ESKOM KOEBERG NUCLEAR POWER STATION

SR

CASK STORAGE BUILDING STORAGE PAD UPGRADE

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REVISIONS

Revision	Date	Scope of the Revision	Designer	Reviewer	Reviewer	Approver
0	2017-07-24	Original Issue for Client Acceptance Review	BvR Holtec	DP AMEC-FW	N/A	JB/JL Holtec
1	2018-03-03	Update to include Phase 2 of the Pad design. Change format to reflect Part A to D status. Numerous updates are indicated with a vertical bar in the left margin.	BvR Holtec Africa	JB Holtec Int	VM Holtec Int	JB/JL Holtec Int
2	2018-03-13	Reduced scope to exclude long term storage impacts. Other updates are indicated with a vertical bar in the left margin. Approved Safety Evaluation added in	BvR Holtec Africa	JB Holtec Int	VM Holtec Int	JB/JL Holtec Int

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PART C: PROCUREMENT SPECIFICATION

No Attachments

PART D: OTHER ATTACHMENTS

D1 Documentation Change Identification Form (DCIF) (331-212) with DDRs

D2 Project Team Concurrence List

DESIGN OF THE CSB STORAGE PAD UPGRADE

07147 DPDRR007

PART A: DESIGN

1.0 INTRODUCTION

This document describes the design for the existing Cask Storage Building (CSB) storage pad / floor that will be demolished and replaced with a new pad. This new pad will be constructed in two phases while still housing casks.

1.1 The Existing Design

The CSB is located onsite at the Eskom Koeberg Nuclear Power Station (KNPS) and is currently used for storage of four CASTOR X/28F ("CASTOR") casks. The casks are stored on specially constructed seismic plinths.

1.2 Problems with the Existing Design

The CSB pad was originally modified with six seismic plinths specifically for the storage of the CASTOR casks. The future dry fuel storage using the Holtec International HI-STAR 100 system requires similar changes and therefore construction of a new storage pad inside of the CSB is being undertaken.

1.3 Overview of the New Design

The CSB storage pad will be modified to meet the HI-STAR 100 FSAR requirements in accordance with 10 CFR 72 dry storage regulations to allow for safe storage of both the CASTOR and HI-STAR 100 casks during normal and accident conditions. These requirements must also be approved by the South African National Nuclear Regulator (NNR). The pad will be constructed in two phases:

Phase 1:

Requires the loaded CASTOR casks to be relocated to the back row (adjacent to the Eastern wall) of the CSB. As described in Figure 1, the area adjacent to these relocated casks ("Excavation Area") will then be excavated such that the occupied portion of the existing support structure will remain stable during Phase 1 activities. The remainder of the unoccupied area beyond the Excavation Area will then be demolished and replaced with a new storage pad structure ("Phase 1 Pad").

Phase 2:

Requires the loaded CASTOR casks to be relocated to the newly completed Phase 1 pad. Prior to moving the CASTOR casks, the Excavation Area will be backfilled with engineered soil or other suitable material with sufficient strength to allow movement of the casks across the area. Once the loaded casks are in position on the Phase 1 pad, the remainder of the existing support structure will be demolished and replaced with a new storage pad ("Phase 2 Pad"). During Phase 2 construction, loaded HI-STAR 100 casks may be placed in storage on the Phase 1 pad.

The Phase 2 modification provides for various storage configurations. It allows for storage of either HI-STAR 100 casks or the CASTOR casks. The Phase 2 modification provides a contingency for storage configurations. It allows for storage of either HI-STAR 100 casks or the CASTOR casks. The Phase 2 modification does not require implementation if the Castor casks are to be stored in their current storage configuration on the four plinths in the back of the building.

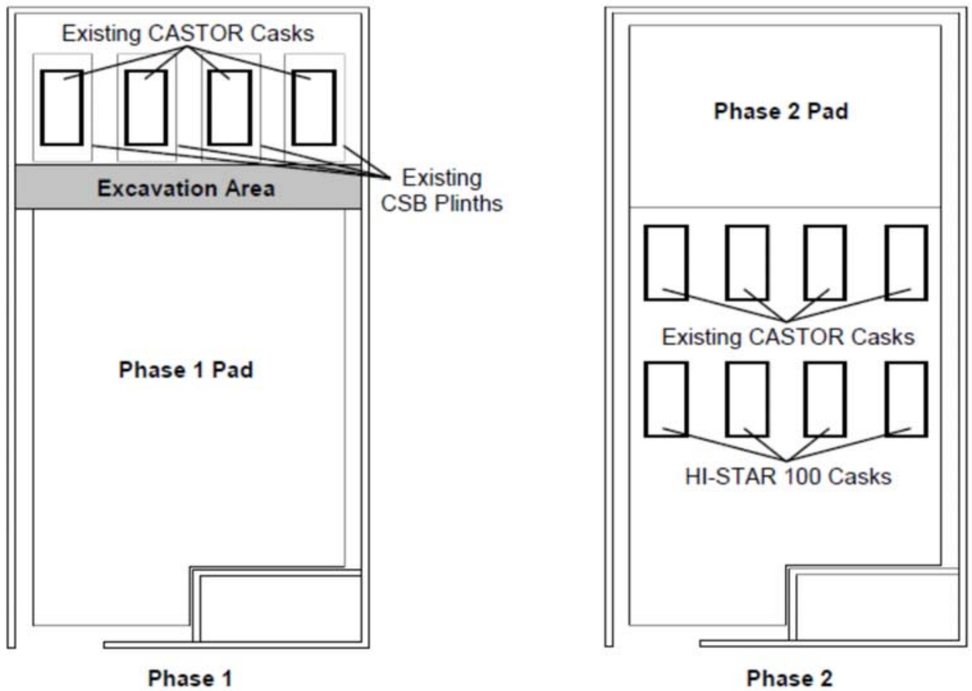

Figure 1: CSB Cask Layout during Phase 1 and Phase 2 Construction

The physical properties of the new design are listed in Table 1.

Table 1: Physical Properties of the Pad

Parameter	Value	Reference
Overall Length Phase 1	41.385 m	[3]
Overall Length Phase 2	16.363 m	
Overall width	21 m	
Thickness of the pad	915 mm	
Thickness of engineered fill	915 mm	

2.0 DESIGN CHANGE

2.1 Design Requirements

The CSB storage pad will be modified to meet the HI-STAR 100 FSAR requirements in accordance with 10 CFR 72 dry storage regulations which includes the American Concrete Institute code, ACI 318, to allow for safe storage of both the CASTOR and HI-STAR 100 casks during normal and accident conditions. These requirements must also be approved by the South African National Nuclear Regulator (NNR).

The HI-STAR 100 FSAR [20] provides two reference pad designs, which insure that the design basis deceleration limits are met for the non-mechanistic tip over (not applicable to horizontal storage) or a drop event. However, although the CSB pad design complies with the FSAR, a site-specific analysis has been performed to demonstrate compliance with the strength requirements of codes for the conditions at the Koeberg site (e.g., earthquake loading, soil properties, etc.).

The pad design, including its support foundation, must have sufficient flexural and shear stiffness to meet the ACI 318 strength limits under factored load combinations. At the same time, the target stiffness of the CSB pad design must be suitably low that the decelerations experienced by the HI-STAR 100 cask due to a non-mechanistic tip over event or a drop event due to a handling accident remains below the design basis deceleration limits established in the HI-STAR 100 FSAR [20].

The analysis is not intended to evaluate the internal forces and moments on the existing CSB storage pad or to make any determinations as to its structural integrity. Rather, the analysis focuses on ensuring that the new CSB storage pad will support the additional HI-STAR 100 casks and existing CASTOR casks.

The following loading criteria are applicable:

Table 2: Storage Load Requirements

Parameter	Value	Reference
Maximum HI-STAR 100 cask system storage weight	128 394 kg	[10]
Maximum CASTOR cask system storage weight	125 330 kg	
Maximum number of casks	16	
No of CASTOR casks	4	
No of HI-STAR 100 casks	12	

2.2 Design Limitations

Storage on the Phase 2 pad is limited to 16 casks.

Electrical and Control design do not form part of this design. Trunking and cabling from the CSB wall to the CASTOR casks must be installed for Phase 2 installation as per the original specification S99075C1 – Spent Fuel Dry Storage Casks Monitoring System. This has been evaluated as part of the electrical design as described in Modification 07147 CSBD001.

2.3 Design Assumptions

1. Thermal forces and moments are ignored since the temperature gradient through the thickness of the CSB pad is expected to be small and restraint against free thermal expansion is minimal at the edges of the pad.
2. Consistent with standard industry practice, locating the first cask at any of the four corners of the pad is not permitted.

Additional assumptions specific to the structural analysis are described in Section 2.14.2.1. Assumptions specific to the analyses performed are stated in the respective discussions in Section 2.18.

2.4 Investigation

The Cask Storage Building Safety Analysis Report for Construction Activities (SARCA) evaluated the following construction impacts:

1. Cask fire hazard evaluation [8].
2. Thermal analyses of cask storage in CSB during construction activities [11].
3. Cask thermal evaluation due to air and surface debris during construction activities [7].
4. Slope stability analysis of the temporary slopes during CSB pad construction [9].
5. Structural and seismic stability of the CASTOR casks during Phase 1 construction [23].

These investigations are summarised in Section 2.18.

2.5 Negative Consequences of this Design

From the evaluations performed and discussed above, it has been concluded that:

1. The entrance door to the CSB and the fire vents in the roof of the CSB must be kept open to ensure sufficient air circulation for heat removal.
2. No particular cask storage array is required; however, locating the first cask at any of the four corners of the pad is not permitted.

2.6 Benefits of this Modification

Since the CSB at Koeberg was not originally designed for storage of casks, the new design demonstrates that the pad is fit for purpose of spent fuel cask storage without adverse impact on the designed safety functions of the casks.

2.7 Location and Environmental Conditions

The CSB pad is designed to accommodate the effects of site specific characteristics including environmental conditions associated with normal and off-normal operation, maintenance, testing, postulated accidents and natural phenomenon. Koeberg site conditions are provided in DSG-310-211 [18] and are re-stated in Table ***3***.

Table 3: Environmental Conditions and Natural Phenomenon at Koeberg

Parameter	Parameter Value
Air Temperatures:	
Mean daily maximum in hottest month	26.2°C
Highest recorded in 18 years	37.9°C
Mean daily minimum in coldest month	7.2°C
Lowest recorded in 18 years	1.8°C
Site design base temperature – maximum	40.2°C
Site design base temperature – minimum	1.8°C
Design Conditions for Ventilation and Air Conditioning:	
Dry bulb temperature	Summer 34°C/ Winter 5°C
Wet bulb temperature	Summer 22°C/ Winter 4°C
Seismic Conditions (ground motion at bedrock level) Design and Damage Levels	
SSE Acceleration	0.3 g
Damage Level Acceleration	0.5 g

2.8 Functional Description

The CSB pad is upgraded to meet the design requirements for a spent fuel cask storage pad.

2.9 Operational Requirements

For Phase 1 implementation the four CASTOR X/28F casks are located in a single row in the back of the CSB. The pressure monitoring to these casks is currently fully operable. As the cabling for the casks is attached to the walls of the CSB it is not expected that the CSB pad construction will affect the operability thereof. In the unlikely event that there is a failure of the CASTOR X/28F cask pressure monitoring equipment for whatever reason, the resolution thereof will be a priority even if it requires that the CSB pad construction must stop.

Trunking and cabling from the CSB wall to the CASTOR casks must be installed for Phase 2 installation as per the original specification S99075C1 – Spent Fuel Dry Storage Casks Monitoring System. This has been evaluated as part of the electrical design as described in Modification 07147 CSBD001.

If a fault should occur on the CASTOR casks that requires the cask to be moved back to the Fuel Building during Phase 1 construction, the CSB pad will be re-established for the purpose of transporting the casks within the required time period.

2.10 Maintenance Requirements and Changes

The CSB building maintenance requirements are un-changed due to the construction of the new pad.

2.11 Nuclear Safety

2.11.1 Safety Evaluation of Storage Pad Design

A safety evaluation for the storage of the HI-STAR 100 casks - E2017-0019, Cask Storage Building (CSB) Storage Pad Upgrade - has been performed in accordance with KAA-709 [17] and included as Attachment A3.

This safety evaluation concludes that:

1. The modification does not result in an unreviewed safety question (USQ). Accordingly, a safety justification is not required.
2. A modification to the Koeberg SAR is required as per update request UR2422. These SAR updates are implemented under SC2017/0005 [27].
3. NNR approval is required for the design change.

2.11.2 Safety Classification of CSB Pad

The Design Classification is Safety Related (SR) due to interfaces with SR components.

The spent fuel storage casks Importance Classification is SR as per 0028/99Q [28].

The Safety Classification for the CSB storage pad is Linked to Safety (LS) as per 0012/14C [29].

The current Importance Classification for the CSB is SR as per 0012/14C.

The following classifications are applied to the construction items of the pad in accordance with NUREG/CR 6407 [30] and KSA-010 [16].

Table 4: CSB Storage Pad Classifications

Item	**Importance to Safety Classification** [NUREG/CR 6407[30]]	**Safety Classification** [KSA-010 [16]]
CSB Pad Concrete	ITS-C	LS
Rebar	ITS-C	LS
Rebar chairs and standees	NITS	NSF
Rebar wire ties	NITS	NSF

NITS: Not important to safety

ITS: Important to safety

LS: Linked to safety

NSF: No safety function

2.11.3 Quality Classification

The construction of the pad is assigned a quality classification of Q2 as per KSA-010 [16] and L3 as per RD-0034 [15].

2.11.4 Applicable Seismic Class

The pad is assigned a seismic classification of Non-Destruct (ND) as per 0012/14C [29].

2.12 Conventional Safety

All industrial safety measures as required by Koeberg Plant Safety Regulations and sound industrial Safety Health and Environmental (SHE) principles will be incorporated into the overall project planning to meet the requirements of the OHSA [31] and related regulations.

In accordance with KLA-027 [32], the intended area of construction is not classified as a hazardous location.

This design does not introduce any new conventional safety issues or concerns after the construction has been completed.

For activities during construction, the flowing construction hazards are identified in the SARCA Hazard Analysis [12] included in Part B Attachment B1.

The potential hazards identified in the document are the following:

- Presence of flammable liquids in construction equipment,
- Explosive and fire hazards,
- Presence of structures that could fall onto the storage casks,
- Extreme ambient temperatures,
- Dust management and noise control,
- The presence of carbon monoxide in the building must be considered and monitored due to operation in an enclosed space,
- Slope stability during excavation is analysed in [9].

A safety file will be developed by the appointed civil contractor. This document will describe the mitigation of the above conventional safety concerns.

2.13 Selection of Equipment

2.13.1 Concrete

All cast in place concrete shall have a minimum compressive strength of 27.6 MPa and a maximum compressive strength of 41.4 MPa at 28 days.

Tests shall be performed in accordance with ASTM C31 [33] or equivalent South African National Standard. Each test set shall consist of a minimum of 9 cylinders for 150 x 300mm cylinders and 12 cylinders for 100 x 200 mm cylinders.

2.13.2 Concrete Reinforcement:

All reinforcing steel shall be manufactured from high strength billet steel conforming to SANS 920:2011 Grade 450 MPa. Steel sizes are Y40, Y25 and Y16 as shown in the ISFSI Pad Detail Drawings [3].

2.14 The New Design

Pad dimensions and descriptions of the earthworks, concrete reinforcement and concrete properties are described in the ISFSI Pad Detail Drawings [3].

The inputs to the seismic analysis of the CSB pad are determined in the Holtec Soil Structure Interaction (SSI) Analysis report. The design values are used as input in the structural calculation summarised in 2.14.2:

2.14.1 Soil Structure Interaction (SSI) analysis of Eskom Phase 1 & 2 CSB Pad

The summary below is extracted from Holtec document HI-2177756 [10] that is fully included herein as Attachment A9.

This calculation package provides the essential details on the seismic analysis of the CSB pad pursuant to the provisions of American Society of Civil Engineers (ASCE 4-98 [34]), Seismic Analysis of Safety-Related Nuclear Structures and Commentary.

Specifically, the CSB pad for Phase 1, which will be used to store eight casks (4 HI-STAR 100 and 4 CASTOR Casks) as shown in Sheet 2 of drawing [3], and Phase 2 which will be used to store sixteen casks (12 HI-STAR 100 and 4 CASTOR Casks) as shown in Sheet 4 of [3] is analyzed in this report. The Phase 1 CSB pad is analyzed under 0.3g design basis earthquake (also known as DBE or Dames & Moore (D&M)). The Phase 2 CSB pad is analyzed under both, design basis (D&M) and design extended condition (also known as DEC or PC Rizzo) earthquake.

The SSI analysis evaluates the upgraded CSB pad for the dead + live + seismic (D+L+E') load combination where the cask is treated as live load and with due consideration of the out-of-plane flexural flexibility of the pad and potential variability in the subgrade properties (best estimate and upper and lower bounds per ASCE 4-98) with multiple time history sets.

A total of sixteen (16) discrete SSI analyses are performed in this calculation package for each of the two phases. This calculation package estimates the peak dynamic impact force between the cask and the pad which is then used for structural qualification of the pad.

The SSI analysis [10] considers that HI-STAR 100 and CASTOR casks will be supported on cradles and stored in horizontal orientation on the CSB pad.

2.14.1.1 Acceptance Criteria

1. The maximum cask sliding shall not result in inter-cask impact or excessive cask migration beyond the edge of the pad under 10% amplified earthquake and an interface coefficient of friction (COF) of 0.2.

2. The maximum predicted rocking angle (mean plus one standard deviation) from the best estimate, upper bound, and lower bound analyses with a COF of 0.8 must be less than 50% of the critical rocking angle.

2.14.1.2 Assumptions

1. The HI-STAR 100 cask system (its internals, MPC and fuel, along with the cradle) are conservatively assumed to be a single rigid body thus neglecting any energy absorption of the cask and its internals itself during the impact event. To preserve the weight and the center of gravity (c.g.) of the loaded HI-STAR 100 cask system, a small additional mass is conservatively lumped to the top center node of the cask system.
2. The extreme bottom layer of the substrate (13th layer in the substrate model) is assumed to be a rigid body representing the bedrock. This is a reasonable assumption needed to apply the 3-D input motion (accelerations) in LS-DYNA.
3. It is conservatively assumed that the damping values corresponding to minimum frequency (percentage damping) of both horizontal directions for each substrate layer, output from the SHAKE2000 analyses documented in Appendix A [10] is used to define the structural damping for the corresponding substrate layer.
4. To ensure further conservatism, a lower damping than that corresponding to the minimum frequency is used in all LS-DYNA runs.
5. In the analysis performed to evaluate maximum cask sliding, a lower bound cask weight of 125 330 kg is conservatively used instead of the bounding fully loaded weight of 128 394 kg.
6. For Phase 2 DEC condition, a differential settlement of 200mm is assumed.

2.14.1.3 Methodology and Codes

Phase 1 CSB pad

1. A total of 16 discrete SSI analyses are performed for the Phase 1 CSB pad, which will be used to store eight cask systems (four HI-STAR 100 Casks and four CASTOR Casks).
2. The LS-DYNA solution is carried out in accordance with the provisions of ASCE 4-98 [34]. As specified in ASCE 4-98, the average of the results from the five time histories can be used for structural qualification of the pad.

Phase 2 CSB pad under DBE:

1. A total of 16 discrete SSI analyses are performed for the Phase 2 CSB pad, which will be used to store sixteen cask systems (twelve HI-STAR 100 Casks and four CASTOR Casks).
2. The LS-DYNA solution is again carried out in accordance with the provisions of ASCE 4-98.

Phase 2 CSB pad under DEC:

1. A total of six discrete SSI analyses are performed for the Phase 2 CSB pad, which will be used to store sixteen cask systems (twelve HI-STAR 100 Casks and four CASTOR Casks).
2. The LS-DYNA solution is carried out in accordance with the provisions of ASCE 4-98.

Note that the DEC calculation considers the complete CSB pad (Phase 1 and 2).

2.14.1.4 Conclusions

The following conclusions are drawn from the SSI analyses for:

Phase 1 CSB pad under DBE

1. The maximum sliding does not result in inter-cask impact or cask migrating beyond the edge of the pad under 10% amplified earthquake; and cask rocking angle does not exceed 50% of the critical rocking angle.
2. No particular cask storage array is required; however, locating the first cask at any of the four corners of the pad is not permitted.

Phase 2 CSB pad under DBE:

3. The maximum sliding does not result in inter-cask impact or cask migrating beyond the edge of the pad under 10% amplified earthquake; and cask rocking angle does not exceed 50% of the critical rocking angle.
4. No particular cask storage array is required; however, locating the first cask at any of the four corners of the pad is not permitted

Phase 2 CSB pad under DEC:

5. The SSI analysis does not show any unacceptable consequences for the Cask system itself. In other words, the maximum cask movement will not result in inter-cask impact or excessive cask migration beyond the edge of the pad. Furthermore, the predicted rocking angle (mean plus one standard deviation) with a COF of 0.8 is less than 50% of the critical rocking angle. Therefore, the stability of the cask will be maintained, and the cask system will meet its safety functions.
6. The acceptance criteria are satisfied. Even though not required, a punching shear check of the CSB pad has been performed. It is noted that the minimum safety factor is 1.80 (conservatively using ACI-318 code allowable strength). Therefore, gross failure of CSB pad under design extended condition (PCR) is not a concern.
7. No particular cask storage array is required; however, locating the first cask at any of the four corners of the pad is not permitted

2.14.2 Structural Analysis

The complete structural assessment of the CSB pad is contained in the structural analysis [5] included herein as Attachment A2.

The analysis [5] details the structural qualification of the CSB pad when subjected to dead load (static loading) and seismic load (dynamic loading). Specifically, the CSB pad for Phase 1 which will be used to store a maximum of eight casks (four HI-STAR 100 and four CASTOR Casks) and after completion of Phase 2 which will be used to store a maximum of sixteen casks (twelve HI-STAR 100 and four CASTOR Casks) is analysed.

The CSB pad is modelled using ANSYS finite element code. The underlying layers of engineered fill and substrates are also included in the model. Based on the resulting top and bottom surface in-plane stress distribution, the bending moments across the pad thickness are computed and demonstrated to be below the limit values computed in accordance with the Ultimate Strength Method set forth in the ACI Code. ACI 318 [19] has been selected as the design code for the structural analysis of the CSB pad consistent with requirements from HI-STAR 100 FSAR [20].

It is noted that the structural analysis [5] considers that the HI-STAR 100 and CASTOR casks are supported on cradles and stored in a horizontal orientation on the CSB pad.

2.14.2.1 Assumptions

1. The finite element analysis assumes all materials are linear, isotropic elastic materials. It is ensured that after the analysis the stresses in the pad remain within the elastic limit and hence the assumption of linear elastic analysis is valid. Also, a linear analysis option is selected in ANSYS Workbench. This is consistent with prior analyses of similar configurations.
2. The interface connections between the CSB pad and other materials (engineered fill and soil) are assumed to be bonded in the ANSYS model.
3. The interface connections between engineered fill and soil are also assumed to be bonded.
4. Pad bending moments are computed assuming that the stress distribution through the thickness of the pad is linear.
5. For conservatism, all concrete covers (top and bottom surfaces) are assumed at the maximum value.
6. The base of the substrate (minimum value of the Z co-ordinate modelled) is assumed as a fixed surface. The far field lateral boundaries of the substrate are assumed to be free.
7. The soil length and width that is modelled is about twice the corresponding dimension of the pad and this is done to remove any boundary edge effects that may arise and as such, no boundary conditions are applied.
8. In order to be consistent with the pad dynamic analysis, the concrete pad is assumed to be half cracked.
9. Thermal forces and moments are ignored since the temperature gradient through the thickness of the CSB pad is expected to be small and restraint against free thermal expansion is minimal at the edges of the pad.

2.14.2.2 Methodology and codes

Phase 1 Design Analysis

Ten loading (five static and five dynamic) scenarios are evaluated in to envelope partial and fully loaded CSB pad configurations for both construction phases.

The results of computed bending moments for all ten loading case scenarios and the bounding results and safety factors are identified. (The safety factor is defined as the allowable bending moment divided by the calculated bending moment).

The uplifting of the pad check in structural qualification is done to validate the ANSYS modelling assumption of bonded connection between the CSB pad and the underlying fill. The check is performed by verifying the tension stress in the bottom of the CSB pad.

Appendix F [5] also contains an evaluation of the punching shear capacity of the slab under the Dynamic Loading and Static Loading. The SSE load is the bounding load and is compared to the capacity of the section in punching shear.

A finite element model of the Phase 1 CSB pad, which will be used to store eight casks (four HI-STAR 100 and four CASTOR Casks), together with underlying substrates has been constructed and bounding loads have been used to establish the stress distribution in the CSB pad.

The stresses are converted to section bending moments and compared with allowable value per the ACI Code.

Phase 2 Design Analysis

Similar to Phase 1, ten loading case scenarios are evaluated for Phase 2 and the bounding bending moments in the pad in the long and short directions are identified.

To address the concern about the uplifting of the pad under the partial loading, the Normal Y stress (perpendicular to the pad bottom surface) contours are plotted on the bottom surface of the concrete pad for all loading cases.

2.14.2.3 Results and Conclusions

Phase 1 Design Analysis

Based on the bounding results, the safety factors of the bending of the pad have been calculated and are all shown to be above 1.0.

To verify that the pad does not lift up under partial loading – the stress contours do not show consistent tension along the edge of the pad, which assures the uplifting of the pad is not a concern and the bonded connection used in the model is appropriate.

The punching shear capacity of the slab under the Dynamic Loading and Static Loading is compared to the capacity of the section in punching shear and is shown to have a resulting safety factor above 1.

The calculated stresses for the CSB pad were converted to section bending moments and compared with allowable value per the ACI Code. All safety factors are well above 1.0 and there is no lift-off of CSB pad observed under various loading cases.

No particular loading pattern is required; however, consistent with standard industry practice, locating the first cask at any of the four corners of the pad is not permitted.

Phase 2 Design Analysis

Based on the bounding results, the margin of safety of the bending of the pad are calculated and they are shown to be above 1.0 (Table H.12 of [5]).

The stress contours do not show consistent tension along the edge of the pad, which assures the uplifting of the pad is not a concern and the bonded connection used in the model is appropriate. All safety factors are well above 1.0 and there is no lift-off of CSB pad observed under various loading cases

2.14.3 Impact of Liquefaction

The possible impact of liquefaction on the new pad design is discussed in GEI Consultants report on Liquefaction [22] that considers a Koeberg seismic site response with a Peak Ground Acceleration of 0.5g. The report and conclusions are summarised below.

2.14.3.1 Purpose:

This calculation provides an evaluation of the liquefaction resistance and the post-earthquake settlement of soils at the proposed Low-Level Waste (LLW) building location at Koeberg.

