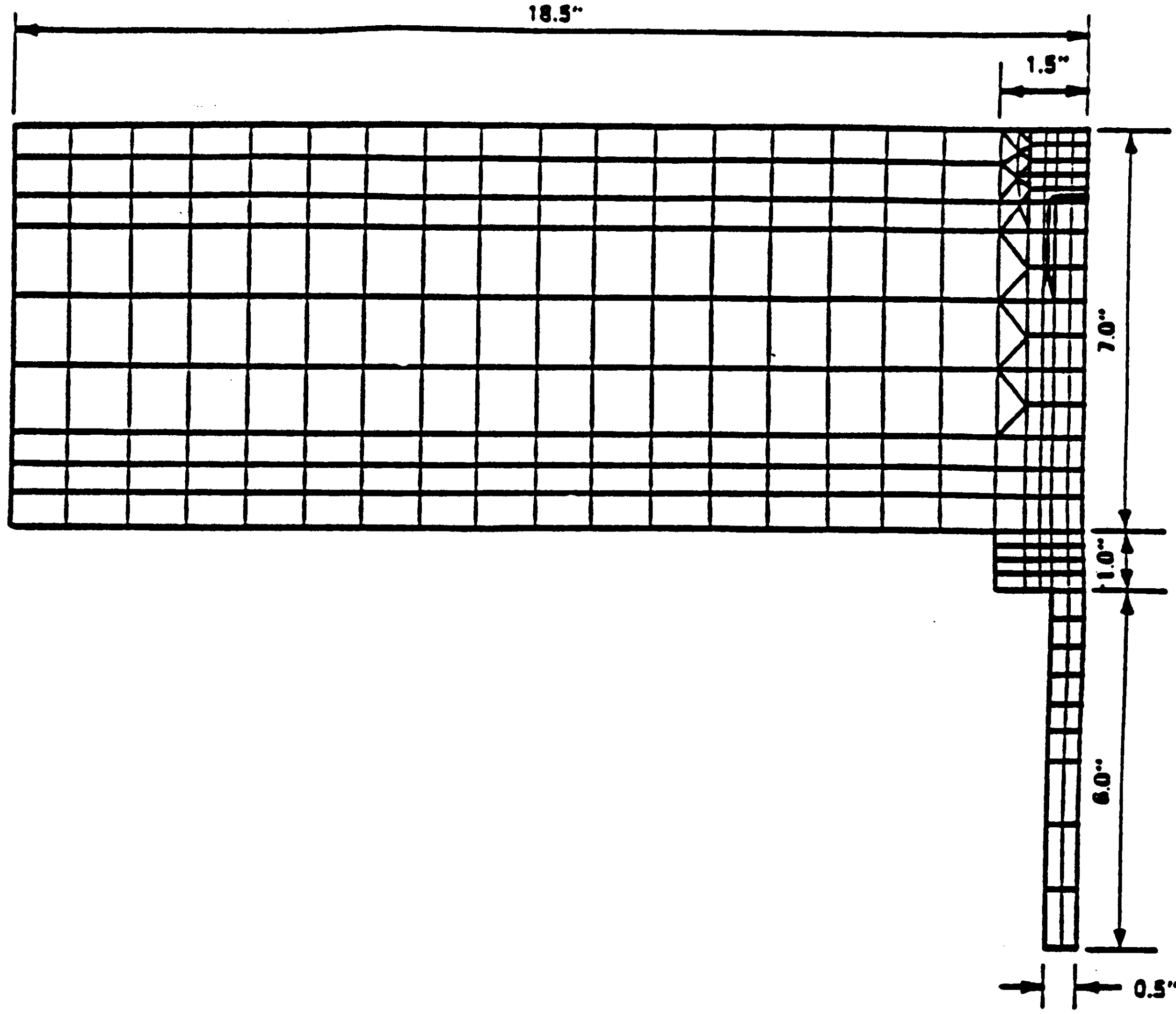
SAFETY ANALYSIS REPORT

DSC BOTTOM REGION ANSYS MODEL

Figure 8.2-3