2.14.3.2 Methodology:

This calculation of the factors of safety against liquefaction uses data generated from the on-site subsurface exploration program and peak shear stresses computed in the site response analysis. The method of calculating the factor of safety against liquefaction is from Youd et al. (2001). The calculation of post-earthquake settlement uses data generated from the on-site subsurface exploration program and uses methods of analysis described in Tokimatsu and Seed (1987) and Ishihara and Yoshimine (1992).

2.14.3.3 Assumptions

No assumptions are stated in the report

2.14.3.4 Results and Conclusions:

This computation evaluates liquefaction potential based on measured N-values in the soil determined from the on-site subsurface exploration program.

The computed safety factor against liquefaction was between 0.1 and 1.1 for 28 of the 122 N-values. The remaining N-values are considered to be not liquefiable. The lowest safety factors may indicate a potential for porewater pressure increase. However, the N-values that correspond to most of the potentially liquefiable samples are at depths greater than approximately 42 feet (13 meters) where the soils are unlikely to become unstable during a seismic event. The N-values that correspond to potentially liquefiable samples at shallower depths (between the ground surface and depths of 23 feet or 7 meters) may experience settlement during a seismic event.

The site is thus characterised as not susceptible to liquefaction, but areas may experience localized settlement.

The maximum computed post-earthquake settlement at any single boring location is 150mm. Calculated settlements range from 25 mm to 150 mm. Therefore, differential settlement will be less than 125 mm.

2.15 PLANT IMPACT ANALIYISIS: Impact on the Simulator and KIT

No impact to plant operation and consequently to the plant simulator and KIT.

2.16 Environmental Impact and Energy Efficiency

The Environmental Impact Assessment (EIA) regulations define an expansion as the "modification, extension, alteration or upgrading of a facility, structure or infrastructure at which an activity takes place in such a manner that the capacity of the facility or the footprint of the activity is increased".

The project construction activities at the CSB involve the following activities which do not translate into the expansion of the building:

- Reconstruction of the CSB storage pad / floor,
- Reinforcing the floor in order to accommodate the loads from loaded spent fuel casks,
- Leaving the entry door and the roof vents open to allow natural air circulation for cooling the building.

Based on the above-mentioned activities, an EIA for CSB activities is not required

Building waste will be generated during removal of the existing floor and during construction activities. The waste will be disposed of in accordance with the Koeberg waste management process.

The existing floor will be inspected for contamination prior to being broken up. All rubble will be removed to a piling area prior to removal from site.

Where possible the waste will be crushed and re-used as part of the engineering fill required.

2.17 Impact on Original Design Bases

1. The re-positioning of the CASTOR casks directly onto the new storage pad has no impact on the original design bases of the casks.

2.18 Risk Assessment

The following construction risks have been analysed and are discussed in this section:

1) Cask Fire Hazard Evaluation [8]
2) Thermal Analyses of Cask Storage in CSB during Construction Activities [11]
3) Cask Thermal Evaluation due to Air and Surface Debris during Construction Activities [7]
4) Slope Stability Analysis of the Temporary Slopes during Pad Construction [9].
5) Structural and Seismic stability of the CASTOR casks during Phase 1 Construction [25]

2.18.1 CONSTRUCTION FIRE HAZARD EVALUATION

The complete evaluation is described in Holtec document HI-2177726 [8] and included herein as Attachment A6

Fire evaluations are performed to determine if controls are to be imposed to prevent accidental fires from construction-related equipment during construction from due to exceeding any design basis cask temperature or pressure limits. Applicable fire controls are determined in [8].

It should be noted that the CASTOR casks are not analysed for a fire originating from a source as performed for the HI-STAR 100 casks, but rather analysed for homogeneous heating of the cask as if engulfed completely by a fire.

2.18.1.1 CASTOR X/28F Casks

It is noted that there are four existing CASTOR casks inside the CSB. The evaluations in [8] apply to the HI-STAR 100 casks only.

CASTOR casks have been analysed for fire accidents in the GNS document [26], Topical Safety Analysis Report, par 6.3. The CASTOR casks have been shown to be able to withstand a homogeneous heating test of 800°C for 30 minutes. Shielding and confinement was maintained during the test.

The CASTOR cask heat test has been performed on the cask transport configuration and not on the storage configuration. A postulated site fire analysis that considers the transport configuration will be normally be less conservative due to the radiation heat shielding provided by the transport equipment. However, the homogeneous heating test performed heats all surfaces equally – therefore it can be regarded as bounding a postulated site fire.

The following extract from GNB B 276/92E [24] describes the analysis in more detail:

Test Criteria

According to the IAEA regulations, the CASTOR transport- and storage cask has to be subjected to a heating test lasting 30 minutes with an average homogeneous ambient temperature of 800°C and the confinement must be maintained during the test.

The emission coefficient of the fire is 1.0 and the absorption coefficient of the cask surface is 0.93. These values are compliant with regulations which demand at least

0.9 for the environment and for the cask surface at least 0.8. The convective heat supply during the fire and the heat dissipation after the fire is taken into account on the basis of stationary ambient air. The ambient temperature is 800 °C during the fire and 38 °C after the fire.

After the fire, the solar insolation according to Regulations-for-the -Safe Transport of Radioactive Materials, 1985; International Atomic Energy Agency must be taken into account. Conservatively, the insolation is considered in the calculation for an overall time of the cooling period of 24 hours, with an absorption coefficient of 1. The heat dissipation is performed in a purely passive manner without active cooling.

Temperature Results during the Heating Test

The max temperatures from the essential components during the heating test including the subsequent cooling period are summarized in Table 3.1:

Table 3.1: Component Temperatures during Heating Test

Items	Max Temp [°C]	Time [Minutes]
Sealing Area		
- Primary Lid	200	139
- Secondary Lid	220	46
Moderator Zone		
- Inner Diameter	201	129
- Outer Diameter	238	42
Cask Wall		
- Inner Surface	200	149
- Outer Surface	389	30
Max Fuel Rod Temperature	372	2 250

The decomposing temperature of the moderator material (Polyethylene Lupolen 5261Z) is 350 °C.

As stated in Table 3.1, this temperature, is not exceeded within the moderator bore holes so that a reduction of the shielding effect can be ruled out. Due to the protective effect of the impact limiter, a failure of the bottom moderator plate can be excluded.

Due to the one-dimensional nature of the calculation, the temperatures of the seals of the primary and secondary lids during the heating test are not explicitly available. The temperatures on the corresponding seal radius within the wall are below the admissible limit values. The temperatures on the radius of the primary and secondary lid seals are 200 °C and 220 °C. These temperatures are below those limit values where a failure of the sealing is to be expected; this applies to both the metal seals (limit value: 380 °C) and the elastomer seals used (limit value: 288 °C).

The maximum fuel-rod -temperature is 372 °C: Due to the short period when these temperatures can be reached the integrity of the fuel elements is not jeopardized.

Maximum Internal Cask Pressure during Heating Test

For the highest temperature of the cavity medium, i.e. for the maximum mean value resulting from the temperature of the hottest fuel rod and the cavity wall temperature, there is an overall pressure of approximately 354 kPa assuming 100 % failed fuel cladding.

This pressure consists of the partial pressures of the cavity medium, the fuel rod admission pressure and the gases of fissile materials.

The integrity of the cask is not impaired by this increase in pressure compared with normal operation as the maximum pressure does not exceed the design pressure for normal operational conditions of 700 kPa.

2.18.1.2 HI-STAR 100 Casks

Design pressures and temperature acceptance criteria for the HI-STAR 100 are provided in Tables 2.2.1 and 2.2.3 of the HI-STAR 100 FSAR [20].

The HI-STAR 100 FSAR permits SA350-LF3 to be used for the Koeberg HI - STAR 100 casks and the allowable temperature for the Koeberg casks inner shell is conservatively set to 316 °C (600°F).

Alternatively, acceptability can be demonstrated by showing that specific fire conditions are bounded by a previously-evaluated fire event that has been found acceptable, namely, those events evaluated in “Evaluation of Site-Specific Fires, Including Onsite Transporter Fire, for HI-STAR 100 at Koeberg” [14].

Approach and Major Assumptions

Two classes of combustible materials associated with construction are identified, namely combustible liquids and combustible solids. The predominant combustible liquids will be:

1. Fuel for internal combustion engines in vehicles or generators and
2. Hydraulic fluid for hydraulically-operated equipment.

The predominant combustible solids will be the rubber tyres on construction equipment. The approaches to evaluate fires of these classes of combustible materials are described for two fire scenarios - during and after construction of the shielding wall:

a) HI-STAR 100 Cask after Installation of the Shield Wall

1. A total quantity of combustible liquids is assumed as input to this calculation, as is the diameter of the resulting puddle of liquid.
2. The puddle diameter is assumed to be 5 meters, which is slightly smaller than the cask-to-cask spacing lateral spacing of 5.66 meters.
3. A shield wall is to be erected between the loaded casks and the construction equipment and will prevent combustible liquids from pooling too close to any cask. But liquid pool fires can have significant flame heights, so it is conservatively assumed that there will be a line-of-sight from such flames to the casks (i.e., the presence of the shield wall is conservatively neglected).
4. A bounding view factor from the fire to the cylindrical side of a cask is very conservatively assumed to be 50% of the bounding view factor from the fire to

the closure end of a cask.

It is noted that the shield wall [4] contains a large amount of Ultra-High Molecular Weight (UHMW) polyethylene. The auto-ignition temperature of this material could be as low as 350°C, so it is possible that this material will ignite and burn. If the polyethylene does burn it will result in combustion heat potentially being directed toward nearby casks. This combustion heat is not explicitly considered but is expected to be bounded by the conservative assumption described in the previous paragraph, specifically the assumption that the shield wall is neglected when determining heating of the casks by burning liquid combustibles. The additional incident heat from burning polyethylene should be smaller than the unblocked heat from the burning liquids flames.

With respect to the solid combustibles, a report documenting a fire test for a large rubber tyre of the type used on construction equipment is consulted. The fire test documented therein involved a 1.75-meter diameter tyre, which is as large as is expected to be used on any construction equipment operating inside the CSB. The fire test report includes multiple photographs taken during the test, which show that the flames extend above the tire by less than about 50% of its diameter. This leads to an expectation that the burning tires flame height would be less than about 2.6 meters. But the shield wall to be erected between the loaded casks and the construction equipment is about 3.7 m tall, so all the heat from a burning tyre would be blocked by the shield wall and is therefore neglected in this evaluation.

The transient response of the HI-STAR 100 cask to the fire environment is determined using the methodology described in the HI-STORM 100 FSAR [2] and previously-implemented for the site-specific fire hazards. Specifically, the Fluent finite-volume model of the cask created previously analysed is modified as follows:

1. The decay heat inside the HI-STAR 100 containing the MPC-32 is reduced to 18 kW (predicted to be 15.7 kW) to reflect the actual loading plan.
2. Before the fire event: all thermal radiation heat transfer from the closure end of the HI-STAR 100 cask (facing the shielding wall) is completely neglected. This conservatively bounds the presence of the shielding wall and applies to both construction phases.
3. During the fire event, the cask is subjected only to thermal radiation heating from the fire (i.e., there is no convection heating because the fire is separated from the cask). The fire-to-surface effective emissivity is determined by multiplying the required surface emissivity of 0.9 by the fire-to-cask view factor.
4. After the fire event, all thermal radiation heat transfer from the closure end of the HI-STAR 100 cask is again completely neglected. This conservatively bounds the presence of the shielding wall.

The post-fire cask internal pressure is determined using the Ideal Gas Law, as described in Chapter 4 of the HI-STORM 100 FSAR [2]. As the temperature results of the fire event analysis demonstrate, the peak fuel cladding temperature remains more than 167 °C (300 °F) below the accident condition temperature limit. Thus, fuel rod failures are not credible, so the fire event pressure is computed without any such failures.

b) HI-STAR 100 Cask during Installation of the Shield Wall

For this scenario, applicable mitigation controls will be determined through a comparison to the previously-performed fire evaluation for the HI-STAR 100 cask exposed to an on-site transporter fire.

Conclusions and Requirements for Implementation

1. HI-STAR 100 cask after installation of the shield wall

   Based on the results it is concluded that the HI-STAR 100 casks will continue to perform all their intended safety functions during the postulated construction equipment fire event, provided

   (1) the distance between the casks and the shield wall be at least 1.5 m and (2) the total quantity of all combustible liquid materials inside the CSB is no more than 6 000 litres.

2. HI-STAR 100 cask during installation of the shield wall

   Based on the results it is concluded that the HI-STAR 100 casks will continue to perform all their intended safety functions during the postulated construction equipment fire event, provided the total quantity of all combustible liquid materials inside the CSB is no more than 1 306 litres, and the total quantity of all combustible solid materials inside the CSB is no more than 2 109 kilograms.

Based on the above should a fire occur it will not be a concern to the HI-STAR 100 or CASTOR casks in the CSB due to the fire mitigation controls - specifically the fire watch, who will ensure prompt response and the station firefighting equipment that is capable of combatting the postulated fuel fire.

2.18.2 Thermal Analyses of Cask Storage in CSB during Construction Activities

The complete analysis is described in Holtec document HI-2177774 [11] and is included herein as Attachment A7.

The purpose of the thermal analysis [11] is to demonstrate safety of casks stored inside the CSB during the construction period i.e., to demonstrate that the cask and its contents will remain within their applicable temperature limits.

1. The shield wall and construction equipment will have an impact on the thermal performance of casks inside the CSB. The shield wall will block the flow of air and the radiative heat transfer from the casks. It is also necessary to ensure that the shield wall temperature is below the operational temperature limit of the shielding material [4].
2. In addition to the blockage of radiation and convection heat transfer, the heat from construction equipment will add to the thermal load inside the CSB. The heat dissipated by the construction equipment may increase the air temperature inside the CSB and therefore warrants additional evaluations.

2.18.2.1 Methodology and Codes

The modelling approach used for the thermal analysis of cask storage during the construction activities are listed in Section 2 of report [11].

1. The air volume inside the CSB, cask geometry, are explicitly modelled. Cask internal components are not modelled as the objective is to predict bounding surface temperatures and the building ambient temperature.
2. The CSB walls and floor are conservatively modelled as adiabatic – that is no credit is taken for heat dissipation to the ambient through the walls, thereby overestimating the building indoor temperatures.
3. The weather louvers are modelled as outlet-vent boundaries. Pressure loss through the ducting and vent screens for the weather louvers are specified as a loss coefficient for the outlet vent boundary. The pressure loss factor for the fire vent vanes are also stated in a similar manner.
4. In order to account for the presence of construction equipment inside the building, approximately 60kW hypothetical thermal load is placed on the construction side of the shield wall. The approximate heat released by a typical construction truck during idling is 25kW.
5. The effect of suspended dust particles during the construction period is neglected. Technical justification provided in [7] establishes that the impact of dust generated during the construction period is minimal and non-detrimental to the heat transfer inside the CSB. Therefore, conservatively understated emissivity of 0.9 is used for the CASTOR cask external surfaces and a bounding emissivity of 0.85 is used for the HI-STAR 100 casks.

2.18.2.2 Assumptions

The major assumptions used for the thermal analysis of cask storage during the construction activities are listed in Section 2 of report [11]. The most important are:

1. The roof fire vents are assumed to be open at all times. This is necessary to allow adequate ventilation for the heated air inside the building. The roof vents are modelled as outlet-vent boundaries.
2. The CSB door is assumed to remain open throughout the construction phase. This is necessary to allow cold air flow into the building.

2.18.2.3 Acceptance Criteria

The following acceptance criteria apply to the analyses.

1. The CASTOR cask surface temperature shall be < 83°C.
2. The temperature of the Ultra-High Molecular Weight (UHMW) plastic used in the shield wall must be below 80 °C.

2.18.2.4 Results

The summary of the results is presented in Table 5:

Table 5: Temperature Rise due to Construction Activities

Component	Allowable Temperature [°C]	Phase 1 [°C]	Phase 2 [°C]
CASTOR Cask External Surface	83	84*	82
Shield Wall	80	68	62
Building Indoor Bulk	38	39	41**

Phase 1:

1. * The CASTOR cask surface temperature is slightly (1°C) above the design basis cask surface temperature computed in the Thermal Design Report. A negligible portion of the cask surface (<0.1%) is at a temperature of 84°C. Such small local hotspots, which is less than 0.01% of the cask surface area, will not challenge the safety of the system. The temperature for rest of the cask body is below 79°C which is well within the design temperature. Such a minor increase in localized cask external surface temperature will have an inconsequential impact on peak rod temperatures inside the CASTOR casks. Hence it can be concluded that the CASTOR cask components and contents are within their safety limits during the CSB Construction Phase 1.
2. The maximum temperature of the shield wall is well within the long-term service temperature of UHMW plastic. Therefore, there is no risk of damage to the shield wall from the heat dissipated by the cask and hypothetical heat sources.
3. The bulk temperature of air around the HI-STAR casks is 1°C above what was adopted for evaluations in Appendix B of Holtec Report HI-2167289 [13] (CSB evaluation under normal conditions). (The evaluation in Appendix B of that report demonstrates safety of HI-STAR inside the CSB).

   This small increase 1°C in air temperature around the HI-STAR 100 casks will have at most an impact of 1°C on the fuel cladding and component temperatures. Considering the robust safety margins available, it can be concluded that the peak cladding temperature and component temperatures for HI-STAR casks during CSB Construction Phase 1 are well within the specified temperature limits.

Phase 2:

1. The CASTOR cask surface temperature is below the acceptance criteria. Therefore, it can be concluded that the CASTOR cask components and contents are within their respective design temperature limits during Phase 2 of construction activities.
2. The maximum temperature of the shield wall during Phase 2 is well within the long-term service temperature of UHMW plastic.

3. ** The bulk temperature of air around the HI-STAR casks is 3°C above what was adopted for evaluations in Appendix B of Holtec Report HI-2167289 [13] (CSB evaluation under normal conditions). (The evaluation in Appendix B of that report demonstrates safety of HI-STAR inside the CSB).

   This small increase 3°C in air temperature around the HI-STAR 100 casks will have at most an impact of 3°C on the fuel cladding and component temperatures. Considering the robust safety margins available, it can be concluded that the peak cladding temperature and component temperatures for HI-STAR casks during CSB Construction Phase 2 are also well within the specified temperature limits.

2.18.2.5 Conclusion

The thermal analysis demonstrates that the cask and its contents will remain within their applicable temperature limits during the construction period with the following constraint:

The entrance door to the CSB and the fire vents in the roof of the CSB must be kept open in order to ensure sufficient air circulation for heat removal. (The door is equipped with a fire switch that will ensure the door will close automatically in the event of a fire).

2.18.3 SARCA Cask Thermal Evaluation of Air and Surface Debris

The complete analysis is described in Holtec document HI-2177722 [7] and is included herein as Attachment A8.

The thermal analysis of air and surface debris is performed to demonstrate that the cask and its contents will remain within their applicable temperature limits.

2.18.3.1 Methodology and Codes

All computations of the cask thermal performance in [7] are performed using the models and methods from the previously performed CSB thermal analysis.

The thermal effects of a layer of construction dust deposited on the cask outer surfaces is modelled:

(1) by reducing the surface emissivity to that of the dust and

(2) by reducing the applied outer surface heat transfer coefficient to account for the additional thermal resistance of the dust layer.

1. Airborne Dust

   During any construction involving significant demolition it is a normal practice to use water (e.g., water trucks, sprinklers and/or sprayers) to suppress the generation of excessive clouds of dust. This would be even more important for demolition taking place indoors, as will be the case for the work in the CSB. In addition, to ensure worker safety from exhaust fumes from internal combustion powered equipment, significant ventilation will be required at all times. The combination of active dust control using water and constant ventilation should prevent quantities of airborne dust from reaching concentrations where radiative heat emitted from the cask would be blocked enough to be of concern. In fact, such a high concentration of airborne dust would most likely preclude human occupation of the CSB, and so would be immediately detected and corrected.

2. Deposited Dust

Despite actions to limit airborne dust, some amount of construction dust will likely accumulate on the casks in the CSB. Periodic inspection and cleaning of the casks will be necessary commensurate with the observed rate of deposition. To ensure the casks will be properly cooled between periodic cleanings a thermal analysis for a dust coated cask is performed.

The first step in evaluating a dust-covered cask is to determine equivalent emissivities for the cylindrical side wall of the cask and for its closure lid end.

The second step in evaluating a dust-covered cask is to determine an effective heat transfer coefficient, for the cask outer surfaces, that reduces the design-basis coefficient to include the thermal resistance of the layer of deposited dust.

The third step in evaluating a dust-covered cask is to implement the equivalent emissivities and the effective outer surface heat transfer coefficient in the design-basis finite-volume model files for the HI-STAR 100 cask in the CSB. The modified model is then solved to obtain temperature fields. The decay heat load of the cask is also reduced from 20 kW to 18 kW, which bounds the actual decay heat loads.

The final step in evaluating a is to determine the MPC internal pressure that results from the computed temperature field

2.18.3.2 Assumptions

1. The dust is assumed to be concrete dust, which will be created during demolition of the existing CSB floor, so the evaluation may not bound dust of significantly different composition.
2. As cement is only one component of concrete, a density of only 20% of the density for bulk cement dust (20% x 800 = 160 kg/m^3) is assumed.
3. The concrete dust is assumed to completely cover the cask external surfaces to a thickness of 2.5 mm, which is conservative as dust will not accumulate to such a significant thickness on vertical or downward-facing surfaces.
4. The thermal conductivity of the deposited dust is conservatively estimated via linear scaling by density.
5. As a highly-conservative lower-bound density is assumed for the deposited dust, the resulting scaled thermal conductivity will also be correspondingly conservative.

2.18.3.3 Results

Temperature results given in [7] are summarized in Table 6:

Table 6: Temperature Effects of Casks due to Construction Dust

Component	Computed	Allowable
Fuel Cladding	553°K	673°K
MPC Outer Shell Surface	332°K	505°K
MPC/Overpack Helium Gap Outer Surface	331°K	477°K
Radial Neutron Shield Inner Surface	328°K	422°K
Overpack Enclosure Shell Surface	325°K	422°K
Overpack Closure Plate	317°K	477°K
Overpack Bottom Plate	340°K	450°K
MPC Cavity Helium Bulk	446°K	N/A

The calculated pressure for the dust-covered cask is:

Table 7: Calculated MPC Internal Pressure due to Construction Dust

Calculated MPC Internal Pressure	
Calculated Pressure	Allowable Pressure
520.4 kPa (g)	690 kPa (g)

2.18.3.4 Conclusion

Collectively, these results demonstrate that dust and other airborne debris generated during construction activities and deposited on the cask surfaces will not unacceptably hamper heat transfer for the HI-STAR 100 casks.

The CASTOR casks are not specifically analyzed but the heat transfer from these casks will be similarly affected by dust on the surface. The rate of heating will however be less than for the HI-STAR 100 analysis as the stored fuel in the CASTOR casks are older and generate less heat.

2.18.4 Slope Stability Analysis of the Temporary Slopes during CSB Pad Construction

The summary below is extracted from the Holtec document HI-2177728 [9] that is fully included herein as Attachment A10.

The purpose of [9] is to analyze the slope stability of the temporary slopes necessary for the Phase 1 construction of the CSB pad.

During the construction of Phase 1, a 1H:1V temporary slope with a depth of 1 455 mm will be maintained near the existing CASTOR casks pad, this temporary slope is analyzed to ensure stability during construction.

Upon completion of phase 1 CSB pad, the 8 casks will be transferred to Phase 1 CSB pad and Phase 2 CSB pad construction will begin.

Phase 2 includes the removal of the existing floor slab including plinths for the CASTOR casks and construction of the new CSB pad at the northern end of the LLW building, a temporary 1H:1V slope with a depth of 915 mm will be maintained during construction and its stability is also analyzed in this report.

2.18.4.1 Methodology and Codes

The analyses of the temporary slopes are performed using the computer program SLOPE/W.

SLOPE/W can effectively analyze both simple and complex problems for a variety of slip surface shapes, pore-water pressure conditions, soil properties, analysis methods and loading conditions, these capabilities can cover the full range of the design and analysis tasks in this report.

The limit equilibrium method is used in SLOPE/W. This method assumes that a potential sliding mass is discretized into several vertical slices, and the solution is merely based on equations of statics of each slice with a single, constant factor of safety.

2.18.4.2 Acceptance criteria

The principal design criteria that the slopes must satisfy are:

1. The allowable factor of safety under static load condition is 1.5.

2. The allowable factor of safety for the pseudo-static analysis which simulates the seismic load condition is 1.1.

2.18.4.3 Assumptions

The following assumptions are made in [9]:

a. Due to lack of information of the existing engineered fill inside the LLW building, the soil properties of the existing engineered fill in this calculation are assumed to be similar to the natural soil surrounding the LLW building. This assumption is conservative since the existing engineered fill was obtained on site and went through proper mix and compaction per CASTOR cask plinth Installation Specification.

b. The properties of the new engineered fill for the CSB pad construction are assumed to have similar properties of the existing engineered fill.

2.18.4.4 Results of Slope Stability Analysis

For the construction **Phase 1** temporary slope (1H: 1V), the factor of safety of the critical surface under seismic load condition is 2.6. Factor of safety of the critical surface under static load condition is 3.2. Both of them satisfy the required factors of safety stated in the Acceptance Criteria, which are 1.1 for seismic load condition and 1.5 for static load condition.

For the construction **Phase 2** temporary slope (1H: 1V), the factor of safety of the critical surface under seismic load condition is 2.4. Factor of safety of the critical surface under static load condition is 3.05. Both of them satisfy the required factors of safety stated in the Acceptance Criteria, which are 1.1 for seismic load condition and 1.5 for static load condition.

Table 8: Slope Stability Safety Factors

	Construction Phase 1 Temporary Slope		Construction Phase 2 Temporary Slope	
	Seismic	**Static**	**Seismic**	**Static**
Factor of Safety	2.405	2.846	2.394	4.447

The results from the analysis in [9] are within the acceptable limits. Therefore, the 1H: 1V temporary slopes will stay stable during the CSB pad construction Phase 1 and Phase 2

2.18.4.5 Conclusions

The following conclusions are drawn from the analyses performed in this calculation package for:

(Note that the Phase 2 analyses includes both Phase 1 and Phase 2 designs).

Phase 1 CSB pad under DBE:

1. The maximum sliding does not result in inter-cask impact or cask migrating beyond the edge of the pad under 10% amplified earthquake; and cask rocking angle does not exceed 50% of the critical rocking angle.
2. No particular loading pattern is required; however, locating the first cask at any of the four corners of the pad is not permitted.

Phase 2 CSB pad under DBE:

1. The maximum sliding does not result in inter-cask impact or cask migrating beyond the edge of the pad under 10% amplified earthquake; and cask rocking angle does not exceed 50% of the critical rocking angle.
2. No particular loading pattern is required; however, locating the first cask at any of the four corners of the pad is not permitted.

Phase 2 CSB pad under DEC:

1. The SSI analysis does not show any unacceptable consequences for the Cask system itself. In other words, the maximum cask movement will not result in inter-cask impact or excessive cask migration beyond the edge of the pad. Furthermore, the predicted rocking angle (mean plus one standard deviation) with a COF of 0.8 is less than 50% of the critical rocking angle. Therefore, the stability of the cask will be maintained, and the cask system will meet its safety functions, as expected.
2. The acceptance criteria is satisfied. Even though not required a punching shear check of the CSB Pad has been performed (in Appendix F of [9]), and it is noted that the minimum safety factor is 1.80 (conservatively using ACI-318 code

allowable strength). Therefore, gross failure of CSB pad under design extended condition (PCR) is not a concern.

3. No particular loading pattern is required; however, locating the first cask at any of the four corners of the pad is not permitted.

2.18.5 Seismic Stability and Structural Safety of the CASTOR Casks during Phase 1 Construction

The summary below is extracted from Holtec document RRTI-2556-001 [23] that is fully included herein as Attachment A12.

The slab modification will be carried out in two phases as shown on Holtec drawing 10941 [3]. During Phase 1 the four CASTOR casks will be moved to the North end of the CSB and placed on existing plinths while the concrete slab to the south undergoes modifications. The RRTI concludes that the shear and moments resulting from the load combinations meet the applicable acceptance limits for the cask foundations.

It also concludes that possible liquefaction settlement will be in the order of 10mm, therefore a cask toppling or cask burial event due to soil liquefaction is not plausible.

Therefore, it can be stated that the Phase 1 modifications to the CSB slab will not affect the seismic stability or structural safety of the CASTOR casks, provided that the soil below the pads are not disturbed.

2.19 ALARA

The ALARA screening for Design Changes is included as Attachment A11. The screening concluded that site dose rates on the outside walls and door (once the HI-STAR 100 casks are in place) will be monitored. In order to allocate dose for the CSB storage pad upgrade the individual tasks to be performed, including the support operations, number of workers, durations and actual work location will be submitted once the construction plans are in place.

3.0 REFERENCES

[1] HI-951251: HI-STAR 100 SAR, Revision 15

[2] HI-2002444: Final Safety Analysis Report (FSAR) for the HI-STORM 100 Cask System, Revision 14

[3] Holtec Drawing No. 10941: IFSIFI Pad Details, Revision 3

[4] Holtec Drawing No. 10988: Radiological Shield Wall for Storage Building, Revision 1

[5] HI-2177762: Holtec Report: Structural Analysis of Eskom Phase 1 ISFSI Pad, Revision 4

[6] HI-2156867: Holtec Report Site Boundary and Cask Storage Building Dose Rates Calculations for HI-STAR 100 System for ESKOM KOEBERG Nuclear Power Station, Revision 4

[7] HI-2177722: CSB SARCA Cask Thermal Evaluation of Air and Surface Debris, Revision 1

[8] HI-2177726: CSB SARCA Cask Fire Hazard Evaluation, Revision 1

[9] HI-2177728: Slope Stability Analysis of the Temporary Slopes During ISFSI Pad Construction, Revision 2

[10] HI-2177756: Soil Structure Interaction (SSI) Analysis of Eskom Phase 1 and 2 ISFSI Pads under Phase 1 and 2, Revision 2

[11] HI-2177774: Thermal Analyses of Cask Storage in CSB during Construction Activities, Revision 1

[12] HI-2177743: CSB Safety Analysis Report for Construction Activities (SARCA) Hazard Analysis, Revision 1

[13] HI-2167289, Thermal Evaluations of HI-STAR 100 Casks in the Cask Storage Building at Koeberg Plant, Revision 1

[14] HI-2167087, Evaluation of Site-Specific Fires, including Onsite Transporter (HI-PORT) Fire for HI-STAR 100 at Koeberg, Revision 1

[15] RD-0034: Quality and Safety Management Requirements for Nuclear Installations Revision 0

[16] KSA-010: Nuclear Safety, Seismic, Environmental, Quality and Importance Classification

[17] KAA-709: Process for Performing Safety Evaluations, Screenings, and Safety Justifications

[18] DSG-310-211: Specification for Spent Nuclear Fuel Transport and Storage Metal Casks, Revision 5

[19] ACI-318-05: Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05)

[20] HI-2012610: HI-STAR 100 FSAR, Revision 1

[21] HI-STAR 100 System Certificate of Compliance 9261, Revision 9, Appendix A, Table A.11.

[22] ESK-CS005 – 00 GEI Consultants Calculation Report: GE-Liquefaction Resistance and Post-Earthquake Settlement of Soils with a Ground Motion with PGA = 0.5g at the Koeberg Nuclear Power Station

[23] RRTI-2556-001 Seismic Stability of the CASTOR Casks during Phase 1 Construction

[24] GNB B 276/92 E, Revision 0: Datasheet for Transport and Handing of the CASTOR X/28F Cask

[25] HI-2156714 R2, Eskom Cask Movement Interface Report

[26] GNB B 127/95E Documents for the Application of the Type B(U)F- Transport License for the Transport and Storage Cask CASTOR X28F

[27] SC2017/0005, Storage of Loaded HI-STAR 100 Spent Fuel Casks in the Koeberg Cask Storage Building

[28] 0028/99Q, The Spent Fuel Storage Casks Classification

[29] 0012/14C: Cask Storage Building (Part of 6HQB000BG Low Level Waste Building)

[30] NUREG/CR 6407 Classification of Transportation Packaging and Dry Spent Fuel Storage System Components

[31] OHSA No 85/93: Occupational Health and Safety Act No 85 of 1993

[32] KLA-027: Hazardous Location Listing

[33] ASTM C31: Standards Practice for making and Curing Concrete Test Specimens in the Field

[34] ASCE 4 - 98: Seismic Analysis of Safety-Related Nuclear Structures

4.0 PART A ATTACHMENTS

A1 Design Input Consideration Checklist: Form 331-211

A2 HI-2177762 Rev 4: Structural analysis of Eskom Phase 1 & 2 ISFSI Pads under DBE

A3 Safety Evaluation E2017-0019

A4 10941: Pad Detail Drawings: ISFSI Pad Details Phase 1 and Phase 2

A5 10988: Radiological Shield Wall

A6 HI-2177726 Rev 1: SARCA Cask Fire Hazard Analysis

A7 HI-2177774 Rev 1: Thermal Analysis of Cask Storage during Construction

A8 HI-2177722 Rev 1: CSB SARCA Cask Thermal Evaluation of Air and Surface Debris

A9 HI-2177756 Rev 3: Soil Structure Interaction (SSI) Analysis of Eskom Phase 1 and 2 ISFSI Pads

A10 HI-2177728 Rev 2: Slope Stability Analysis of the Temporary Slopes during ISFSI Pad Construction

A11 ALARA Review

A12 RRTI-2556-001 Seismic Stability of the Castor Casks during Phase 1 Construction

ATTACHMENT A1

DESIGN INPUT CONSIDERATION CHECKLIST

Eskom	Nuclear Engineering Design Input Consideration Check-list	Document Identifier:	331-211
		Revision: 3	Page: 1 of 2
		Associated Procedure:	331-89 & 331-86

	TAF / DESIGN NUMBER: 07147 DPDRR007	Applicable	Not Applicable
1	Basic functions of each system, structure, and component.	☒	☐
2	Performance requirements such as capacity, rating, system output.	☒	☐
3	Codes, standards and regulatory requirements including the applicable issue and/or addenda. If ASME III is used refer to the latest NRC 10 CFR 50.55a for any limitations of use.	☒	☐
4	Design process conditions such as pressure, temperature, fluid chemistry and radiation levels.	☒	☐
5	Operational requirements under various conditions such as plant start-up, shutdown, power operation or emergency operation.	☐	☒
6	Reactivity management considerations such as heat balance, boron concentration, burnup, poisons and control rod positioning.	☐	☒
7	Interface requirements including definition of the functional and physical interfaces involving structures, systems and components.	☒	☐
8	Mechanical requirements such as vibration, stress, shock and reaction forces.	☒	☐
9	Loads such as seismic, wind, thermal and dynamic.	☒	☐
10	Structural requirements covering such items as equipment foundations and pipe supports.	☒	☐
11	Hydraulic requirements such as pump suction and discharge elevations and pressures, allowable pressure drops and allowable fluid chemistry.	☐	☒
12	Chemistry requirements such as provision for sampling and limitations on water chemistry.	☐	☒
13	Electrical requirements such as source of power, voltage, impact on back up battery loading (in particular DTV), raceway requirements, electrical insulation and motor requirements.	☐	☒
14	Instrumentation and control requirements including indicating instruments, controls and alarms required for operation, testing and maintenance. Other requirements such as the type of instrument, installed spares, range of measurement and location of indication should also be included. [Compressed Air Requirements]	☐	☒
15	Software and programming requirements.	☐	☒
16	Environmental conditions anticipated during storage, construction and operation such as pressure, temperature, humidity, corrosiveness, site elevation, wind direction, nuclear radiation, electromagnetic radiation and duration of exposure.	☒	☐
17	Radiation exposure to the public and to plant personnel (application of the ALARA principle). Complete and attach KFU-028 if applicable.	☒	☐
18	Safety requirements for preventing personnel injury including such items as restricting the use of dangerous materials, escape provisions from enclosures, grounding of electrical systems and other conventional safety considerations.	☒	☐
19	Requirements to prevent undue risk to the health and safety of the public.	☐	☒
20	Material requirements including such items as compatibility, electrical insulation properties, protective coating and corrosion resistance.	☒	☐
21	Layout and arrangement requirements.	☒	☐
22	Accessibility, maintenance, repair and in-service inspection requirements for the plant, including the conditions under which these will be performed.	☒	☐
23	Relevant Operating Experience.	☐	☒
24	Redundancy, diversity and separation requirements of structures, systems and components.	☐	☒
25	Access and administrative control requirements for plant security.	☒	☐
26	Failure modes and effects considerations of structures, systems and components including a definition of those events and accidents for which they must be designed to withstand.	☐	☒
27	Fire protection or resistance requirements.	☒	☐
28	Common-mode failures and other common-mode effects.	☐	☒
29	Test requirements including in-plant tests and the conditions under which they will be performed.	☒	☐
30	Personnel requirements and limitations including the qualification and number of personnel available for plant operation, maintenance, testing and inspection and permissible personnel radiation exposures for specified areas and conditions.	☐	☒

Eskom	Nuclear Engineering Design Input Consideration Check-list	Document Identifier:	331-211
		Revision: 3	Page: 2 of 2
		Associated Procedure:	331-88 & 331-86

	TAF / DESIGN NUMBER:	Applicable	Not Applicable
31	Transportation, handling and storage requirements such as size, shipping weight and legal limitations.	☒	☐
32	Foreign Material Exclusion (FME) requirements during all intrusive mechanical work such as cutting, grinding and welding.	☒	☐
33	Effect of the design on the Control Room Human Engineering Factors.	☐	☒
34	Impact on the South African Grid Code – Complete and attach KFU-018 if applicable.	☐	☒
35	Diesel Generator Load Balance Performed.	☐	☒
36	Determined the effect on Severe Accident Management Guidelines?	☐	☒
37	Avoided selecting materials that contain zinc in components to be installed in containment.	☐	☒
38	Considered if there is an effect of the design on the RP Migration Model.	☐	☒
39	Has HOLTEC implemented a similar modification, has this information been taken into account in this design? If so, are the input parameters similar?	☒	☐
40	Has this modification resulted in new classifications? Has the impact on technical specifications, procedures, transient files and programmatic controls been determined? Has the new classification been considered adequately for safety importance?	☒	☐
41	Have the conventional safety risks that will be present during construction been considered? Does the design consider constructability and the construction process?	☐	☒
42	Have KGU-035 and KGU-038 been considered with respect to Single Point Vulnerabilities, that is SPV's eliminated and /or no new SPV's introduced.	☐	☒
43	Microprocessor and Automation Design Checklist – Complete and attach KFU-019 if applicable.	☐	☒
44	Software Design Consideration Checklist – Complete and attach KFU-020 if applicable.	☐	☒
45	Effect on Environmental Qualifications – Complete and attach KFU-021 if applicable.	☐	☒
46	Was any EPRI guidance/report/study considered?	☐	☒
47	New electrical board loads calculated and original drawings updated with new values?	☐	☒
48	Have the appropriate drains been identified and are they being used?	☐	☒
49	Code reconciliation to ASME XI of new plant items not conforming to the DSE referenced construction code.	☐	☒
50	Compliance with the requirements of ANSI/ANS-58.8 Time Response Design Criteria for Safety-Related Operator Actions.	☐	☒
51	Has the system operator been informed of any modification, in particular GEV, GEX, GSY, GPA and LGR (including LGR protection settings) to determine if it affects Transmission protection equipment settings?	☐	☒
52	Have surface treatment processes on new equipment been evaluated in relation to the elimination or reduction of high dose radio-isotopes?	☐	☒
53	Have KLM-011 and KLM-012 been considered with respect to the required accuracy of any new instrumentation?	☐	☒
54	Have all of the hazardous location requirements been addressed?	☐	☒
55	Are any additional nuclear safety analyses necessary for the design and is there an update required to Koeberg analysis models and codes (e.g. PSA, MAAP, RELAP, and SCALE)?	☒	☐
56	Is the current design change being simultaneously implemented on the same system with another design change package and has the impact been assessed and been documented in the both design change packages?	☒	☐
57	Are the safety screening / evaluation and design input consideration checklist completed using the latest design scope changes?	☒	☐

The design input requirements are correctly selected and reasonable

Feb	B van Rooyen COMPILER	SIGNATURE	7 Feb 2018 DATE
	J Venter REVIEWER	SIGNATURE	7 Feb 2018 DATE

CONTROLLED DISCLOSURE

ATTACHMENT A2

STRUCTURAL ANALYSIS

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STRUCTURAL ANALYSIS OF ESKOM PHASE 1 & 2 ISFSI PADS UNDER DBE

FOR

ESKOM

Holtec Report No: HI-2177762

Holtec Project No: 2556

Sponsoring Holtec Division: NPD

Report Class : SAFETY RELATED

HOLTEC INTERNATIONAL

DOCUMENT ISSUANCE AND REVISION STATUS[1]

DOCUMENT NAME:	STRUCTURAL ANALYSIS OF ESKOM PHASE 1 & 2 ISFSI PADS UNDER DBE			
DOCUMENT NO.:	HI-2177762	CATEGORY: ☐ GENERIC		
PROJECT NO.:	2556	☑ PROJECT SPECIFIC		

Rev. No. [2]	Date Approved	Author's Initials	VIR #
4	2/6/2018	V.Mathur	415871

DOCUMENT CATEGORIZATION

In accordance with the Holtec Quality Assurance Manual and associated Holtec Quality Procedures (HQPs), this document is categorized as a:

- ☑ Calculation Package[3] (Per HQP 3.2)
- ☐ Technical Report (Per HQP 3.2) (Such as a Licensing Report)
- ☐ Design Criterion Document (Per HQP 3.4)
- ☐ Design Specification (Per HQP 3.4)
- ☐ Other (Specify):

DOCUMENT FORMATTING

The formatting of the contents of this document is in accordance with the instructions of HQP 3.2 or 3.4 except as noted below:

DECLARATION OF PROPRIETARY STATUS

☐ Nonproprietary ☑ Holtec Proprietary ☐ Privileged Intellectual Property (PIP)

Notes

1. This document has been subjected to review, verification and approval process set forth in the Holtec Quality Assurance Procedures Manual. Password controlled signatures of Holtec personnel who participated in the preparation, review, and QA validation of this document are saved on the company"s network. The Validation Identifier Record (VIR) number is a random number that is generated by the computer after the specific revision of this document has undergone the required review and approval process, and the appropriate Holtec personnel have recorded their password-controlled electronic concurrence to the document.

2. A revision to this document will be ordered by the Project Manager and carried out if any of its contents including revisions to references is materially affected during evolution of this project. The determination as to the need for revision will be made by the Project Manager with input from others, as deemed necessary by him.

3. Revisions to this document may be made by adding supplements to the document and replacing the "Table of Contents", this page and the "Revision Log".

PREFACE

This section contains quality related information on this document in conformance with the provisions in Holtec's Quality Assurance program docketed with the USNRC (Docket # 71-0784).

This document is classified as "Safety Significant" under Holtec International's quality assurance system. In order to gain acceptance as a *safety significant* document in the company's quality assurance system, this document is required to undergo a prescribed review and concurrence process that requires the preparer and reviewer(s) of the document to answer a long list of questions crafted to ensure that the document is purged of all errors of any material significance. A record of the review and verification activities is maintained in electronic form within the company's network to enable future retrieval and recapitulation of the programmatic acceptance process leading to the acceptance and release of this document under the company's QA system. Among the numerous requirements that this document must fulfill, as applicable, to muster approval within the company's QA program are:

- The preparer(s) and reviewer(s) are technically qualified to perform their activities per the applicable Holtec Quality Procedure (HQP).
- The input information utilized in the work effort is drawn from referenceable sources. Any assumed input data is so identified.
- Significant assumptions are stated or provided by reference to another source.
- The analysis methodology is suitable for the physics of the problem.
- Any computer code and its specific versions used in the work are formally admitted for use within the company's QA system.
- The content of the document is in accordance with the applicable Holtec quality procedure.
- The material content of the calculation package is understandable to a reader with the requisite academic training and experience in the underlying technical disciplines.

Once a safety significant document, such as this calculation package, completes its review and certification cycle, it should be free of any materially significant error and should not require a revision unless its scope of treatment needs to be altered. Except for regulatory interface documents (i.e., those that are submitted to the regulator in support of a license amendment and request), editorial revisions to Holtec *safety significant* documents are not made unless such editorial changes are deemed necessary by the Holtec Project Manager to prevent erroneous conclusions from being inferred by the reader. In other words, the focus in the preparation of this document is to ensure correctness of the technical content rather than the cosmetics of presentation.

Furthermore, this Calculation Package is focused on providing technical results that demonstrate compliance with the applicable safety limits. Informational material that does not bear upon reaching a safety conclusion is minimized in this document to the extent possible. Because of its function as a repository of all analyses performed on the subject of its scope, this document will require a revision only if an error is discovered in the computations or the equipment design is modified. Additional analyses in the future may be added as numbered supplements to this Package. Each time a supplement is added or the existing material is revised, the revision status of this Package is advanced to the next number and the Table of Contents is amended. Calculation Packages are Holtec proprietary documents. They are shared with a client only under strict controls on their use and dissemination. This Calculation Package will be saved as a Permanent Record under the company's QA System.

Generic Reports

Holtec International maintains a number of so-called "generic reports" which provide the methodology, computer models and associated modeling assumptions for a specific physical problem. The technical content of a generic report is fully aligned with the System FSAR, Reg. Guides, NUREGs, etc., as applicable. In other words, the generic report contains Holtec's standardized analysis approach, method and model to analyze a technical problem. Developed under Holtec's self-funded R&D program, the generic reports are treated as "vital intellectual property" of the Company and *are accordingly prohibited from dissemination to any external entity.* The generic reports are subject to inspection by the NRC's staff at Holtec's corporate headquarters during NRC's triennial inspection of Holtec. The Calculation Package can invoke a Generic Report in whole or in part (see table below) to improve conciseness and to enable it to be submitted un-redacted to the Company's clients.

Holtec Approved Computer Program List (ACPL)

Holtec International maintains an active list of QA validated computer codes on the Company's network that are approved for use in Safety significant projects. The table below identifies the Codes and applicable versions (listed in the ACPL) that have been used in this work effort.

Generic Report & ACPL Information	
Generic Report # invoked in this Calc Package, if applicable	N/A
Code(s) name(s) (must be listed in the ACPL)	ANSYS
Code(s) version # (must be approved in the ACPL)	17.1

Computer ID #(s) (must be approved in the ACPL for the applicable code name and version)	1269
ACPL Revision # and Date of Issue	Rev. 349 / August 24th, 2017

Quality Validation Questionnaire

The questionnaire below is a distilled version of the vast number of questions that the preparer and reviewer of a Holtec safety-significant report must answer and archive in the Company's network to gain a VIR number (the identifier of QA pedigree in Holtec's electronic configuration control system).

An affirmative answer (unless the question is "not applicable" or N/A) to each of the following questions by the preparer of the report (or editor of a multi-author document) is an essential condition for this document to merit receiving a QA validated status.

	Criterion	Response Yes or No
1	Are you qualified per HQP 1.0 to perform the analysis documented in this report?	Yes
2	Are you aware that you must be specifically certified if you use any Category A computer code (as defined in HQP 2.8 in the preparation of this document?	Yes
3	Are you fully conversant with the pertinent sections of the applicable Specification invoked in this report?	Yes
4	Is the input data used in this work fully sourced (i.e., references are provided)?	Yes
5	Are you fully conversant with the user manual and validation manual of the code(s) used in this report, if any?	Yes
6	Is (Are) Category A computer code(s) (if used) listed in the Company's "Approved Computer program list"?	Yes
7	Are the results clearly set down and do they meet the acceptance criteria set down in the governing Specification?	Yes
8	Are you aware that you must observe all internal requirements on needed margins of safety published in Holtec's internal memos, if applicable (which may exceed those in the reference codes and standards or the specification)?	Yes
9	Have you performed numerical convergence checks to ensure that the solution is fully converged?	Yes
10	Is it true that you did not receive more than 10 quality infraction points in the past calendar year or thus far this year?	Yes

REVISION LOG

Rev. 0 - Original Issue

Rev. 1 – This revision is issued to address client comments. Additionally, the report has been updated per the latest revision of Holtec drawing 10941. All changes to the report are highlighted with revision bars on right hand margin. The automated Mathcad results are not highlighted with revision bars.

Rev. 2 – This revision is issued to add the results from Phase 2 ISFSI pad analysis. All changes to the report are indicated with revision bars in right hand margin. Appendices G and H are newly added and therefore not highlighted with revision bars. The automated Mathcad results are not highlighted with revision bars.

Rev. 3– This revision is issued to address client comments. All changes to the report are highlighted with revision bars on right hand margin. The automated Mathcad results are not highlighted with revision bars.

Rev. 4– This revision is issued to add Appendix I for the evaluation of the loaded trailer on the ISFSI pad. All changes to the main body of the report are indicated with revision bars in the right hand margin. Appendix I is newly added and therefore, not highlighted with revision bars.

TABLE OF CONTENTS

Safety Analysis Summary [1]

1.0 INTRODUCTION

This report documents the structural qualification of the above ground ISFSI pad at Koeberg Nuclear Power Station (KNPS) when subjected to dead load (Static Loading) and seismic load (Dynamic Loading). Specifically, the ISFSI pad for Phase 1, which will be used to store eight casks (4 HI-STAR 100 and 4 Castor Casks) as shown in Sheet 2 of [5], and Phase 2 which will be used to store sixteen casks (12 HI-STAR 100 and 4 Castor Casks) as shown in Sheet 4 of [5] will be analyzed in this report. The seismic impact loads in [1] are used in this report. The ISFSI pad is modeled using ANSYS finite element code and the underlying layers of engineered fill and substrates are also included in the model. The elements are all higher order Hexahedral elements with mid-side nodes. Based on the resulting top and bottom surface in-plane stress distribution, the bending moments across the pad thickness are computed and demonstrated to be below the limit values computed in accordance with the Ultimate Strength Method set forth in the American Concrete Institute Code. ACI-318-05 [9] has been selected as the design code for the structural analysis of the KNPS ISFSI pad consistent with requirements from HI-STAR 100 FSAR [19].

It is noted that the factored load combinations for the ISFSI pad design are not explicitly listed in [19]. The factored load combinations for ISFSI pad design are provided in NUREG-1536 [20] and are explicitly listed in HI-STORM 100 FSAR [15]. Therefore, the load combinations from HI-STORM 100 FSAR are used in the analysis.

It is noted that the HI-STAR 100 [11] and Castor [24] casks will be supported on cradle [23] & [25] and stored in horizontal orientation on the ISFSI pad. Therefore, in this analysis the horizontal configuration of the cask is analyzed. Both, HI-STAR 100 on transport cradle (shown in [11] & [23]) and Castor cask on cradle (shown in [25]) will be hereafter referred to as “Cask System(s)”. Figure 1.1 & 1.2 shows the Phase 1 & 2 configurations that are analyzed in this report. The rectangular regions represent the locations of HI-STAR 100 and Castor cask systems.

Two separate ANSYS analyses are performed for Phase 1 and Phase 2 ISFSI pads. The analysis methodology, and material properties of ISFSI pad, underlying layers of engineered fill, and substrates remain the same in both, Phase 1 and Phase 2 analyses.

[1] This Safety Analysis Summary constitutes the main body of the Calculation Package and is intended to be used as an autonomous document for safety justification on the project. The calculation details that provide back-up information to the material herein are contained in the Appendices which are maintained in Holtec’s configuration control system.