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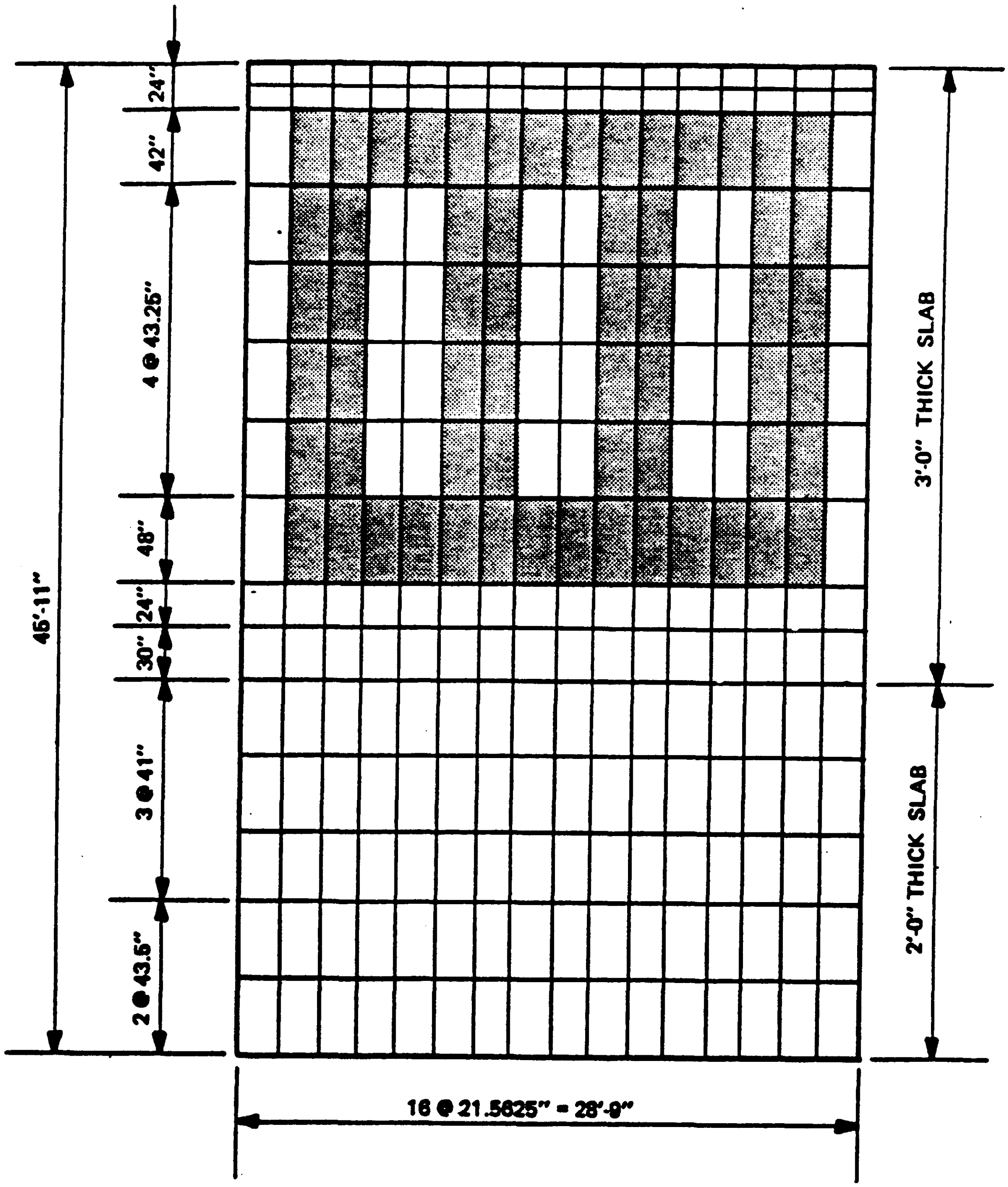
DSC TOP REGION ANSYS MODEL