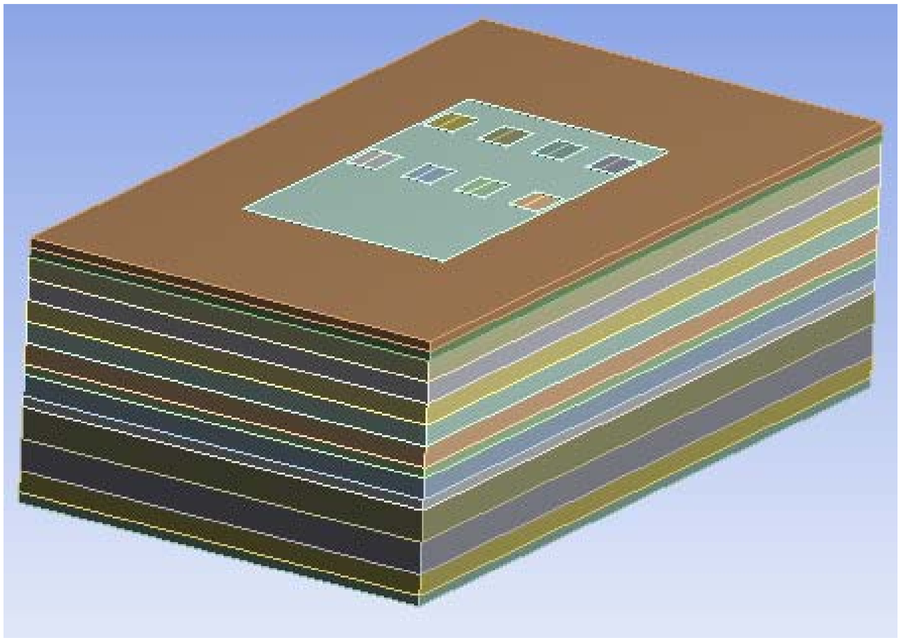

Figure 1.1 – Phase 1 ISFSI Pad and Substrate Solid Model for Finite Element Analysis

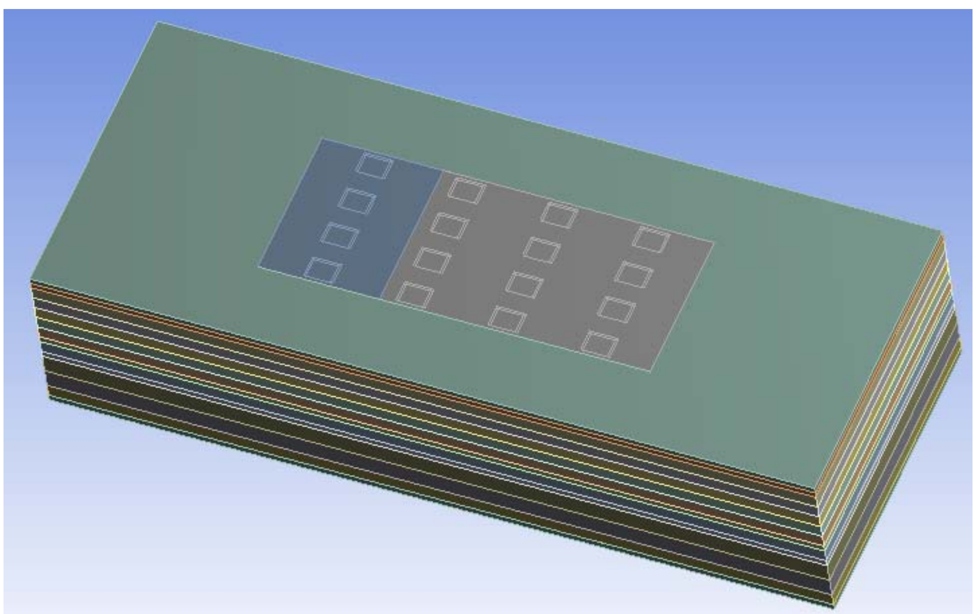

Figure 1.2 – Phase 2 ISFSI Pad and Substrate Solid Model for Finite Element Analysis

2.0 METHODOLOGY

The analysis methodology consists of the following steps:

1. Compute the cumulative settlement of the pad, d, under the sustained weight of the cask systems assuming that the pad is fully populated with loaded cask systems for the entire duration of its License Life. This settlement, d, is sought to be maximized by assuming that all cask systems are present on the pad from the very first day of ISFSI loading (a clearly untenable scenario) so as to maximize its effect on the flexural stress in the pad.
2. Compute conservative "effective elastic constants" that are to be used in the finite element simulation of the subgrade to represent the effect of settlement, d, based on the soil profile at site.
3. Prepare a finite element model of the pad and the subgrade using a sufficiently well discretized grid to represent the structural response of the pad in an accurate manner.
4. Perform the stress analysis of the pad under static loading (Dead & Live loads) with the subgrade simulated by the "effective elastic constants" to incorporate the exacerbating effect of settlement on the pad's flexural stress field. The "effective elastic constants" shall be determined using the Boussinesq approach described in Holtec Position Paper DS-338 [21].
5. Perform the stress analysis of the ISFSI pad under the seismic loading using the same finite element model as used above except that the elastic constants of the subgrade are modified to be the strain compatible moduli.
6. Utilize the maximum vertical loading obtained from [1] in the above stress analysis. The use of the maximum vertical load, V, to obtain the seismic load component in the load combination is an extremely conservative approach for the following reasons:

   (i) V is a transient load obtained by scanning the vertical loading time history of a cask system for the entire duration of the earthquake.

   (ii) No attempt to find the static equivalent loading for V (which is dead weight plus seismic load) is made. Rather V is treated as a static load representing the effect of the earthquake. (Recall that the ACI load combinations pre-suppose static loads.)

   Thus, the peak vertical load obtained from [1] is provided as the input to this structural analysis report. Moreover, because the pad is founded on an elastic half space, the effect of the rotational moment on the pad from the horizontal loading is essentially a local effect. Because only the primary moments are relevant and applicable to the strength capacity comparison (per ACI code [9]) under the applicable factored loads, the horizontal shear loading on the pad is not considered in this pad strength analysis.
7. The bounding value of V is assumed to act under every loaded cask system location in the finite element model for the stress analysis under the seismic load, no matter how many cask systems constitute the loading status of the pad. All cask systems loading scenarios (fully loaded, half loaded, etc.) use the same bounding load at each cask system location to represent the effect of the earthquake on the ISFSI pad.
8. The stress field in the pad is computed using the load combinations given in Section 2.1. In this step, another major simplification (and overarching conservatism) is employed: The maximum value of the bending moment under the static and dynamic load cases, even though they occur at different locations in the pad are combined

arithmetically as though they developed at the same location. The shear forces in the pad are also checked.

9. As the effect of all loadings is to produce shear and flexure in the pad, the internal force and moment in the pad from the load combinations are compared with the section capacities. The section shear and moment capacities must exceed the corresponding internal shear force and moment load at all locations for the pad to muster structural qualification.

2.1 Load Combinations

Section 2.0.4.2b of HI-STORM FSAR [15] requires the evaluation of the following three load combinations.

Normal Event (Static Loading):	Load Combination #1: $U_c > 1.4D + 1.7L$
Off-Normal Event:	Load Combination #2: $U_c > 1.05D + 1.275(L+T)$
Accidents (Dynamic Loading):	Load Combination #3: $U_c > D+L+E+T$

Where
U_c = reinforced concrete available strength
D = dead load
L = live load
T = thermal load
E = DBE (or SSE) seismic load

According to FSAR [15], the thermal loads acting on the ISFSI slab are small because of the low decay heat loads from cask. In addition, standard construction practices for slabs serve to ensure that extreme fluctuations in environmental temperatures are accommodated without extraordinary design measures. Therefore, all thermal loads are eliminated in the above combinations. The load combination #2 is bounded by the load combination #1 and therefore is not evaluated in this analysis. Load combination #1 and Load combination #3 are evaluated in this analysis. The analyses performed in [1] provide a maximum value for the vertical dead plus SSE seismic load transmitted to the ISFSI pad. The loading is used as design basis input for the structural analysis of the ISFSI pad under the SSE seismic load in the load combination #3. It is noted that the dead weight of ISFSI pad is treated as dead load and the dead weight of the cask system is treated as live load (L).

2.2 Structural Analysis of ISFSI Pad

The structural models shown in Figure 1.1 & 1.2 are generated in the ANSYS environment [6] (using the WORKBENCH module), which is a commercially available program and has been independently QA validated under Holtec's approved program. The qualification document is [12]. The finite element models include the ISFSI pad, engineering fill, and the soil subgrade. The detailed substrate layers are from Table A.2 of [1]. The substrate properties are developed in Table C2 of Appendix C for the soil layers in the finite element model. The finite element models are extended beyond the ISFSI pad. Higher order solid elements are used to model all components. The linear elastic models are subject to both the Static Loading (SL, 1.4 times dead load + 1.7 times live load) and Dynamic Loading (DL, dead load + live load + SSE load). To consider the effect of settlement, different soil properties are used for the Static Loading and Dynamic Loading. The Young's moduli of soils for Static Loading for both Phase 1 and Phase 2, summarized in Appendix C, are established in Appendices E & G, respectively.

The strain compatible Young's moduli of soil are used for Dynamic Loading. There are three types of strain compatible properties and they are Best Estimate (BE), Upper Bound (UB) and Lower Bound (LB). The average maximum cask-to-pad impact loads for BE, UB and LB, using the LS-DYNA method, are developed in [1]. The "average" refers to the average value of the maximum cask-to-pad impact loads obtained from the multiple LS-DYNA SSI runs performed in [1]. For each LS-DYNA SSI run, the maximum or peak cask-to-pad impact load is obtained for the whole duration of the seismic event. For structural analysis of the pad, the BE strain compatible properties are used along with the bounding maximum average cask-to-pad loads from either of BE, UB and LB cases from [1]. This is appropriate as the variation in strain compatible properties is considered in obtaining the demand loads on the ISFSI pad [1]. Also, this approach is consistent with industry practice and has been used in previous similar analyses. The Young's moduli of soils for Dynamic Loading are developed in Appendix C.

For each loading (Static or Dynamic) in Phase 1, the Full Loading (pad is fully populated with all 8 cask systems), Half Loading (50% of the pad is populated with 4 cask systems), Quarter Loading (25% of the pad is populated with 2 cask systems), End Loading (one corner of the pad is populated with 2 cask systems) and Single Loading (pad is populated with 1 cask system) are evaluated. Therefore, a total of ten loading case scenarios are evaluated in the Phase 1 model and they are listed in Table 2.1.

For each loading (Static or Dynamic) in Phase 2, the Full Loading (pad is fully populated with all 16 cask systems), Half Loading (50% of the pad is populated with 8 cask systems), Quarter Loading (25% of the pad is populated with 4 cask systems), End Loading (one corner of the pad is populated with 4 cask systems) and Single Loading (pad is populated with 1 cask system) are evaluated. Therefore, a total of ten loading case scenarios are evaluated in the Phase 2 model and they are listed in Table 2.2.

The critical positions for individual casks are determined based on the guidance by [18], which states "Based on these results, it is unlikely that any other combination of casks, consistent with a loading sequence that minimizes soil settlement, could produce significantly higher response than the 3-cask case, except perhaps for a single isolated cask at one end of the pad, which should probably be avoided." It is recommended that the cask in the single cask loading campaign should be placed at the location which is one storage slot off the corner of the pad. And such configuration is analyzed in ANSYS simulations.

Table 2.1 – Load Cases for Phase 1

Load Cases	Full Name	Short Name	Substrate Properties
1	Dynamic Loading, 1 Cask System	DL&1	Strain Compatible Moduli
2	Dynamic Loading, 2 Cask System	DL&2	
3	Dynamic Loading, 4 Cask System	DL&4	
4	Dynamic Loading, 8 Cask System	DL&8	
5	Dynamic Loading, 2 Cask System (End loading)	DL&EL2	
6	Static Loading, 1 Cask System	SL&1	Static Moduli
7	Static Loading, 2 Cask System	SL&2	
8	Static Loading, 4 Cask System	SL&4	
9	Static Loading, 8 Cask System	SL&8	
10	Static Loading, 2 Cask System (End loading)	SL&EL2	

Table 2.2 – Load Cases for Phase 2

Load Cases	Full Name	Short Name	Substrate Properties
1	Dynamic Loading, 1 Cask System	DL2&1	Strain Compatible Moduli
2	Dynamic Loading, 4 Cask System	DL2&4	
3	Dynamic Loading, 8 Cask System	DL2&8	
4	Dynamic Loading,16 Cask System	DL2&16	
5	Dynamic Loading, 4 Cask System (End loading)	DL2&EL4	
6	Static Loading, 1 Cask System	SL2&1	Static Moduli
7	Static Loading, 4 Cask System	SL2&4	
8	Static Loading, 8 Cask System	SL2&8	
9	Static Loading, 16 Cask System	SL2&16	
10	Static Loading, 4 Cask System (End loading)	SL2&EL4	

Two ANSYS Workbench models each, which have the identical geometry and mesh, are used to simulate the Dynamic Loading and Static Loading (mainly to account for the different Young's moduli for substrate) for Phase 1 and Phase 2, and the results are compiled in Appendix A. SOLID186 element type is used, by default, in ANSYS Workbench.

Appendix C derives the loadings for the Dynamic Loading cases and for the Static Loading cases, respectively. All loads are in the form of pressure on the ISFSI pad in the ANSYS simulations in Appendix A. For dynamic load cases, the SSE vertical load of the cask system is applied as linearly varying pressure over partial contact area of cradle baseplate area and ISFSI pad interface. For Static Loading cases, the factored live load (dead weight of the cask system) is applied as uniform pressure over the contact area of cradle and ISFSI pad (as listed in Appendix C), and the factored dead load (dead weight of the ISFSI pad) is applied as a uniform pressure over the whole ISFSI pad area.

Assuming a linear stress variation through the thickness, the top and bottom surface stresses suffice to compute the bending moment on the two faces normal to the horizontal axes. After applying the load combinations #1 and #3 in Section 2.1, structural integrity is demonstrated by comparing the calculated bending moment at the limiting sections of the pad with the available bending capacity.

The analysis presented in the main body of this report is based on the bounding loads from [1].

3.0 REFERENCES

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135/133J.

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4.0 ASSUMPTIONS

The finite element analysis assumes all materials are linear, isotropic elastic materials. It is made sure that after the analysis the stresses in the pad remain within the elastic limit and hence the assumption of linear elastic analysis is valid. Also, a linear analysis option is selected in ANSYS Workbench. This is consistent with prior analyses of similar configurations.

The interfacial connections between the ISFSI pad and other materials (engineered fill and soil) are assumed to be bonded in the ANSYS model. The interfacial connections between engineered fill and soil are also assumed to be bonded. The bonded condition is a valid assumption since the ISFSI pad and the engineered fill do not separate, and the engineered fill and the soil do not separate. This assumption is validated by the analysis results presented in Appendix A and is demonstrated in Section 9.0.

The ISFSI pad is discretized using two layers of higher order finite elements through the thickness of the pad. Reference [2] demonstrates that flat plates under pressure produce results in good agreement with thin shell element results. Therefore, the solutions capture the appropriate bending behavior of the ISFSI pad.

Pad bending moments are computed assuming that the stress distribution through the thickness of the pad is linear. Page B-3 of Appendix B contains the relationship of bending moments to surface stresses.

For conservatism, all concrete covers (top and bottom surfaces) are assumed at the maximum value and the moment capacities are obtained in Appendix B.

The base of the substrate (minimum value of the Z coordinate modeled) is assumed as a fixed surface. The far field lateral boundaries of the substrate are assumed to be free. The depth of the soil modeled in this analysis is consistent with [1] which follows the ASCE 4-98 criteria [16] and hence in order to simulate the end of the soil column (bedrock layer) the column is fixed at the bottom. The soil length and width that is modeled is about two times the corresponding dimension of the pad and this is done to remove any boundary edge effects that may arise and hence no boundary conditions are applied.

Best Estimate values for substrate properties are used in the structural analyses along with the bounding maximum average cask-to-pad loads from either of BE, UB and LB cases from [1].

In order to be consistent with the pad dynamic analysis [1], the concrete pad is assumed to be half cracked.

Thermal forces and moments are ignored since the temperature gradient through the thickness of the ISFSI pad is expected to be small and restraint against free thermal expansion is minimal at the edges of the pad.

Consistent with standard industry practice, locating the first cask at any of the four corners of the pad is not permitted.

5.0 INPUT DATA

Minimum 28-Day Compressive Strength of ISFSI Pad Concrete = 4,000 psi [5]

Poisson's ratio of ISFSI pad concrete v = 0.17 (Section 3.1.2.1.1 of [16])

The Poisson's ratio for substrate is considered to be 0.33 [1]

Concrete cover = 50 mm on top surface of ISFSI pad and 75 mm on bottom surface of ISFSI pad [5]

Rebar = Y40 bar on 225 mm spacing with yield strength = 450 MPa [5]. There are rebars in both the long direction and short direction of the ISFSI pad. There is no gap between the rebars in the long direction and short direction. The pad has concrete cover of 50 mm on top surface and 75 mm at the bottom surface as identified in [5]. Appendix D uses this concrete covers for capacity calculation.

Minimum Young's Modulus of Engineered Fill = 5,000 psi (34.47 MPa) [5]

Bounding Weight of Cask System = 283,060 lb. (128,394 kg) [1]

Input loads (vertical) come directly from average value of peak impact loads computed from the dynamic analyses in [1].

Average Peak Impact Loads on Phase 1 ISFSI Pad (from results of analyses in main body of [1], Vertical Impact Load, including cask system weight plus seismic increments)
V_{BE} = 590,844 lb. (2,628 kN) (Vertical, for Best Estimate Properties)
V_{LB} = 570,524 lb. (2,538 kN) (Vertical, for Lower Bound Properties)
V_{UB} = 1,028,982 lb. (4,577 kN) (Vertical, for Upper Bound Properties)

Average Peak Impact Loads on Phase 2 ISFSI Pad (from results of analyses in Appendix D of [1], Vertical Impact Load, including cask system weight plus seismic increments)
V_{BE} = 651,150 lb. (2,896 kN) (Vertical, for Best Estimate Properties)
V_{LB} = 606,730 lb. (2,699 kN) (Vertical, for Lower Bound Properties)

V_{UB} = 1,064,772 lb. (4,736 kN) (Vertical, for Upper Bound Properties)

The following bounding value is used in analysis:
Bounding Vertical load for Phase 1 = 1,040,000 lbf (4,626 kN)
Bounding Vertical load for Phase 2 = 1,075,000 lbf (4,782 kN)

Nominal Pad Thickness = 36” (915 mm) [5]

Density of Engineering Fill = 100 lb./ft^3 (1,602 kg/m^3) [5]

Note: A tolerance on engineering fill density is provided in [5]. Therefore, a sensitivity study was performed using the upper bound engineering fill density. As expected, the results from the sensitivity run show no difference in the bending stresses in Table 9.1 thru Table 9.10. Therefore, using the above listed engineering fill density is appropriate.

Dimensions of ISFSI pad are from [5] and the dimensions of all under-pad layers are from [1].

Any other input data that is used in the calculations presented in Appendices B thru I is presented appropriately in those appendices.

6.0 ACCEPTANCE CRITERIA

All applicable strength limits of the governing ACI Code [9] shall be satisfied, i.e., all the safety factors (also refereed as Margin of Safety) shall be larger than one.

7.0 COMPUTER FILES AND COMPUTER CODES

All the computer files associated with this report are saved on the HOLTEC network under:

G:\Projects\2556\REPORTS\Structural Reports\HI-2177762 (Structural Qualification Phase 1&2 ISFSI Pad)\

The computer files associated with the latest revision are saved on the network under the following directory:

G:\Projects\2556\REPORTS\Structural Reports\HI-2177762 (Structural Qualification Phase 1&2 ISFSI Pad)\Revision 4

8.0 ANALYSIS

Figures AD-2 & AD-3 in Appendix A show mesh details for the finite element modeling of the KNPS Phase 1 ISFSI pad and substrate components.

Appendix A contains complete details of the finite element model for the ten loading case scenarios (summarized in Table 2.1).

For each load case, the in-plane stress normal to the X face and the Z face are output in the form of color plots. Page B-3 of Appendix B contains a derivation of the relationship between in-plane top and bottom extreme fiber stress and section moment. Appendix C contains some direct inputs and the calculations that determine the input properties for each material layer.

9.0 RESULTS FROM PHASE 1 ISFSI PAD ANALYSIS

The results presented in this section are specific to Phase 1 ISFSI pad analysis. The results for Phase 2 ISFSI pad are documented in Appendix H of this report. Therefore, the results and associated discussion below are specific to Phase 1 ISFSI pad analysis.

Using the actual input load combinations, the appropriate surface pressure can be computed assuming that all loads are applied as pressures on the whole or partial area representing the cask system interface with the ISFSI pad. The dead weight of the slab plus vertical seismic adder is incorporated as a pressure on the whole area of the ISFSI pad in the –Y direction. The calculations to compute the actual pressures applied on the rectangular interface areas are performed in Appendix C.

Tables 9.1 through 9.10 present results for the condition where the maximum and minimum surface stresses are used *without regard for location on the ISFSI pad*. This approach maximizes the computed section bending moment that is compared to the allowable moment. The allowable moment is the bending capacity for concrete section from Appendix B, which outputs the section properties based on the specified reinforcement.

Table 9.11 summarizes the results of computed bending moments for all ten loading case scenarios of Phase 1 ISFSI pad and the bounding results are identified. Table 9.12 establishes the margin of safety based on the bounding results in Table 9.11. The margin of safety is defined as the allowable bending moment divided by the calculated bending moment.

Ten loading case scenarios are evaluated and the bounding bending moments in the pad in the long and short directions are identified. Based on the bounding results, the margin of safety of the bending of the pad are calculated and they are shown to be above 1.0 in Table 9.12. The minimum computed margin of safety for the Phase 1 ISFSI pad for static loading condition (1.4 D + 1.7L) is **2.31**. Per Table 9.12, the minimum computed margin of safety for the dynamic loading condition (D + L + E) is **1.39**, which is based on a peak vertical load of 1,040,000 lbf per [1].

To address the concern about the uplifting of the pad under the partial loading, the Normal Y stress (perpendicular to the pad bottom surface) contours are plotted on the bottom surface of the concrete pad for all loading cases as shown in Figures AD-9, AD-13, AD-17, AD-21, and AD-25 and Figures AS-5, AS-9, AS-13, AS-17, and AS-21 of Appendix A. The stress contours do not show consistent tension along the edge of the pad, which assures the uplifting of the pad is not a concern and the bonded connection used in the model is appropriate.

Appendix D calculates the linearly varying pressure over a partial contact area of cradle baseplate under seismic conditions to be used in the finite element simulations in Appendix A. Appendix E specifies conservative “effective elastic constants” that are to be used in the finite element simulation of the subgrade to represent the effect of settlement based on the soil characteristics at ISFSI site.

Appendix F also contains an evaluation of the punching shear capacity of the slab (using bounding load from both, Phase 1 and Phase 2) under the Dynamic Loading and Static Loading. The SSE load is the bounding load and is compared to the capacity of the section in punching shear. The resulting margin of safety is **1.26**.

The impact of loaded trailer on ISFSI pad is assessed in Appendix I and demonstrated to be bounded by cask system on ISFSI pad.

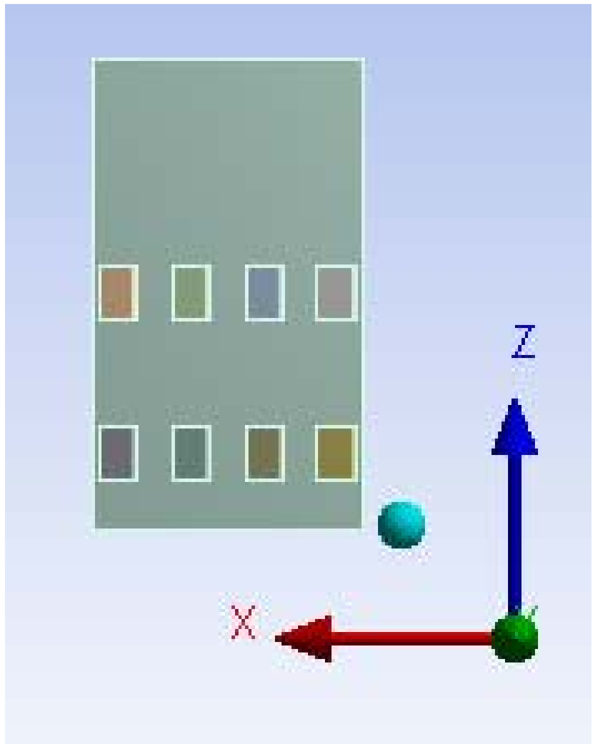


Figure 9.1: ANSYS Model of Phase 1 ISFSI Pad

10.0 CONCLUSIONS

Finite element models of the ESKOM Phase 1 (used to store eight casks (4 HI-STAR 100 and 4 Castor Casks)) and Phase 2 ISFSI pads (used to store sixteen casks (12 HI-STAR 100 and 4 Castor Casks)), together with underlying substrates has been constructed and bounding loads have been used to establish the stress distribution in the ISFSI pad. The stresses are converted to section bending moments, and compared with allowable value per the ACI Code [9]. All margins of safety are well above 1.0, and there is no lift-off of ISFSI pad observed under various loading cases.

The minimum margin of safety against bending of Phase 1 and Phase 2 ISFSI pad is **1.39** (Section 9.0) & **1.38** (Appendix H), respectively. The margin of safety against the punching shear is **1.26** for both Phase 1 and Phase 2 ISFSI Pad.

No particular loading pattern is required; however, locating the first cask at any of the four corners of the pad is not permitted (see Section 4.0).

11.0 APPENDICES

Appendix A – ANSYS DATA AND RESULTS FOR PHASE 1 & 2

Appendix B – MISCELLANEOUS INFORMATION

Appendix C – SUPPORTING CALCULATIONS FOR KNPS

Appendix D – CALCULATION OF PARTIAL CONTACT AREA OF CASK SYSTEMS

Appendix E – CALCULATION OF SETTLEMENT UNDER PHASE 1 ISFSI PAD

Appendix F – PUNCHING SHEAR AND BEARING EVALUATION

Appendix G – CALCULATION OF SETTLEMENT UNDER PHASE 2 ISFSI PAD

Appendix H – RESULTS FROM PHASE 2 ISFSI PAD ANALYSIS

TABLE 9.1 – RESULTS SUMMARY FROM FEA FIGURES REPORTED IN APPENDIX A for Phase 1 ISFSI Pad (Dynamic Loading, 1 Cask System)

KOEBERG STRUCTURAL EVALUATION (Dynamic Loading, 1 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.7	-901.95	595.93	**-161771.0**
ABSOLUTE VALUE			**161771.0**
Z-FACE		36	**LONG DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.8	-665.99	415.57	**-116808.5**
ABSOLUTE VALUE			**116808.5**

Note:

- Tables 9.1 through 9.10 calculate the unit moments in the long and short directions of the pad. The pad thickness is 36 inches.
- Tables 9.1 through 9.10 use the surfaces stresses “SU” and “SL” from the two load cases (described in Section 9.0) in the finite element analysis (Appendix A) to calculate the unit moment “M” for the two perpendicular sections of pad which are normal to Figure 9.1’s X-axis (short direction of the pad) and Z-axis (long direction of the pad), respectively. The surfaces stresses are reported in plain font and the source figures from Appendix A are also provided.
- Tables 9.1 through 9.10 present the maximum and minimum surface stresses without regard for their location on the ISFSI pad.

TABLE 9.2 – RESULTS SUMMARY FROM FEA FIGURES REPORTED IN APPENDIX A for Phase 1 ISFSI Pad (Dynamic Loading, 2 Cask System)

KOEBERG STRUCTURAL EVALUATION (Dynamic Loading, 2 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.11	-872.23	533.43	**-151811.3**
ABSOLUTE VALUE			**151811.3**
Z-FACE		36	**LONG DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.12	-766.4	449.89	**-131359.3**
ABSOLUTE VALUE			**131359.3**

TABLE 9.3 – RESULTS SUMMARY FROM FEA FIGURES REPORTED IN APPENDIX A for Phase 1 ISFSI Pad (Dynamic Loading, 4 Cask System)

KOEBERG STRUCTURAL EVALUATION (Dynamic Loading, 4 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.15	-868.24	514.32	**-149316.5**
ABSOLUTE VALUE			**149316.5**
Z-FACE		36	**LONG DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.16	-773.07	493.4	**-136778.8**
ABSOLUTE VALUE			**136778.8**

TABLE 9.4 – RESULTS SUMMARY FROM FEA FIGURES REPORTED IN APPENDIX A for Phase 1 ISFSI Pad (Dynamic Loading, 8 Cask System)

KOEBERG STRUCTURAL EVALUATION (Dynamic Loading, 8 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.19	-868.86	523.46	**-150370.6**
ABSOLUTE VALUE			**150370.6**
Z-FACE		36	**LONG DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.20	-731.58	460.45	**-128739.2**
ABSOLUTE VALUE			**128739.2**

TABLE 9.5 – RESULTS SUMMARY FROM FEA FIGURES REPORTED IN APPENDIX A for Phase 1 ISFSI Pad (Dynamic Loading, 2 Cask System (End loading))

KOEBERG STRUCTURAL EVALUATION (Dynamic Loading, 2 END CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.23	-749.49	408.82	**-125097.5**
ABSOLUTE VALUE			**125097.5**
Z-FACE		36	**LONG DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.24	-694.45	423.04	**-120688.9**
ABSOLUTE VALUE			**120688.9**

TABLE 9.6 – RESULTS SUMMARY FROM FEA FIGURES REPORTED IN APPENDIX A for Phase 1 ISFSI Pad (Static Loading, 1 Cask System)

KOEBERG STRUCTURAL EVALUATION (Static Loading, 1 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.3	-390.82	355.04	**-80552.9**
ABSOLUTE VALUE			**80552.9**
Z-FACE		36	**LONG DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.4	-356.59	309.51	**-71938.8**
ABSOLUTE VALUE			**71938.8**

TABLE 9.7 – RESULTS SUMMARY FROM FEA FIGURES REPORTED IN APPENDIX A for Phase 1 ISFSI Pad (Static Loading, 2 Cask System)

KOEBERG STRUCTURAL EVALUATION (Static Loading, 2 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.7	-341.02	307.38	**-70027.2**
ABSOLUTE VALUE			**70027.2**
Z-FACE		36	**LONG DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.8	-447.16	389.17	**-90323.6**
ABSOLUTE VALUE			**90323.6**

TABLE 9.8 – RESULTS SUMMARY FROM FEA FIGURES REPORTED IN APPENDIX A for Phase 1 ISFSI Pad (Static Loading, 4 Cask System)

KOEBERG STRUCTURAL EVALUATION (Static Loading, 4 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	SHORT DIRECTION BENDING
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.11	-293.29	261.87	-59957.3
ABSOLUTE VALUE			59957.3
Z-FACE		36	LONG DIRECTION BENDING
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.12	-477.23	425.22	-97464.6
ABSOLUTE VALUE			97464.6

TABLE 9.9 – RESULTS SUMMARY FROM FEA FIGURES REPORTED IN APPENDIX A for Phase 1 ISFSI Pad (Static Loading, 8 Cask System)

KOEBERG STRUCTURAL EVALUATION (Static Loading, 8 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	SHORT DIRECTION BENDING
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.15	-316.22	278.76	-64257.8
ABSOLUTE VALUE			64257.8
Z-FACE		36	LONG DIRECTION BENDING
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.16	-431.14	364.58	-85937.8
ABSOLUTE VALUE			85937.8

TABLE 9.10 – RESULTS SUMMARY FROM FEA FIGURES REPORTED IN APPENDIX A for Phase 1 ISFSI Pad (Static Loading, 2 Cask System (End loading)

KOEBERG STRUCTURAL EVALUATION (Static Loading, 2 END CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	SHORT DIRECTION BENDING
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.19	-247.96	216.09	**-50117.4**
ABSOLUTE VALUE			50117.4
Z-FACE		36	LONG DIRECTION BENDING
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.20	-362.58	296.98	**-71232.5**
ABSOLUTE VALUE			71232.5

Table 9.11 – SUMMARY OF MOMENTS FROM TABLE 9.1 TO TABLE 9.10 FOR PHASE 1 ISFSI Pad

		1 Cask System	2 Cask System	4 Cask System	8 Cask System	2 Cask System (End Loading)
Dynamic Loading	X-Face Moment (in-lb/in)	**161771**	151811	149316	150371	125097
	Z-Face Moment (in-lb/in)	116808	131359	**136779**	128739	120689
Static Loading	X-Face Moment (in-lb/in)	**80553**	70027	59957	64258	50117
	Z-Face Moment (in-lb/in)	71939	90324	**97465**	85938	71232

The highlighted results in the above table are the results from Table 9.1 through Table 9.10. Therefore, to calculate margin of safety in Table 9.12 under static and dynamic loading for Phase 1 ISFSI pad, results from Table 9.11 are used.

Table 9.12 – MARGIN OF SAFETY ON BENDING MOMENT COMPUTED USING BOUNDNG RESULTS IN TABLE 9.11 FOR PHASE 1 ISFSI PAD

LOCATION	ALLOWABLE MOMENT (in.-lb./in)*	COMPUTED MOMENT (in.-lb./in.)**		MARGIN OF SAFETY***	
		Dynamic Loading	Static Loading	Dynamic Loading	Static Loading****
Face Normal to X (Bending in Short Direction)	225,336	161,771	80,553	**1.39**	**2.80**
Face Normal to Z (Bending in Long Direction)	225,336	136,779	97,465	**1.65**	**2.31**

*Appendix B calculates the unit section capacities for ISFSI pad after applying a conservative reduction factor of 0.75 from [9].
**The computed moments are the factored moments based on combination of V (D+L+E) for the Dynamic Loading cases and 1.7L+1.4D for Static Loading cases.
*** The Margin of Safety is defined as SF = (allowable moment)/(computed moment). A SF > 1.0 means that the configuration is acceptable.
**** For the Static load case, it is noted that the static substrate Young's modulus calculated in Appendix E is 2,668 psi as opposed to 2,827 psi used in the analysis (in Appendix A). The young's modulus calculated in Appendix E is very conservative as it uses a settlement value of 2.5 inches as opposed to the actual calculated value of 1.73 inches. However, a sensitivity run has been performed using lower Young's modulus and confirmed that the results are within 2-3%. Since there are large safety factors for the Static Load case, the analysis results have not been updated with the lower Young's modulus run.

Appendix A – ANSYS DATA AND RESULTS FOR PHASE 1 & 2

Note: 1) The density of the engineering fill used in the ANSYS model is (120lb/ft3) as opposed to the lower density of 100 lb/ft3 listed in the main body of the report. This has negligible effect on the results and therefore the density has not been updated.
2) For the Phase 1 Static load case, it is noted that the static substrate Young's modulus calculated in Appendix E is 2,668psi as opposed to 2,827 psi used in the analysis. The young's modulus calculated in Appendix E is very conservative as it uses a settlement value of 2.5 inches as opposed to the actual calculated value of 1.73 inches. However, a sensitivity run has been performed using lower Young's modulus and confirmed that the results are within 2-3%. Since there are large safety factors for the Static Load case, the analysis results have not been updated with the lower Young's modulus run.

Phase 1 Dynamic Loading

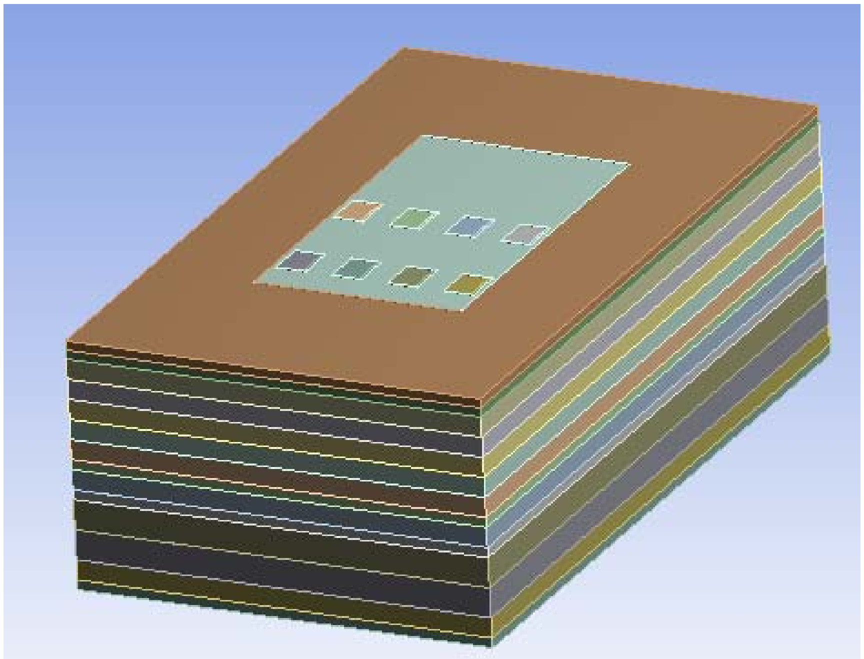


Figure AD-1 ANSYS Model of the Phase 1 ISFSI Pad, Engineering Fill, and Soil Layers

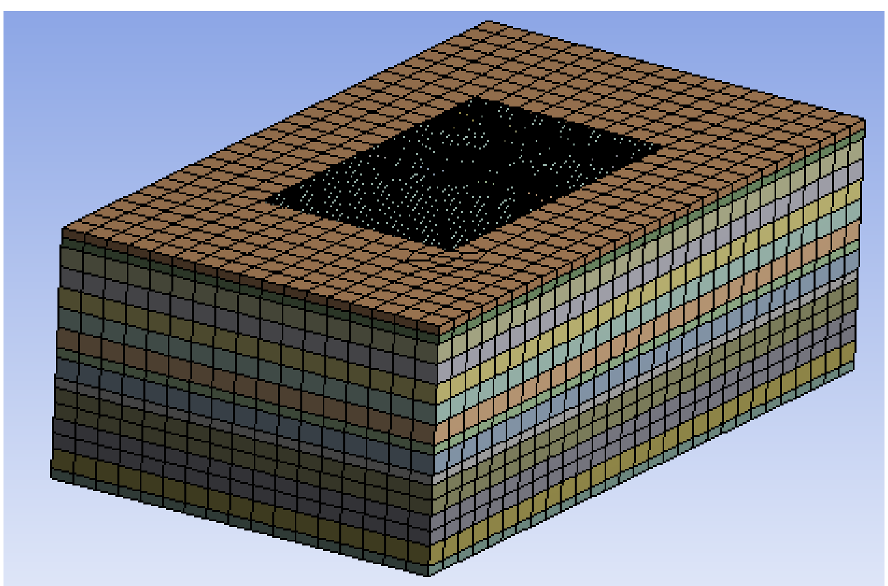


Figure AD-2 Finite Element Mesh of the Phase 1 ISFSI Pad, Engineering Fill, and Soil Layers

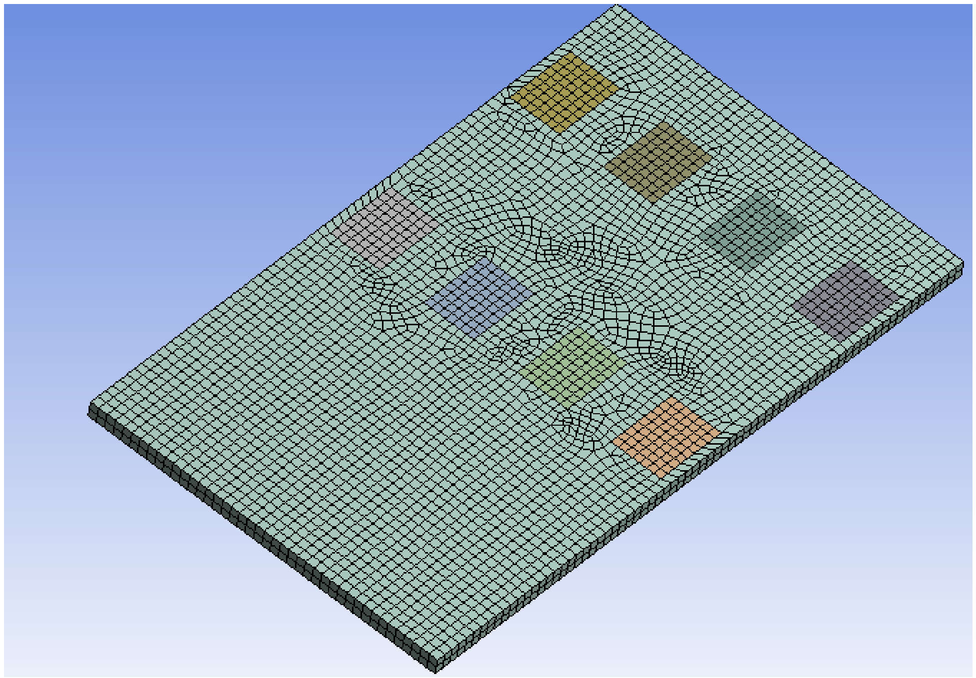


Figure AD-3 Finite Element Mesh of the Phase 1 ISFSI Pad

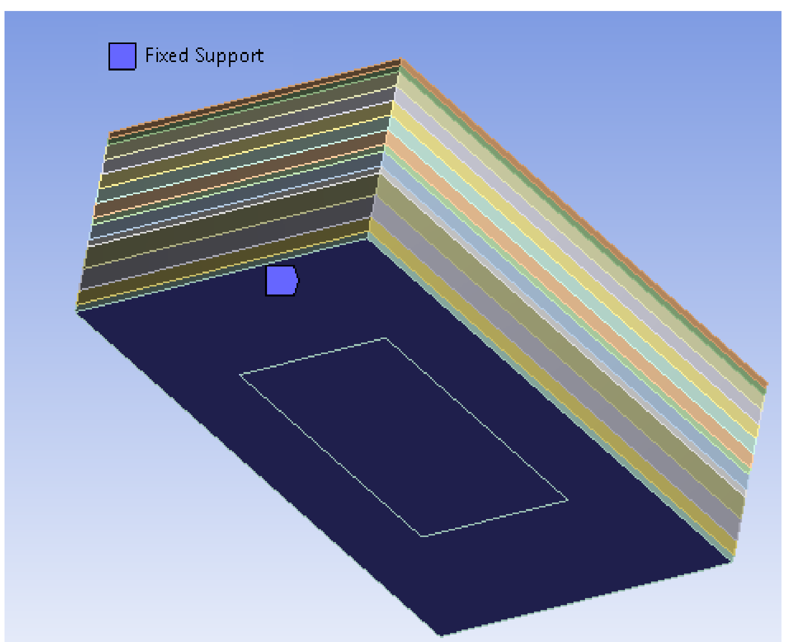


Figure AD-4 ANSYS model showing the fixed boundary condition for all load cases (Static and Dynamic)

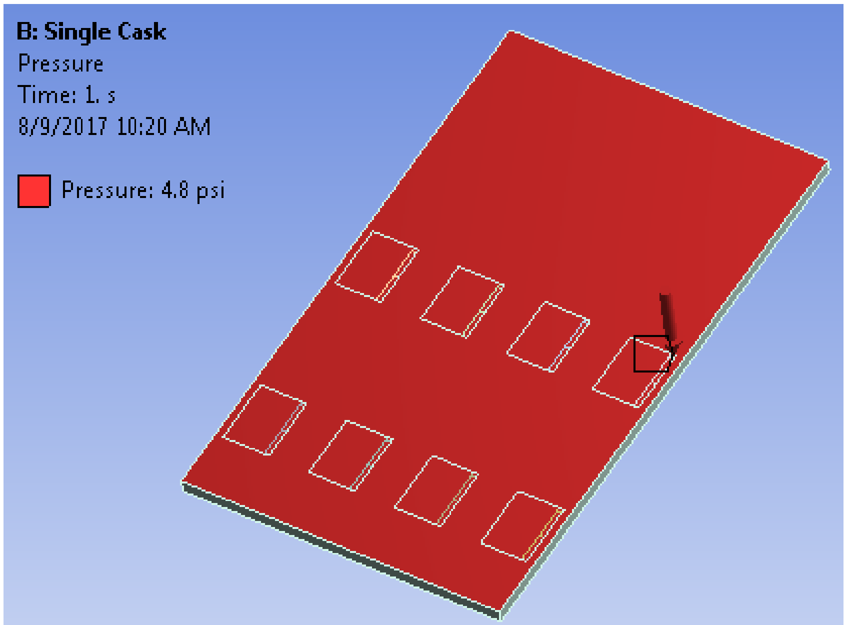


Figure AD-5 Dead plus seismic pressure load from the ISFSI pad for all Dynamic load cases

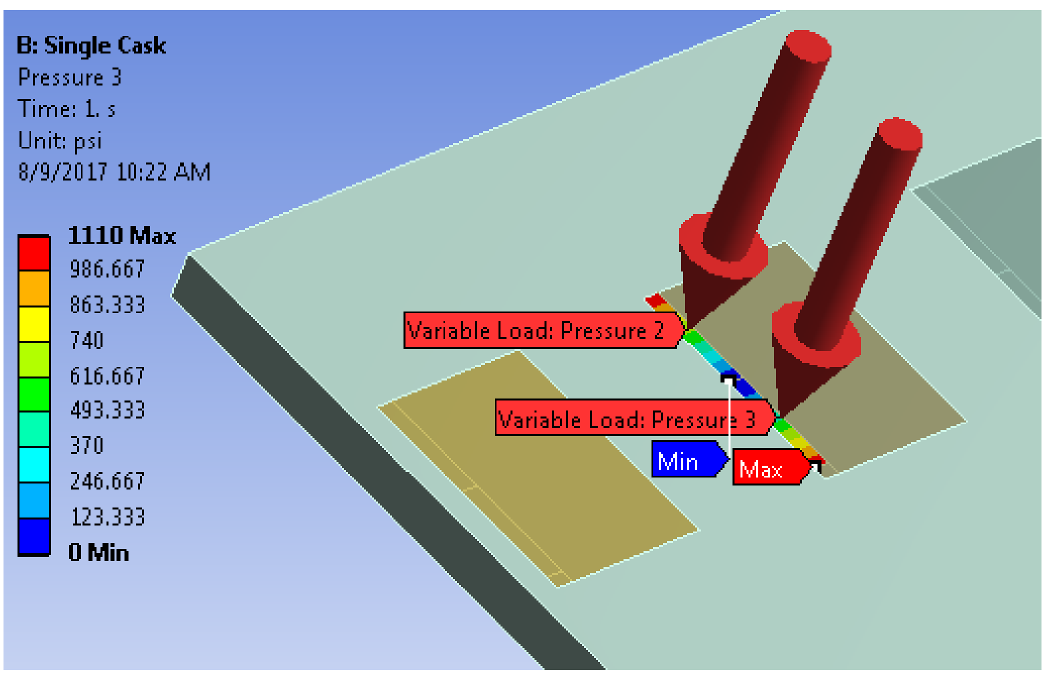
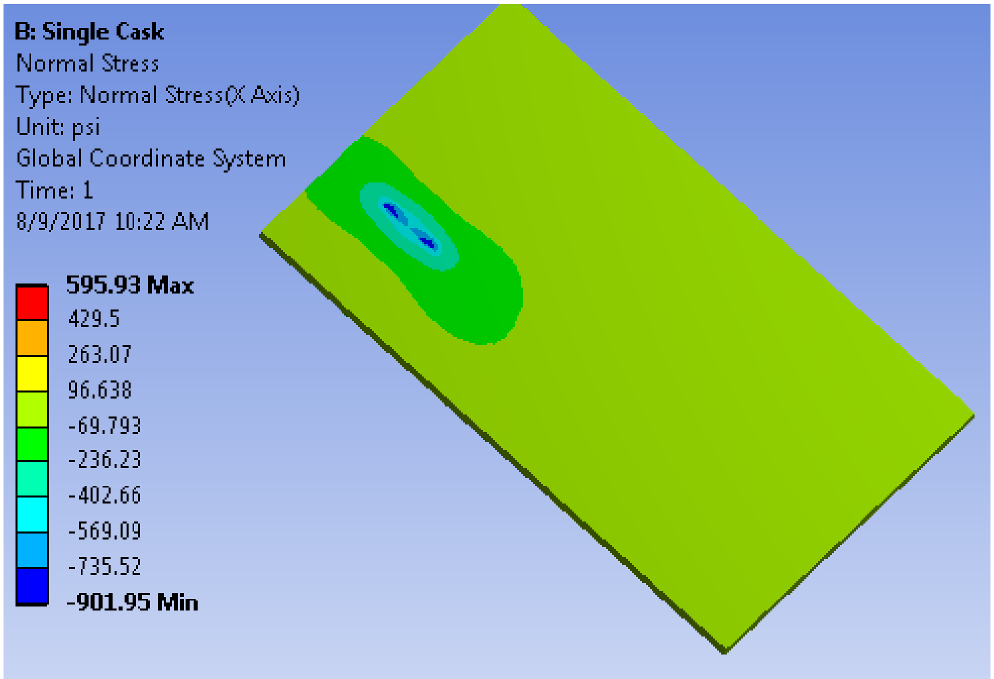


Figure AD-6 Phase 1 single loaded cask system dynamic case – Variable Pressure Load



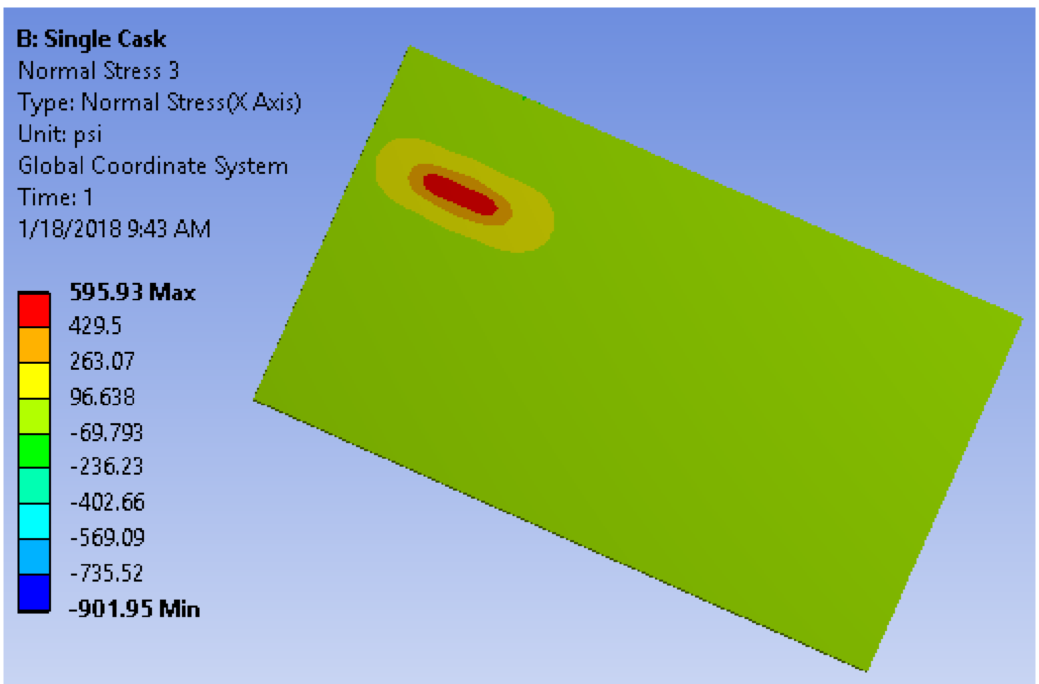
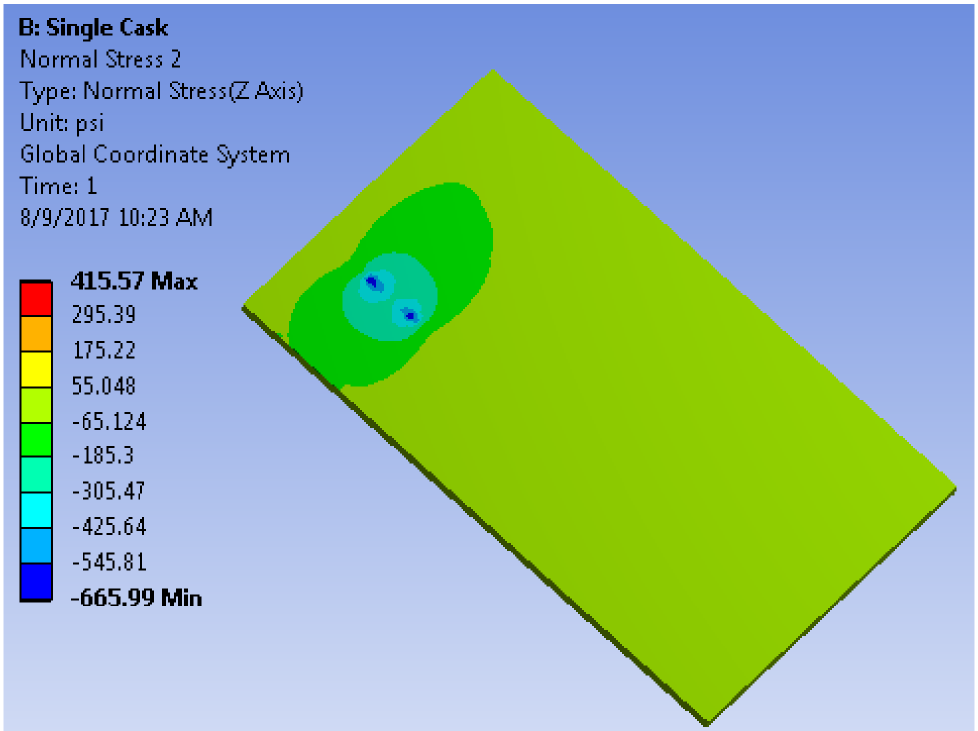


Figure AD-7 Phase 1 single loaded cask system dynamic case – Normal Stress in X-direction



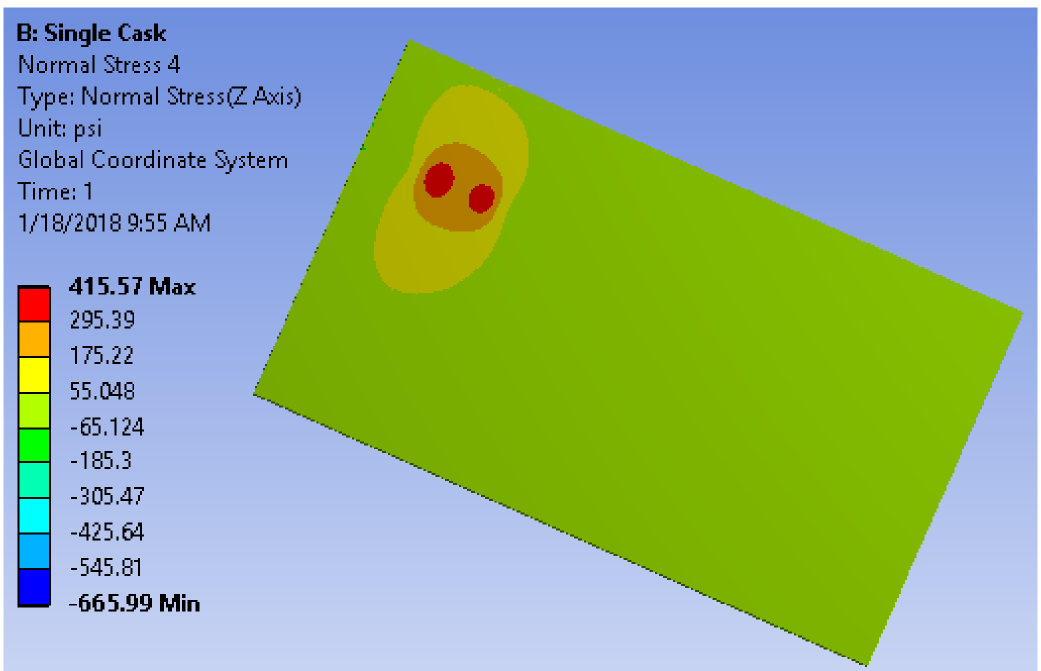


Figure AD-8 Phase 1 single loaded cask system dynamic case – Normal Stress in Z-direction