Figure 8.2-4



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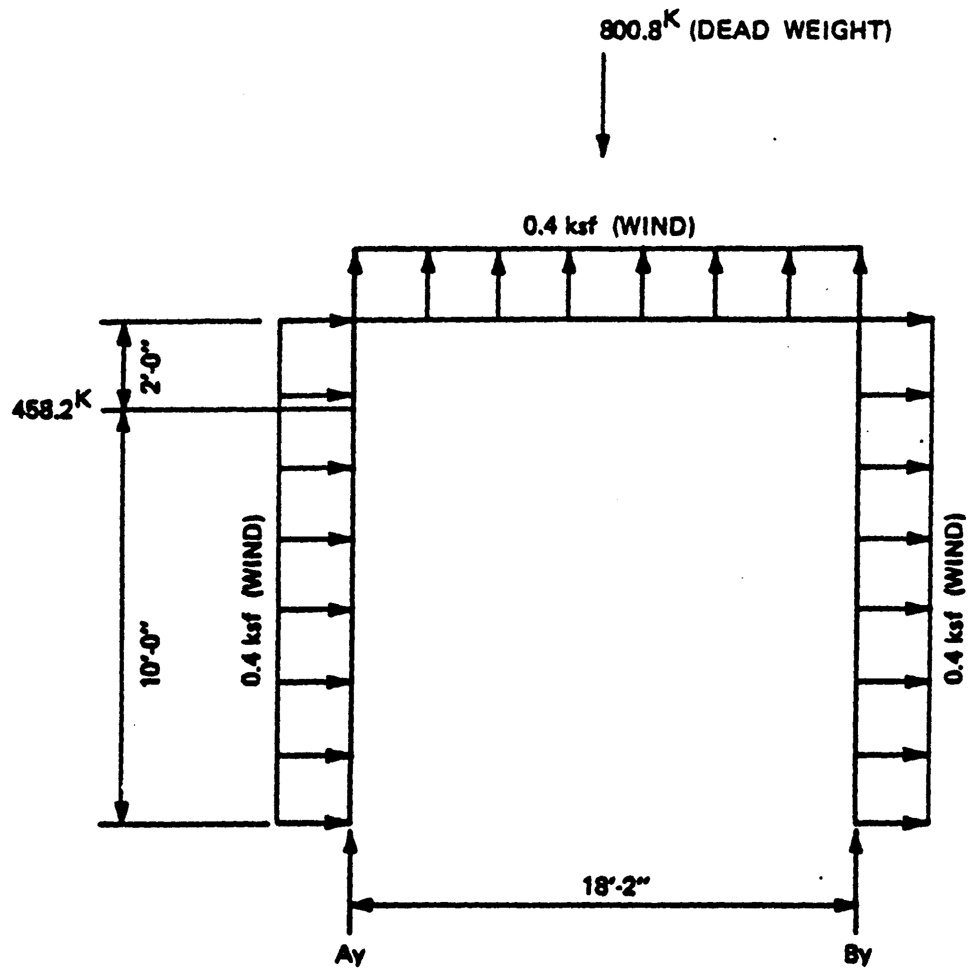
MAT FOUNDATION STARDYNE MODEL
Figure 8.3-1



Ay = 38.80^K (UPLIFT)
By = 622.59^K

NOTE
1) MODEL IS 301.875" WIDE

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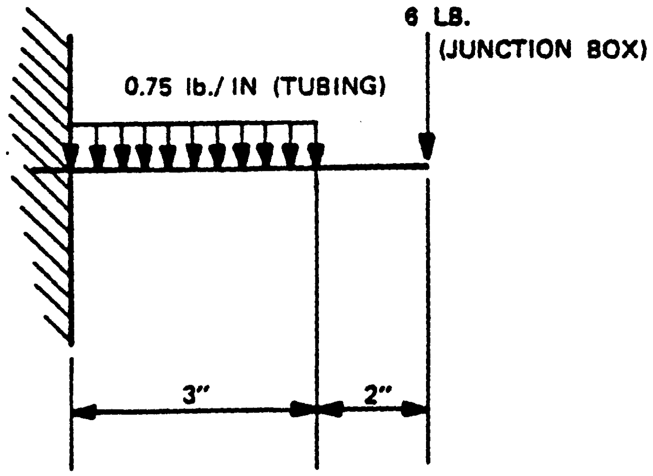
FOUNDATION UPLIFT MODEL
Figure 8.3-2



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PENETRATION MODEL FOR 8-FOOT
HORIZONTAL DROP ANALYSIS
Figure 8.4-1