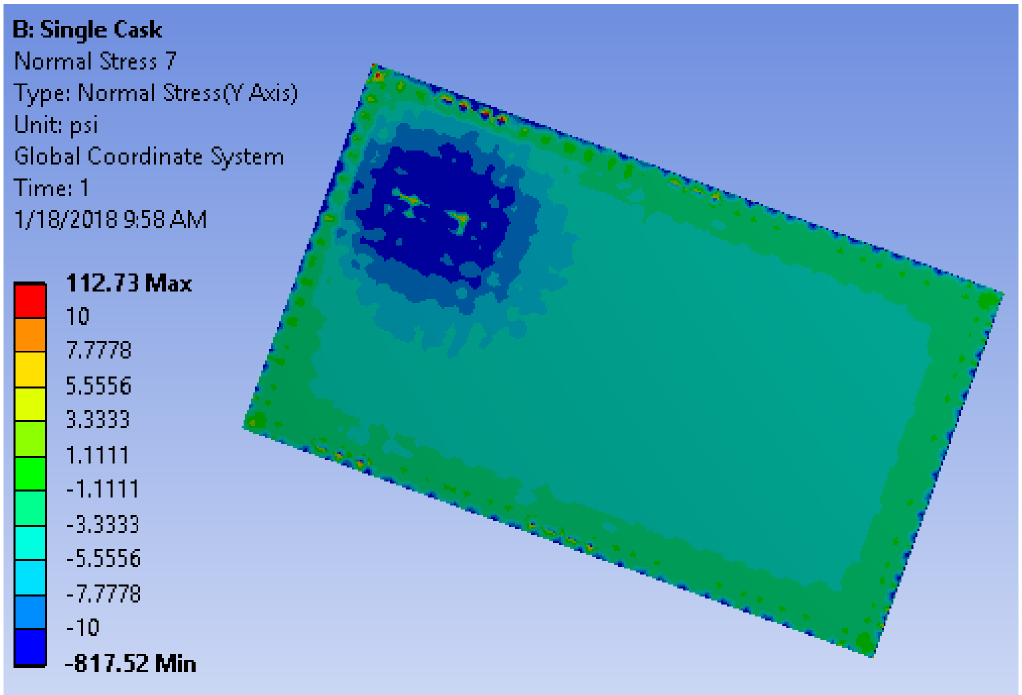


Figure AD-9 Phase 1 single loaded cask system dynamic case – Normal Stress in Y-direction

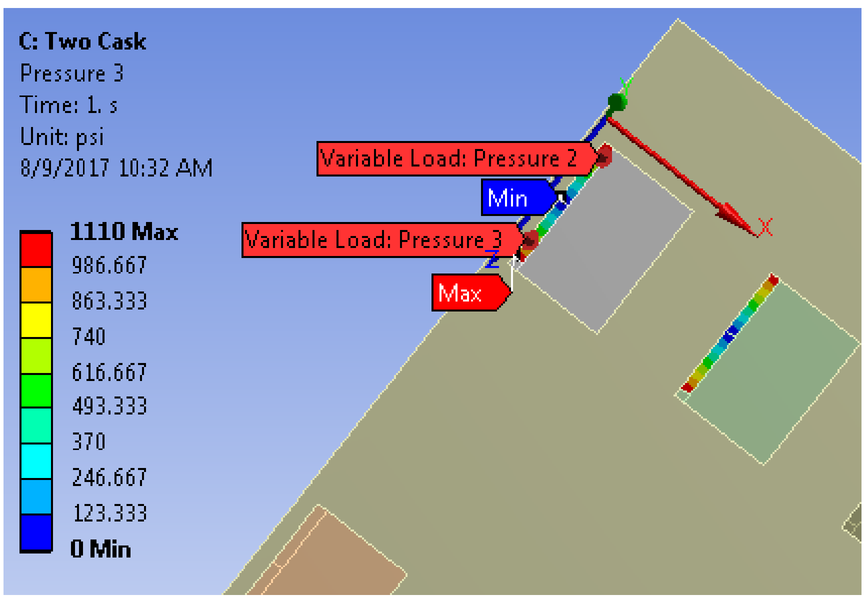
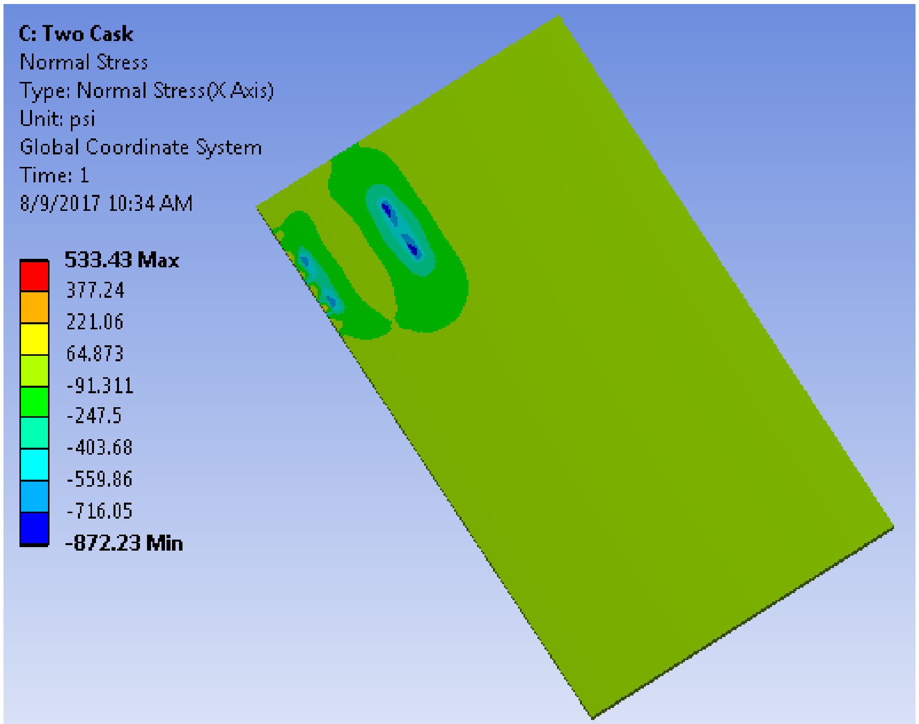


Figure AD-10 Phase 1 two loaded cask system dynamic case – Variable Pressure Load



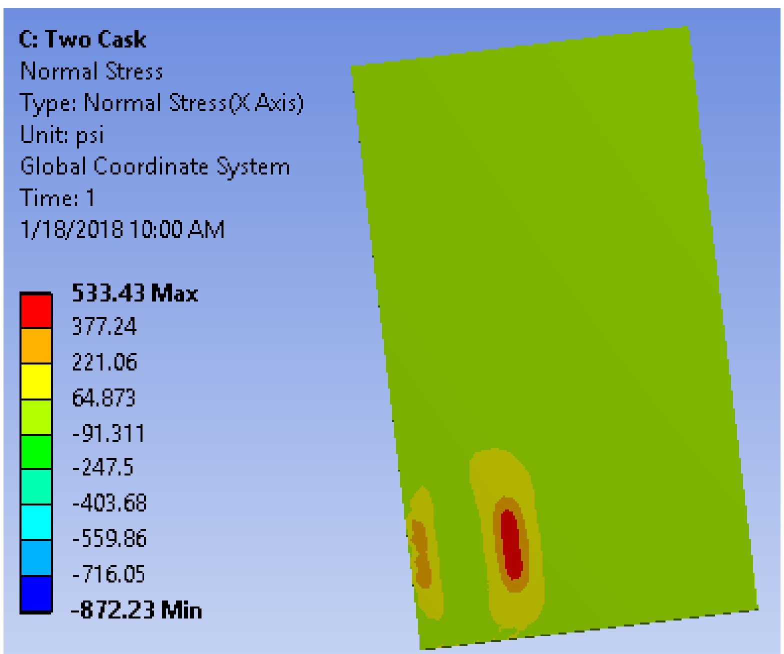
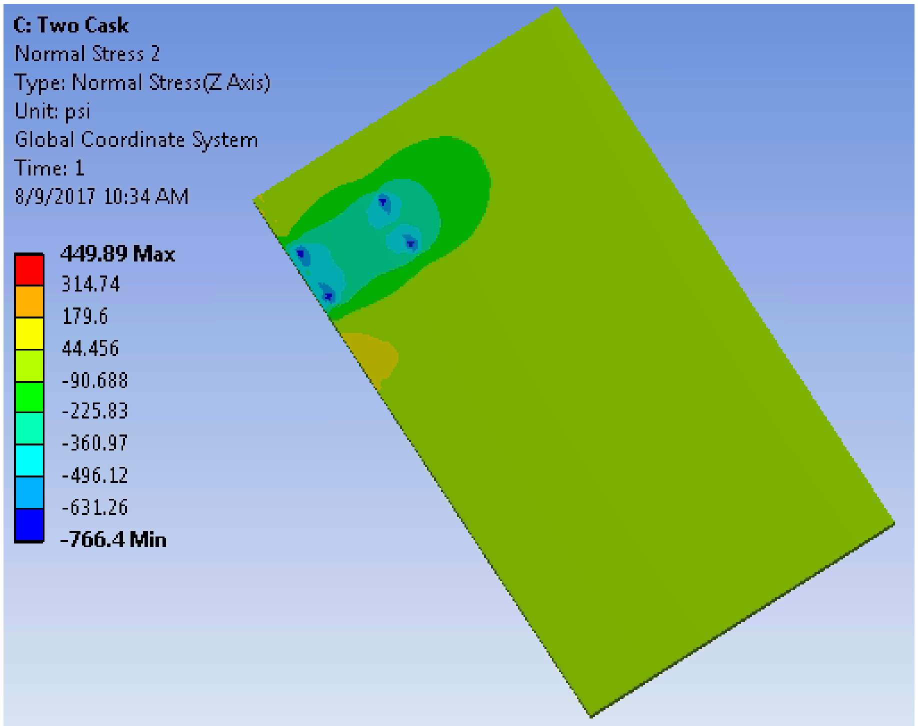


Figure AD-11 Phase 1 two loaded cask system dynamic case – Normal Stress in X-direction



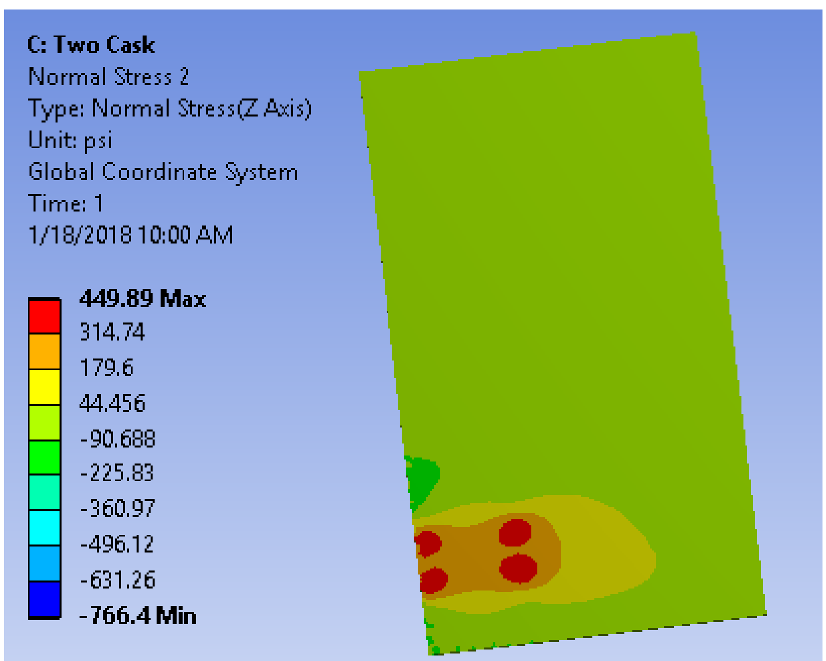


Figure AD-12 Phase 1 two loaded cask system dynamic case – Normal Stress in Z-direction

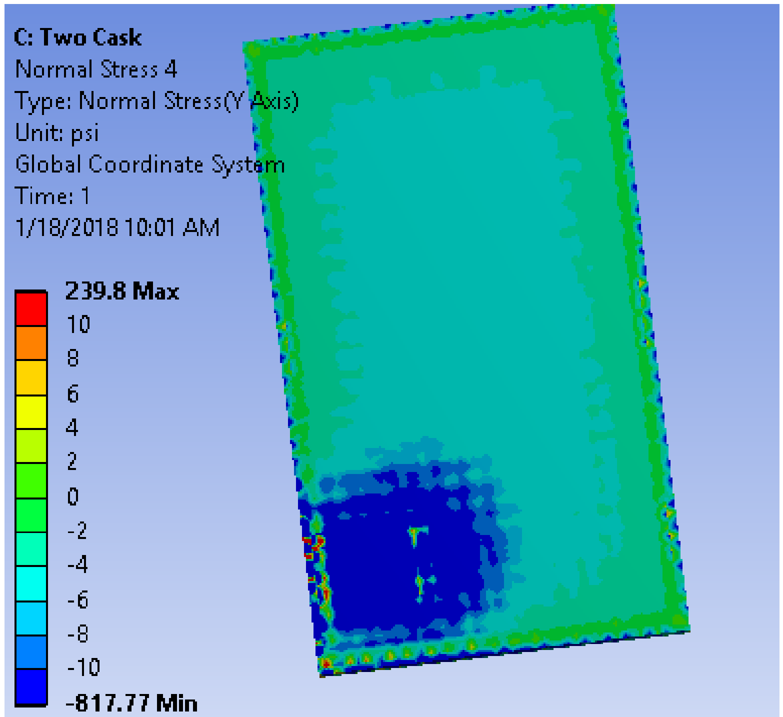


Figure AD-13 Phase 1 two loaded cask system dynamic case – Normal Stress in Y-direction

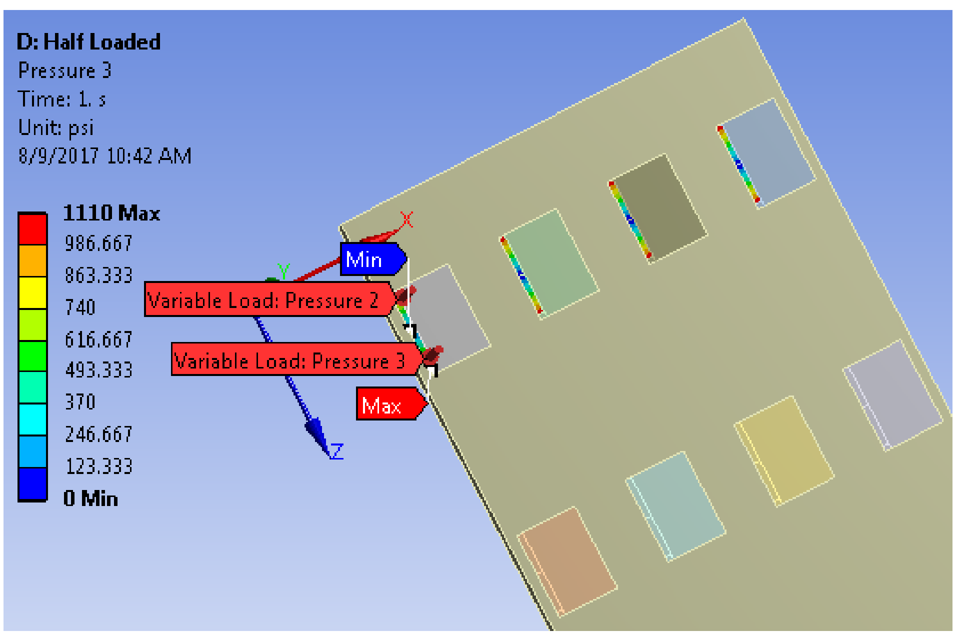


Figure AD-14 Phase 1 half loaded cask system dynamic load case – Variable Pressure Load

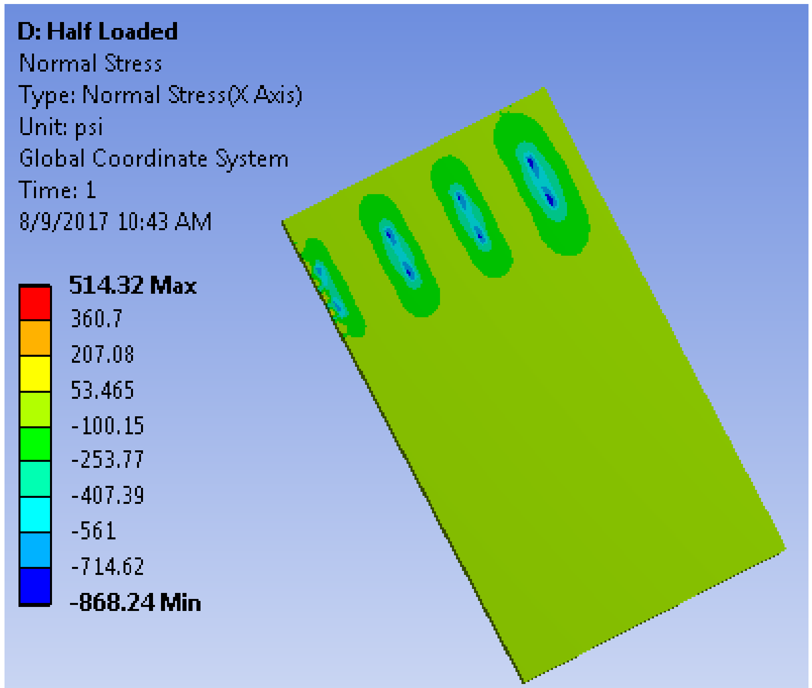
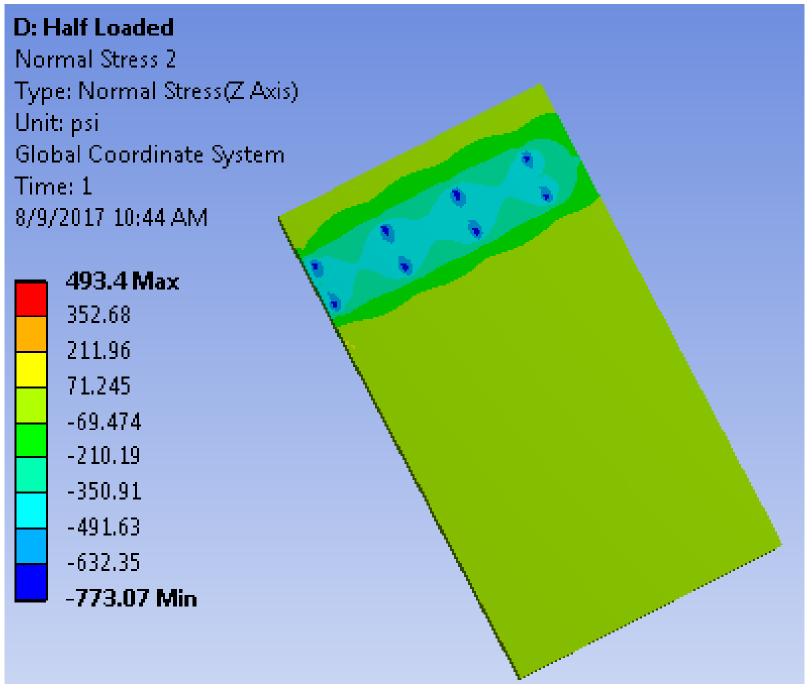


Figure AD-15 Phase 1 half loaded cask system dynamic load case – Normal Stress in X-direction



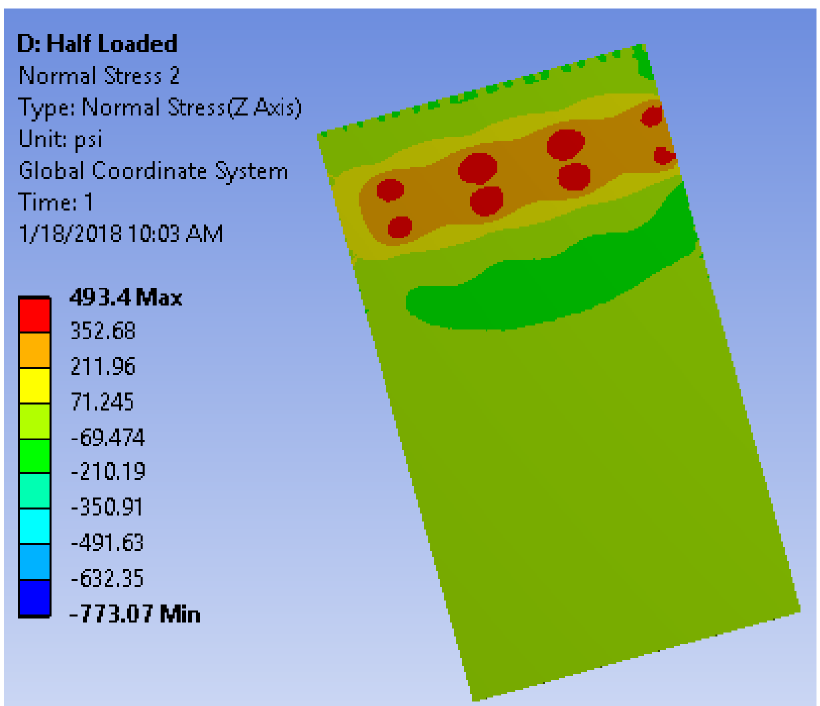


Figure AD-16 Phase 1 half loaded cask system dynamic load case – Normal Stress in Z-direction

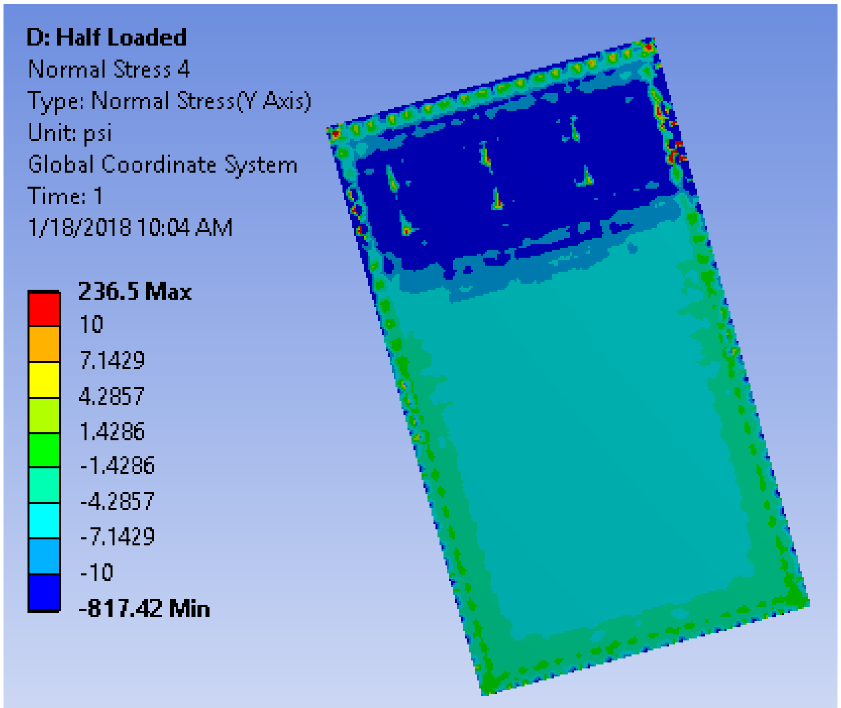


Figure AD-17 Phase 1 half loaded cask system dynamic load case – Normal Stress in Y-direction

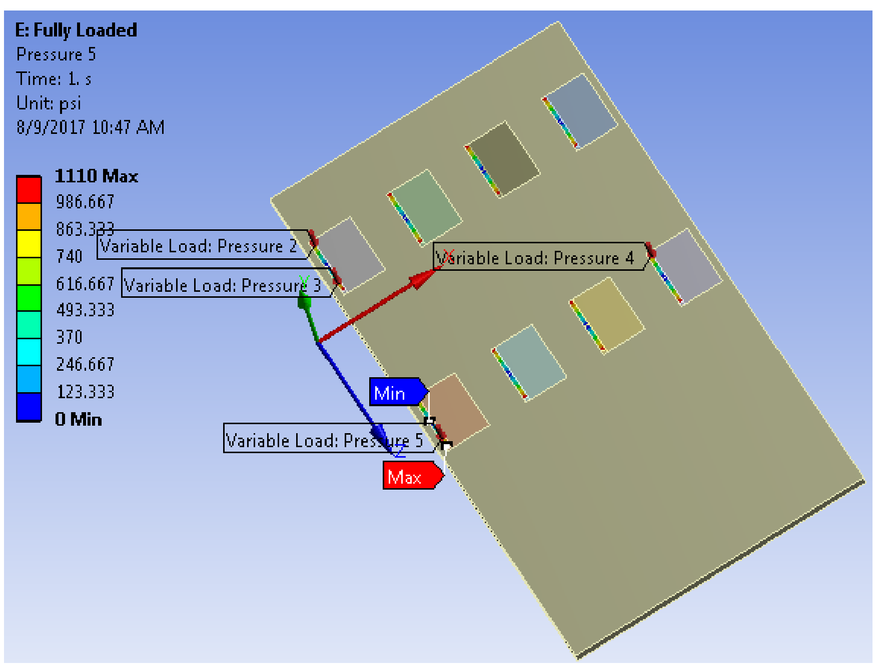
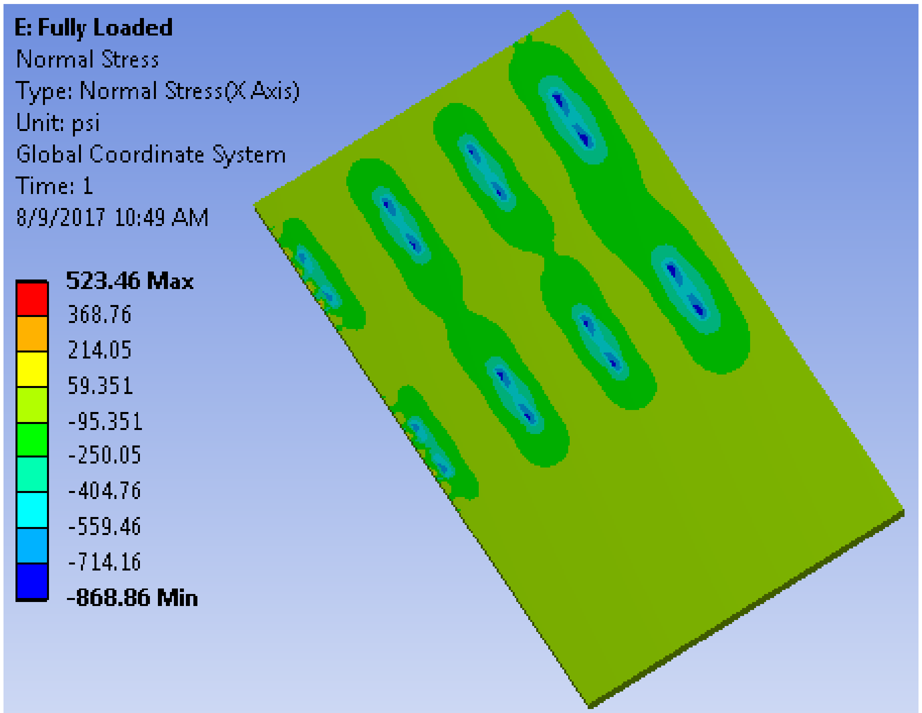


Figure AD-18 Phase 1 full loaded cask system dynamic case – Variable Pressure Load



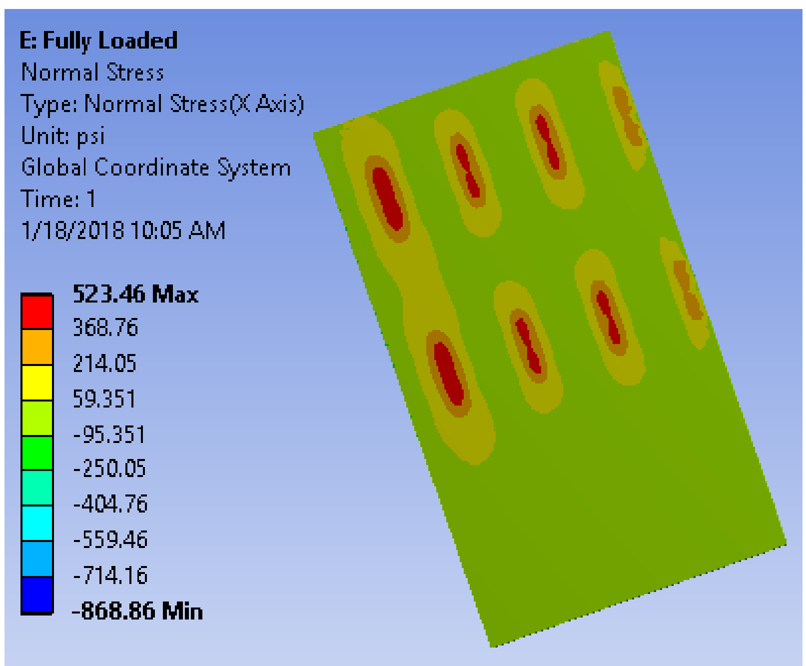
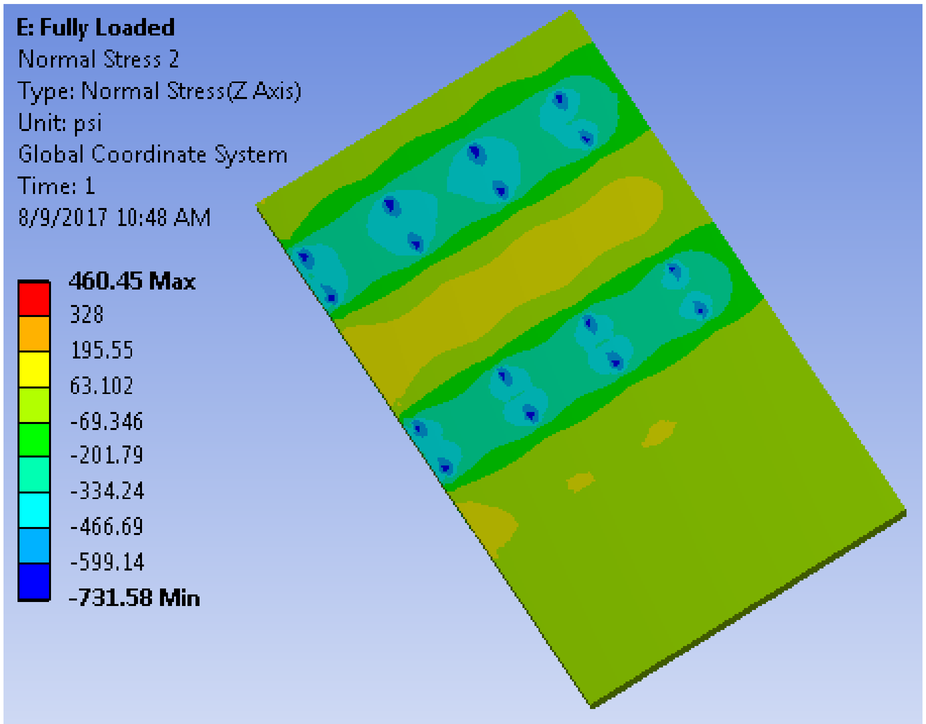


Figure AD-19 Phase 1 full loaded cask system dynamic case – Normal Stress in X-direction



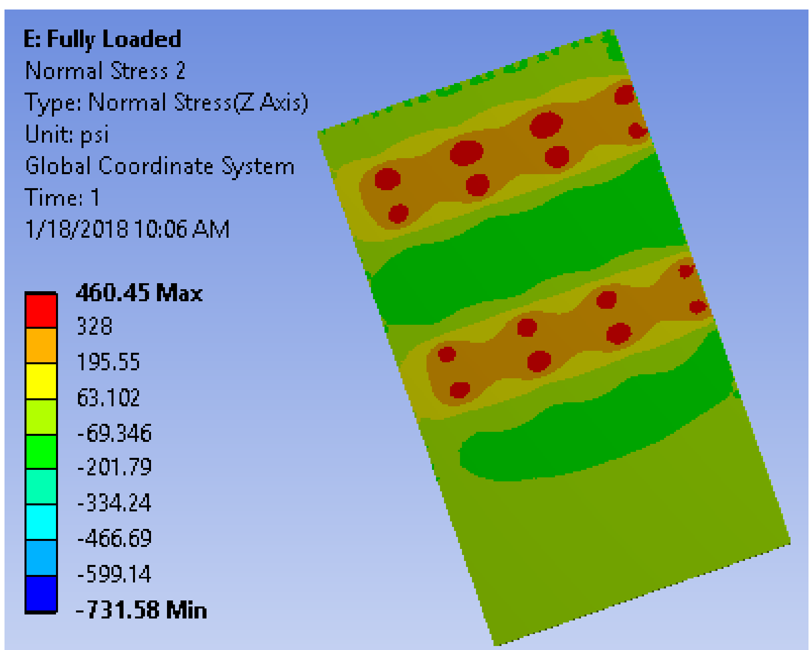


Figure AD-20 Phase 1 full loaded cask system dynamic case – Normal Stress in Z-direction

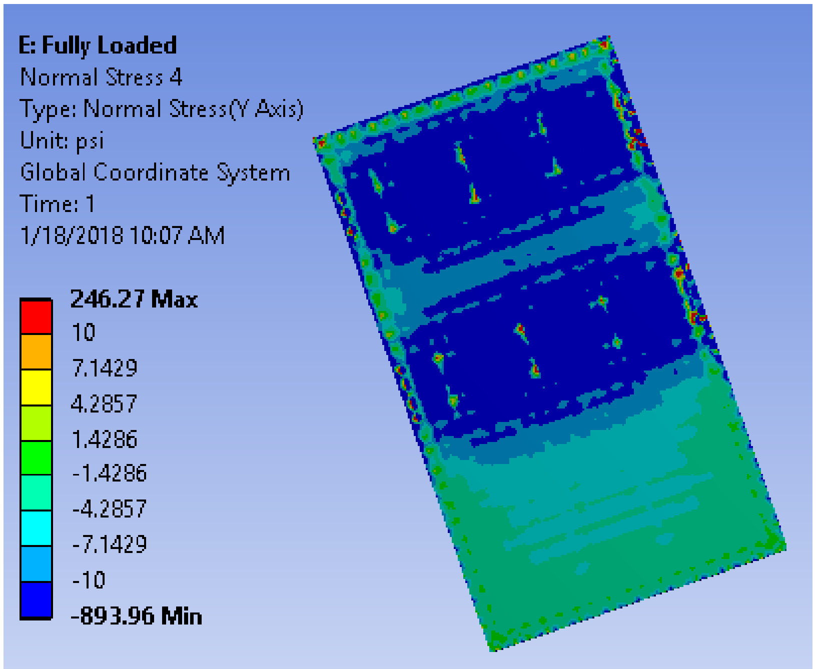


Figure AD-21 Phase 1 full loaded cask system dynamic case – Normal Stress in Y-direction

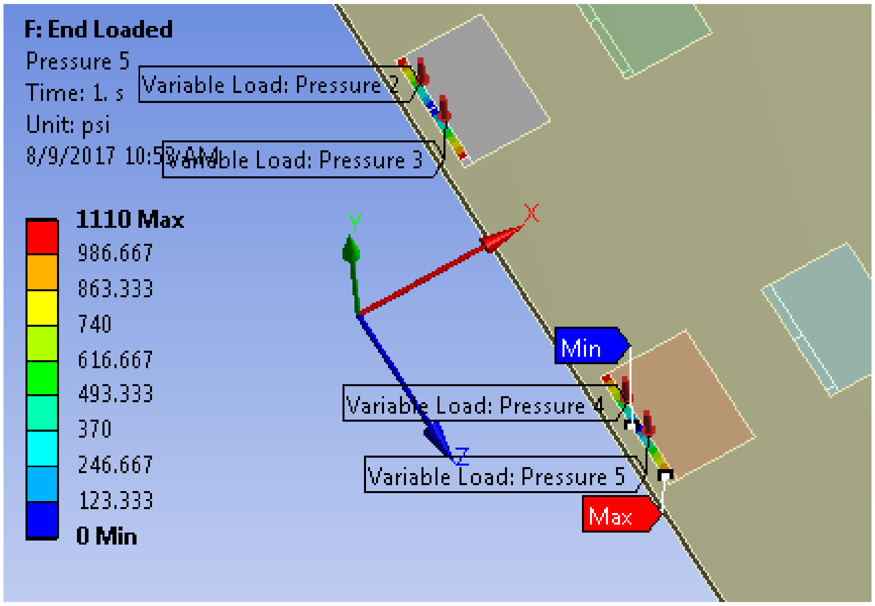
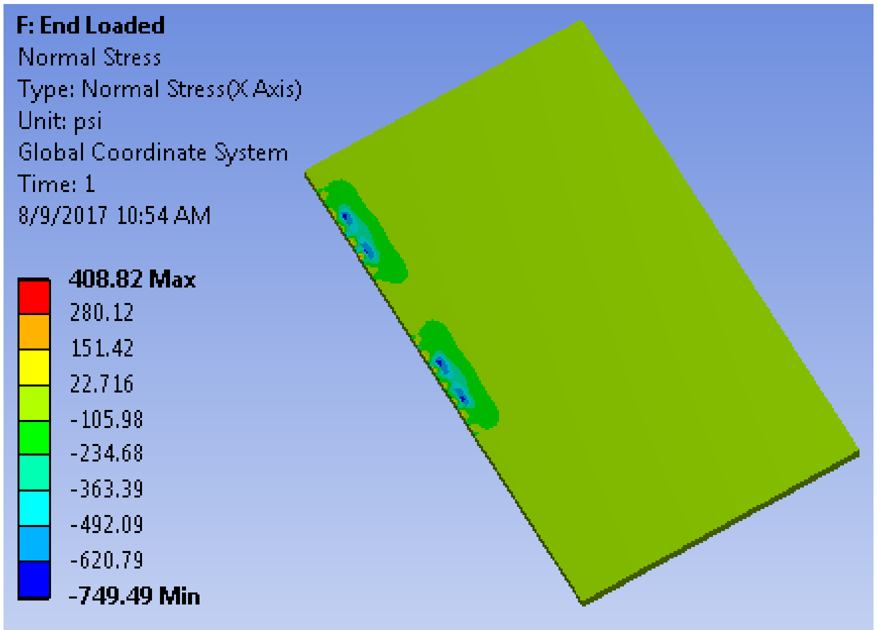


Figure AD-22 Phase 1 end loaded cask system dynamic case – Variable Pressure Load



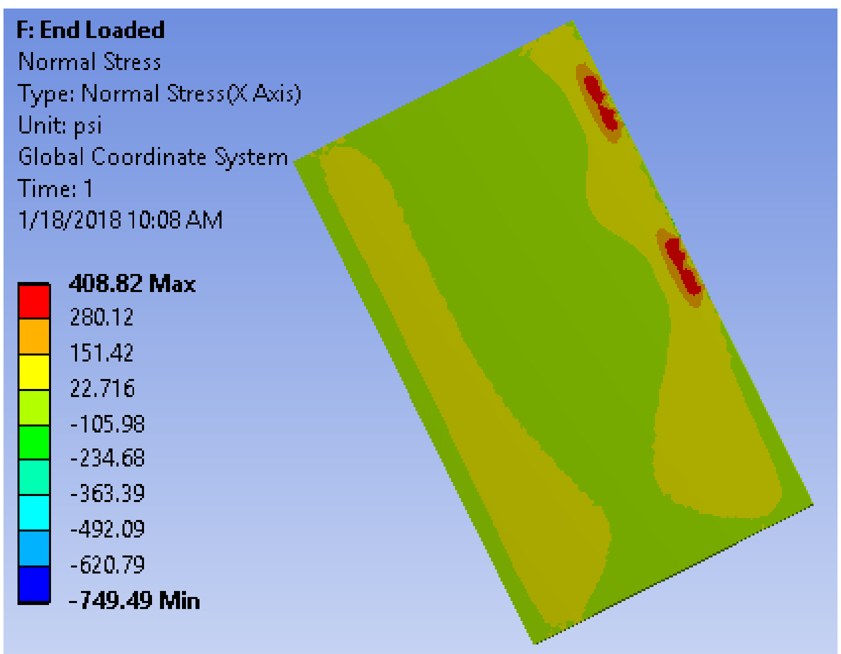
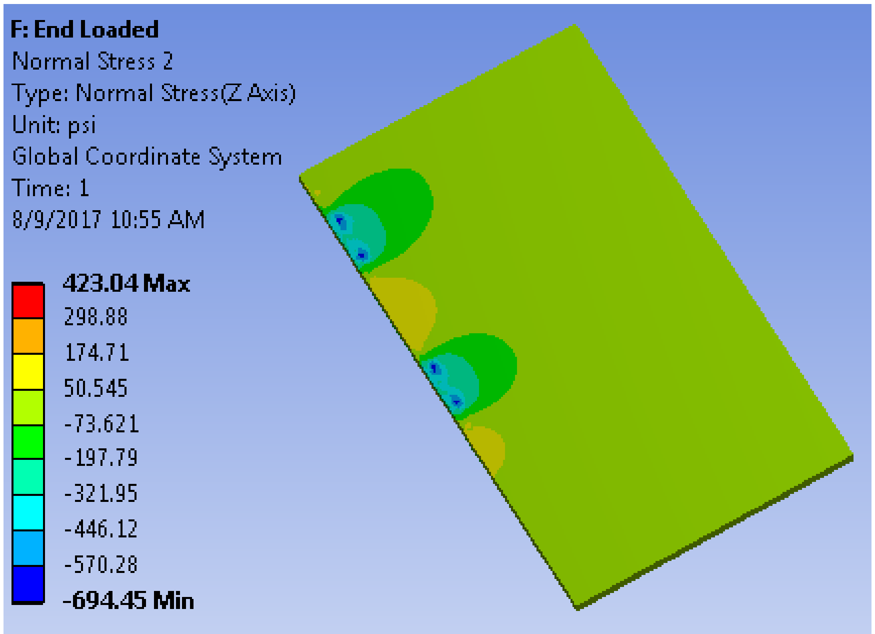


Figure AD-23 Phase 1 end loaded cask system dynamic case – Normal Stress in X-direction



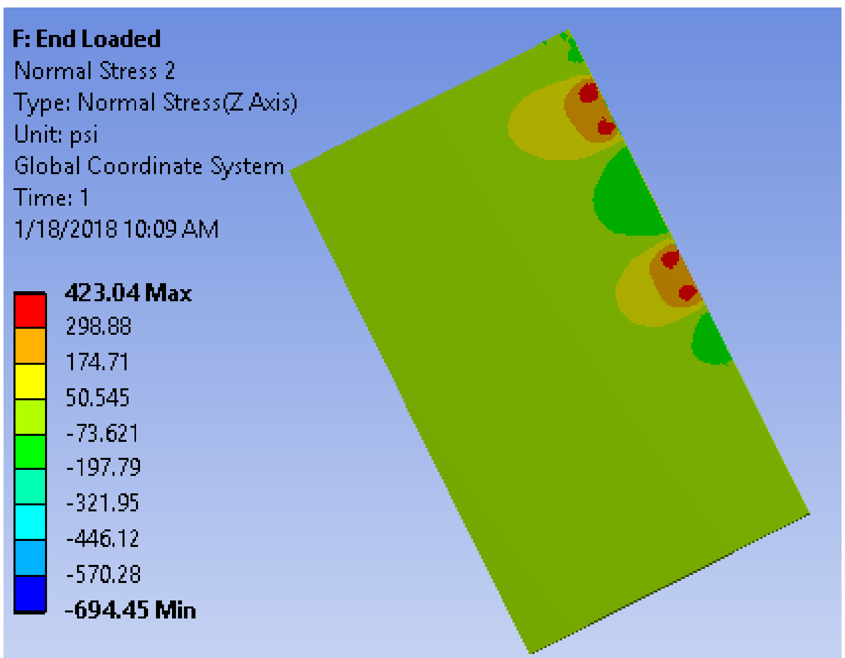


Figure AD-24 Phase 1 end loaded cask system dynamic case – Normal Stress in Z-direction

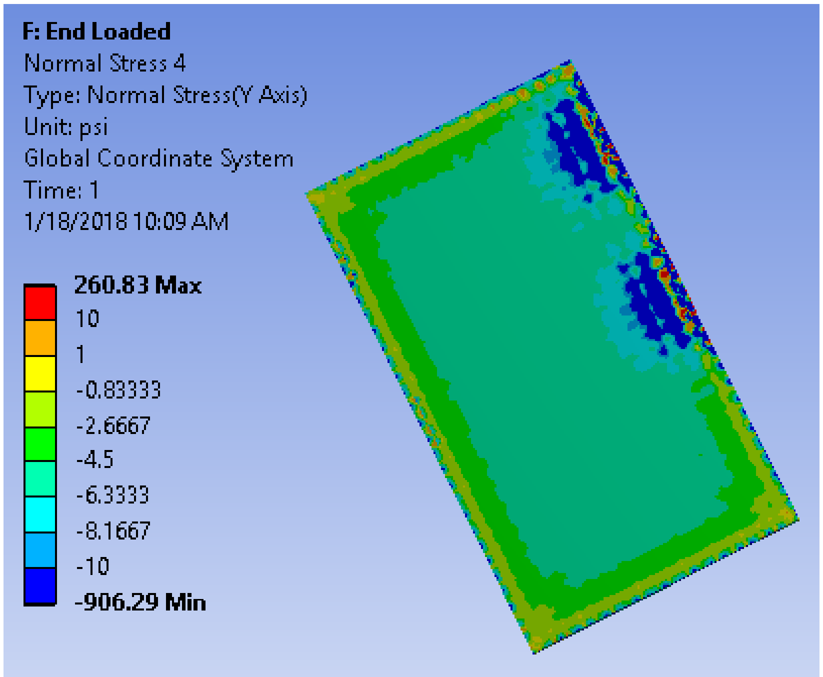


Figure AD-25 Phase 1 end loaded cask system dynamic case – Normal Stress in Y-direction

Phase 2 Dynamic Loading

Unlike Phase 1 results above, only the bounding case results for Phase 2 are presented in this appendix. The results for all other cases are stored on the Holtec network.

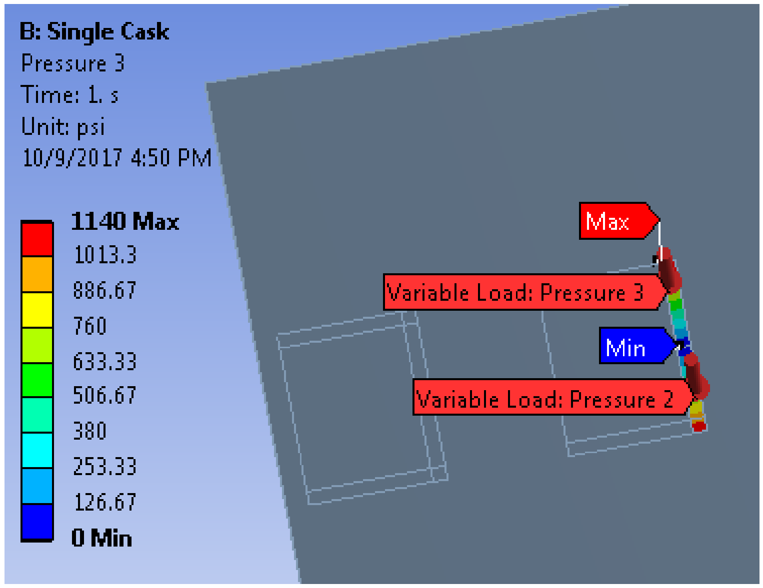
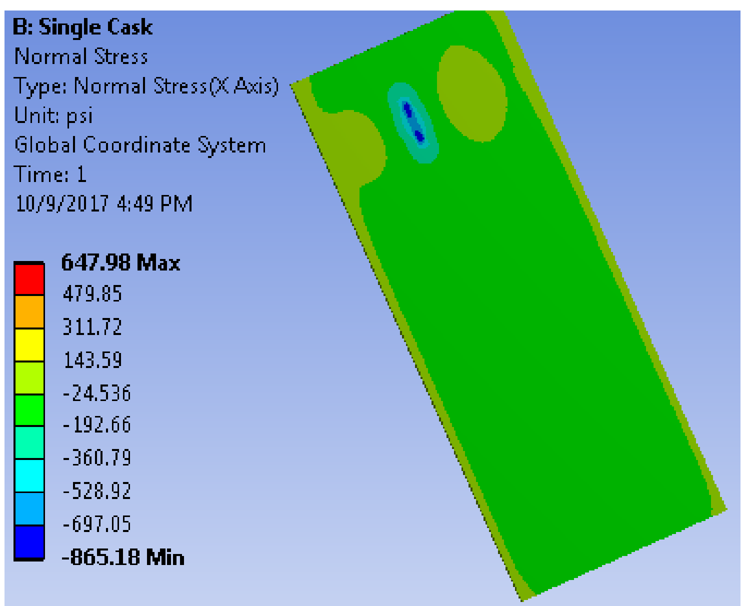


Figure AD-26 Phase 2 single loaded cask system dynamic case – Variable Pressure Load



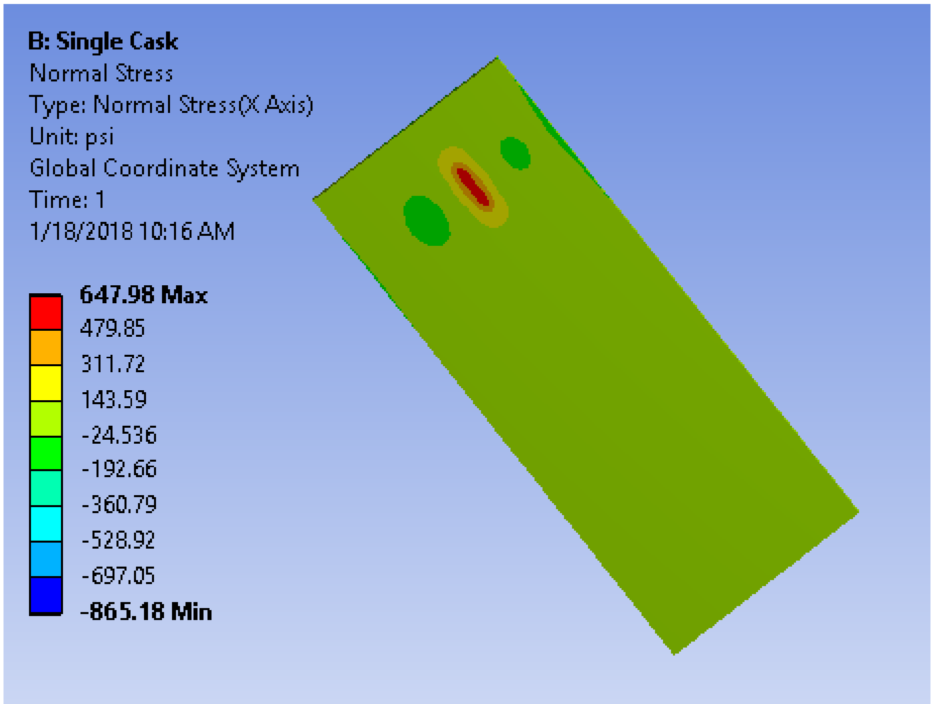
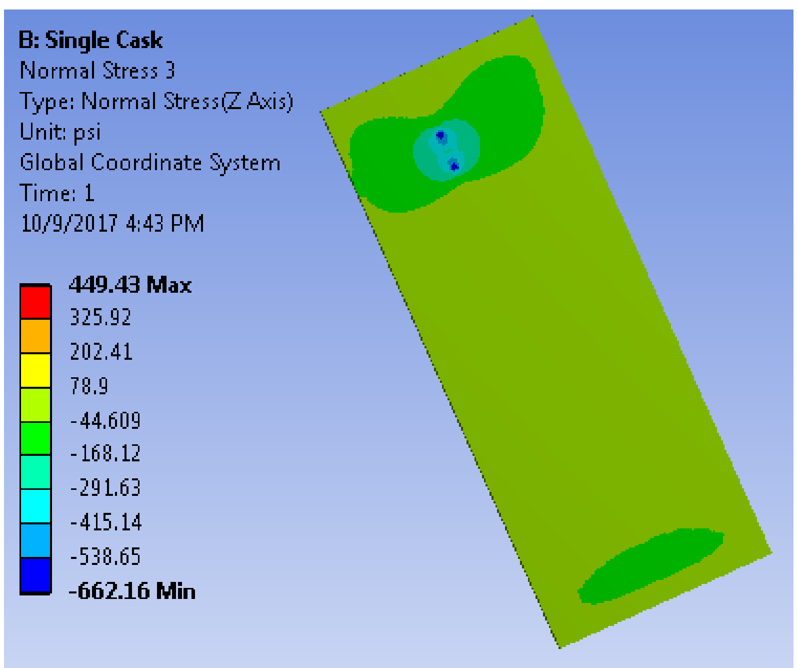


Figure AD-27 Phase 2 single loaded cask system dynamic case – Normal Stress in X-direction



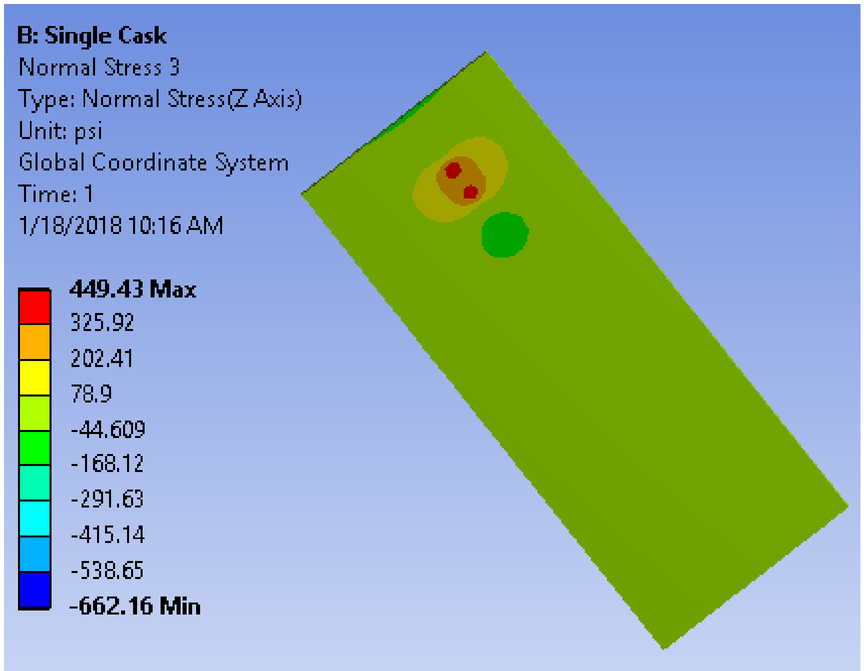


Figure AD-28 Phase 2 single loaded cask system dynamic case – Normal Stress in Z-direction

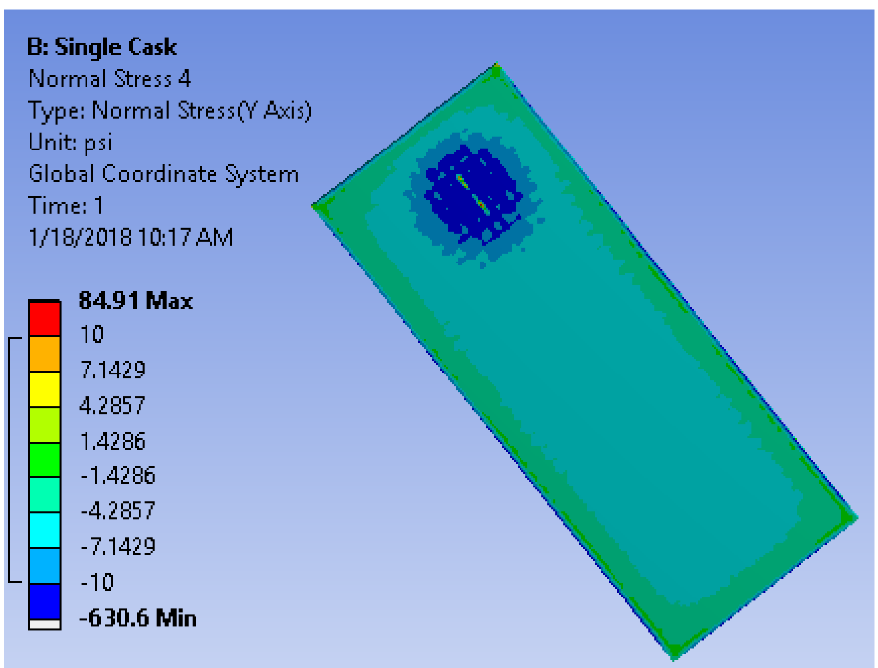


Figure AD-29 Phase 2 single loaded cask system dynamic case – Normal Stress in Y-direction

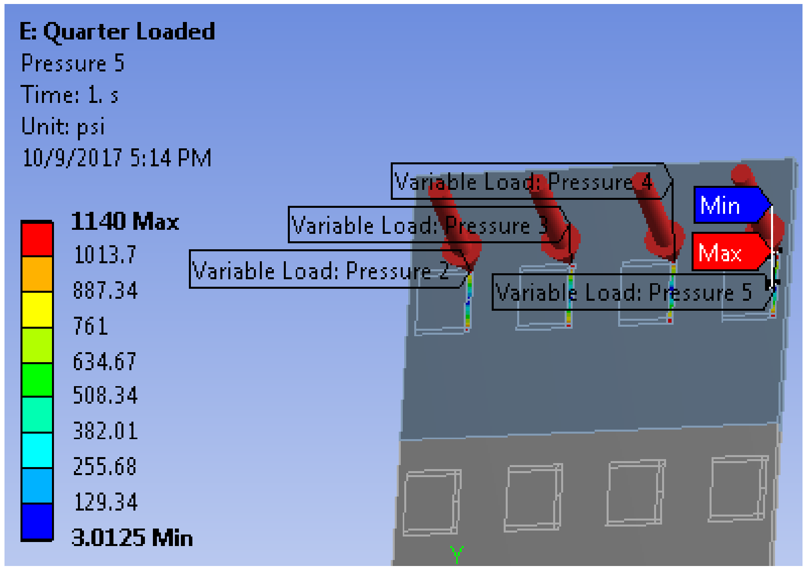
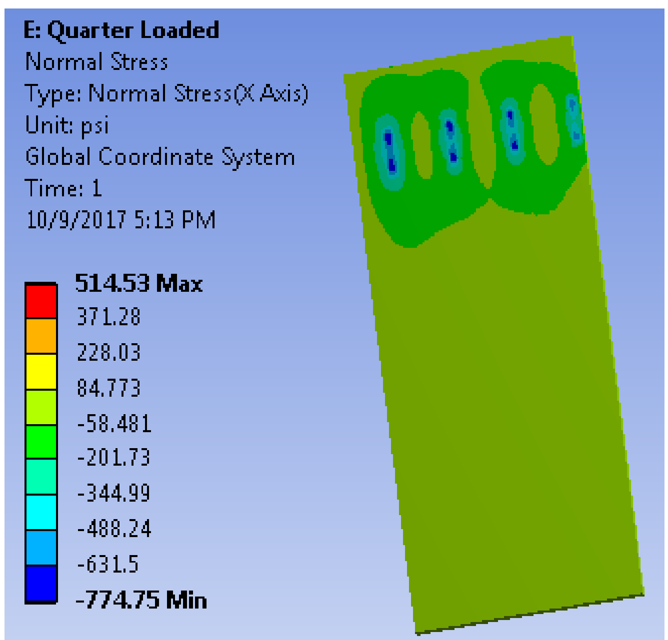


Figure AD-30 Phase 2 quarter loaded cask system dynamic case – Variable Pressure Load



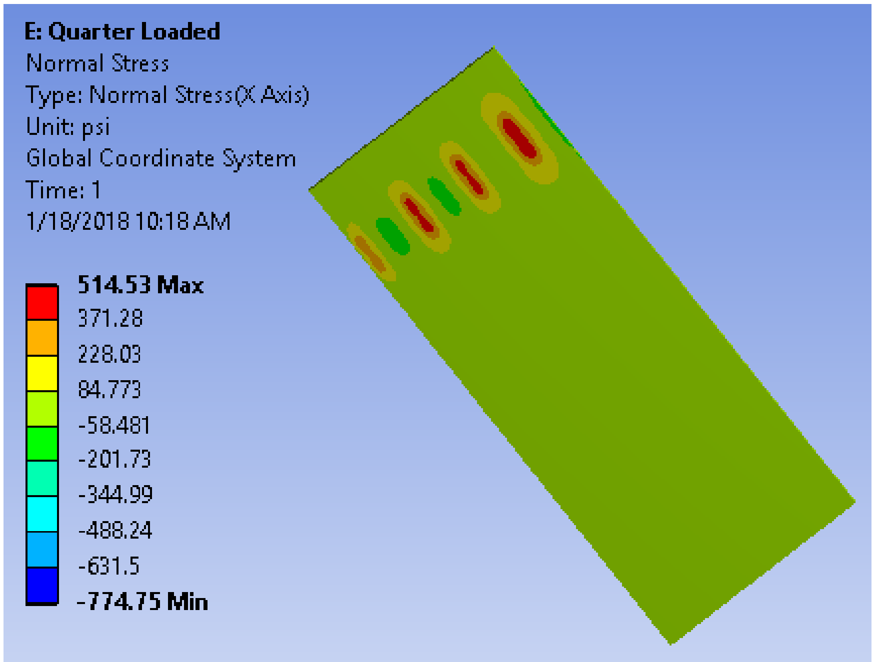
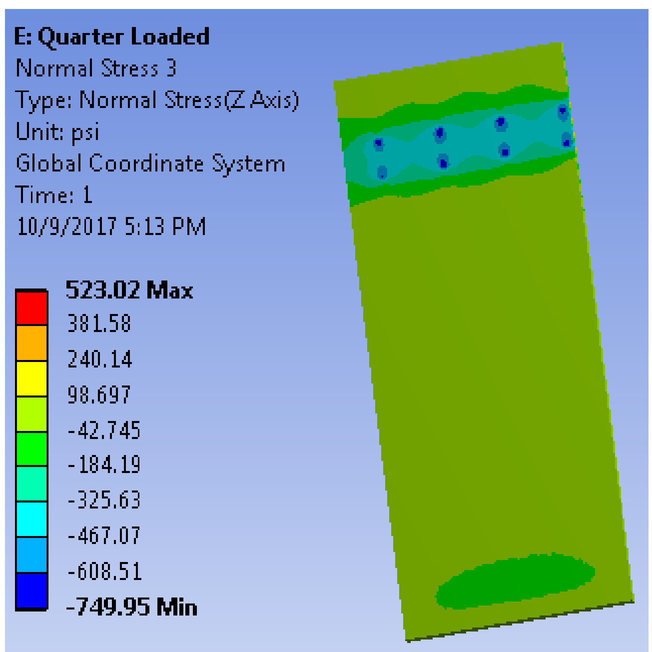


Figure AD-31 Phase 2 quarter loaded cask system dynamic case – Normal Stress in X-direction



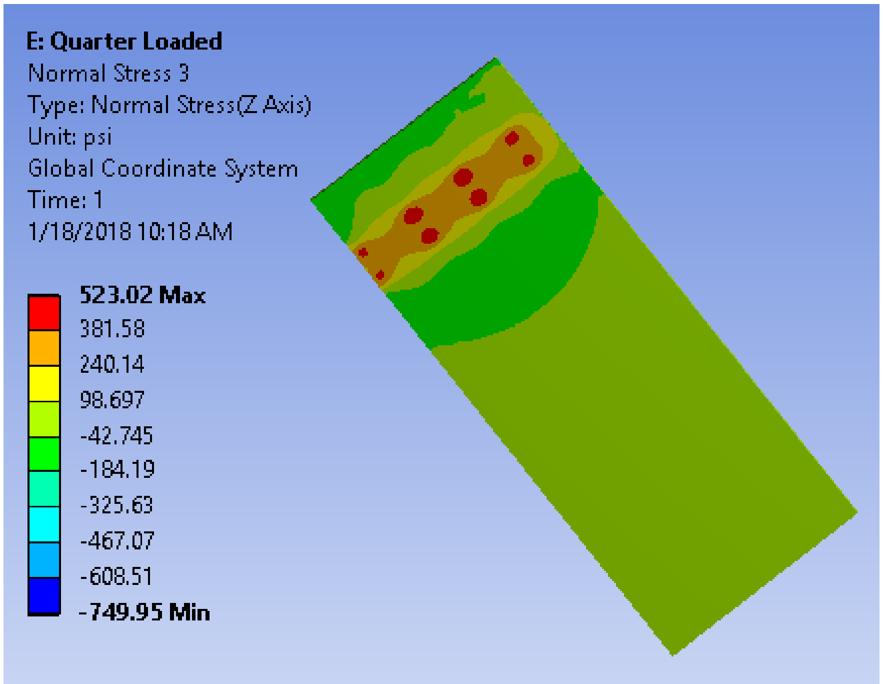


Figure AD-32 Phase 2 quarter loaded cask system dynamic case – Normal Stress in Z-direction

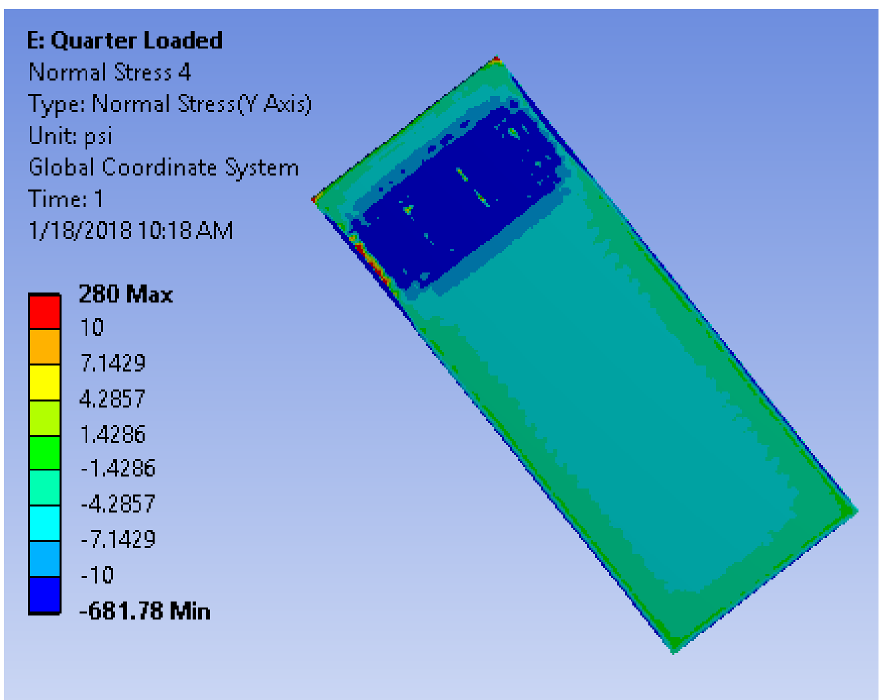


Figure AD-33 Phase 2 quarter loaded cask system dynamic case – Normal Stress in Y-direction

Phase 1 Static Loading

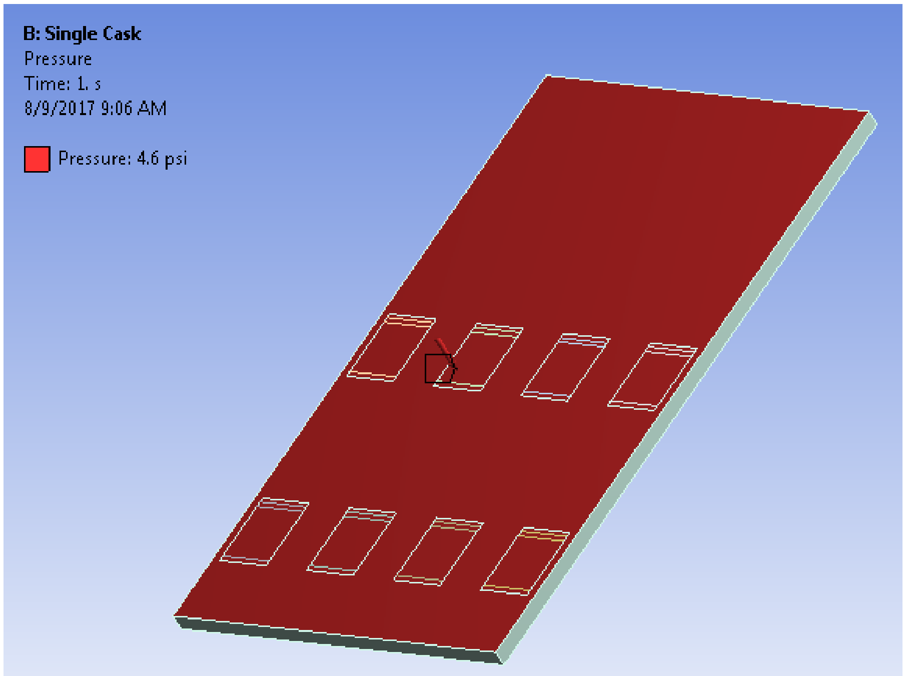


Figure AS-1 Factored dead pressure load from the Phase 1 ISFSI pad for all Static load cases

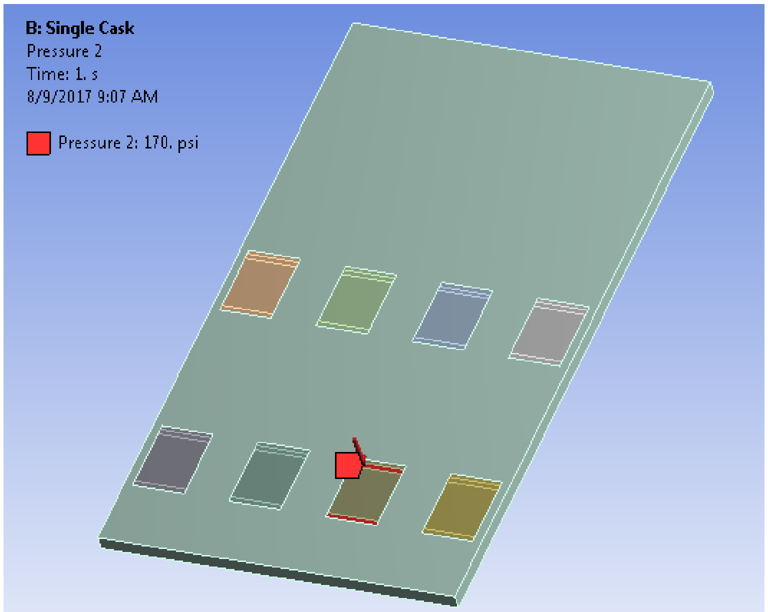
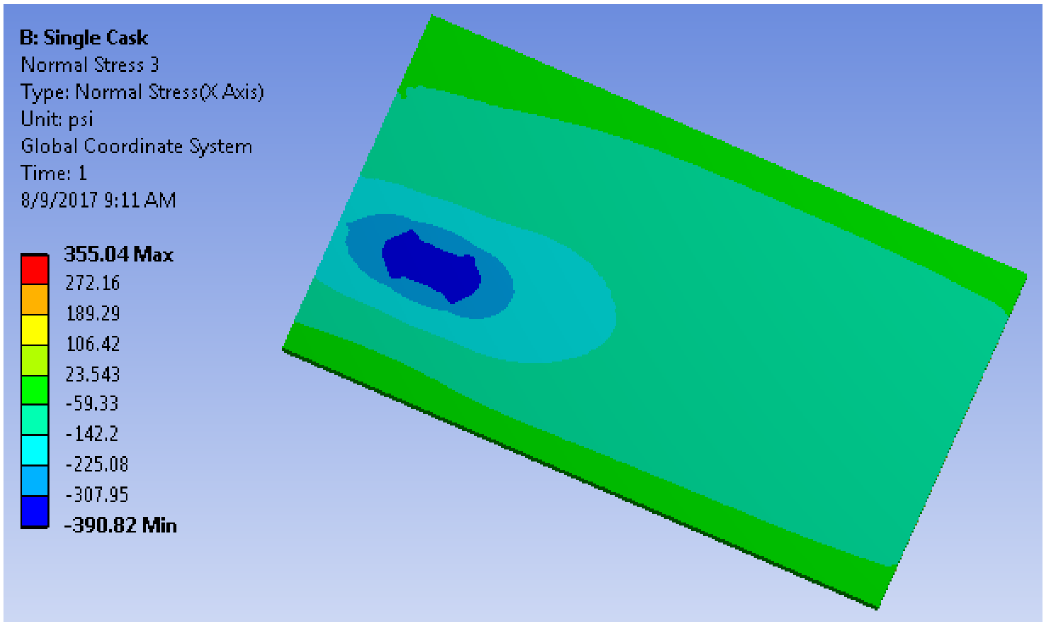


Figure AS-2 Phase 1 single loaded cask system static case – Factored live pressure load



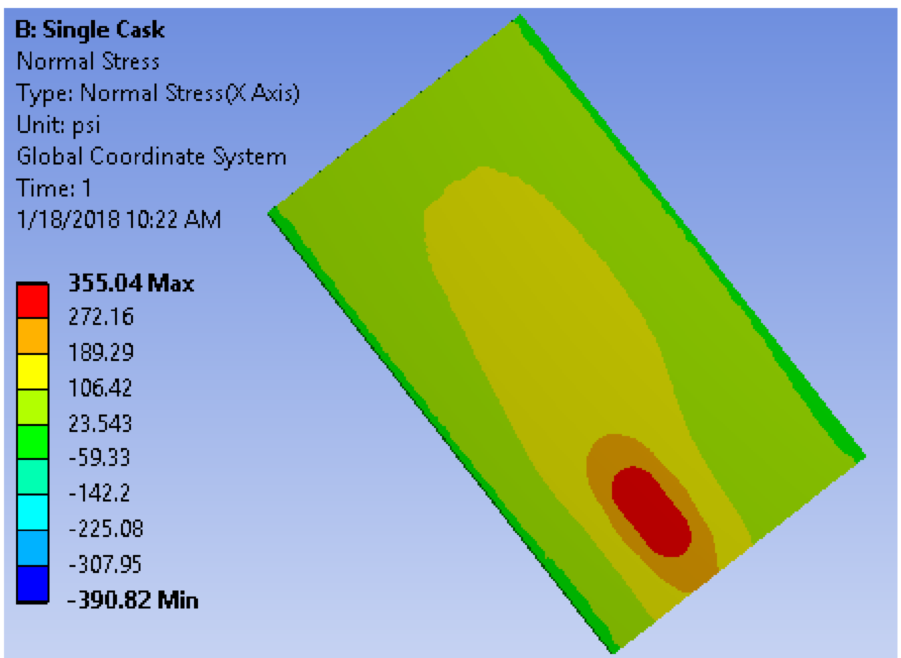
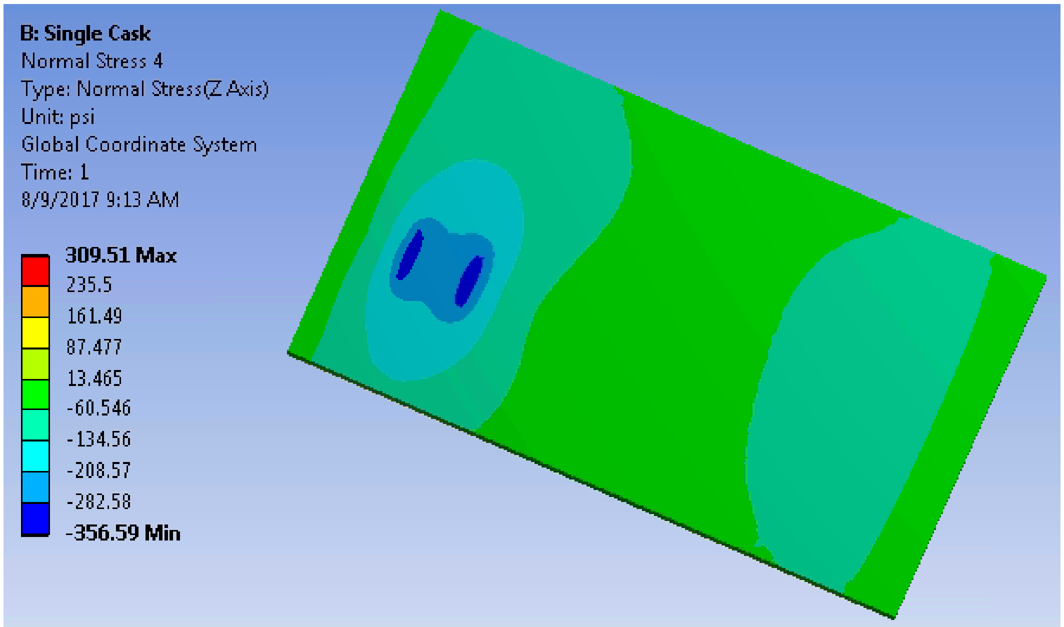


Figure AS-3 Phase 1 single loaded cask system static case – Normal Stress in X-direction



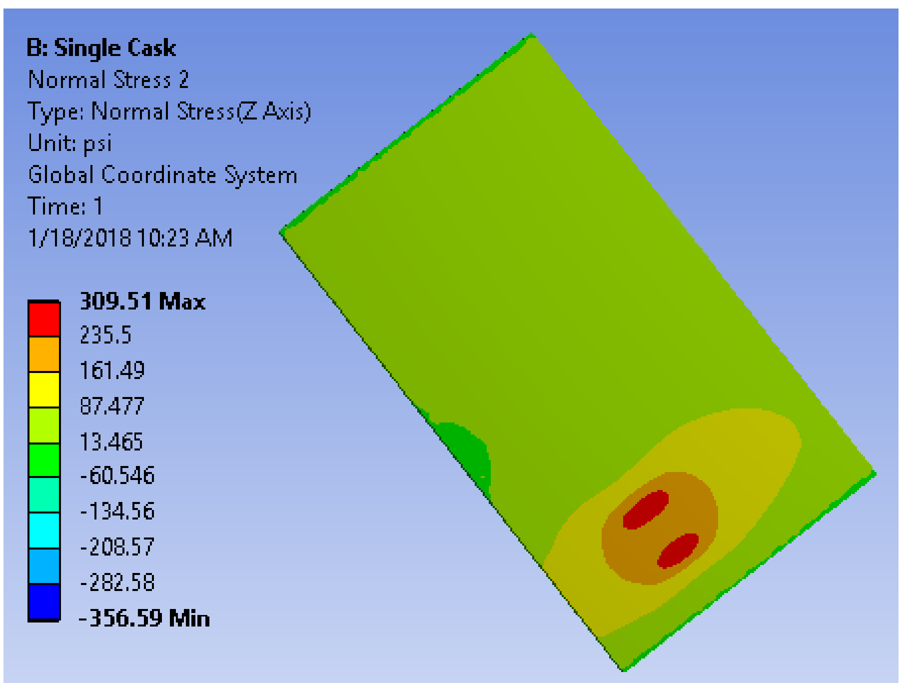


Figure AS-4 Phase 1 single loaded cask system static case – Normal Stress in Z-direction

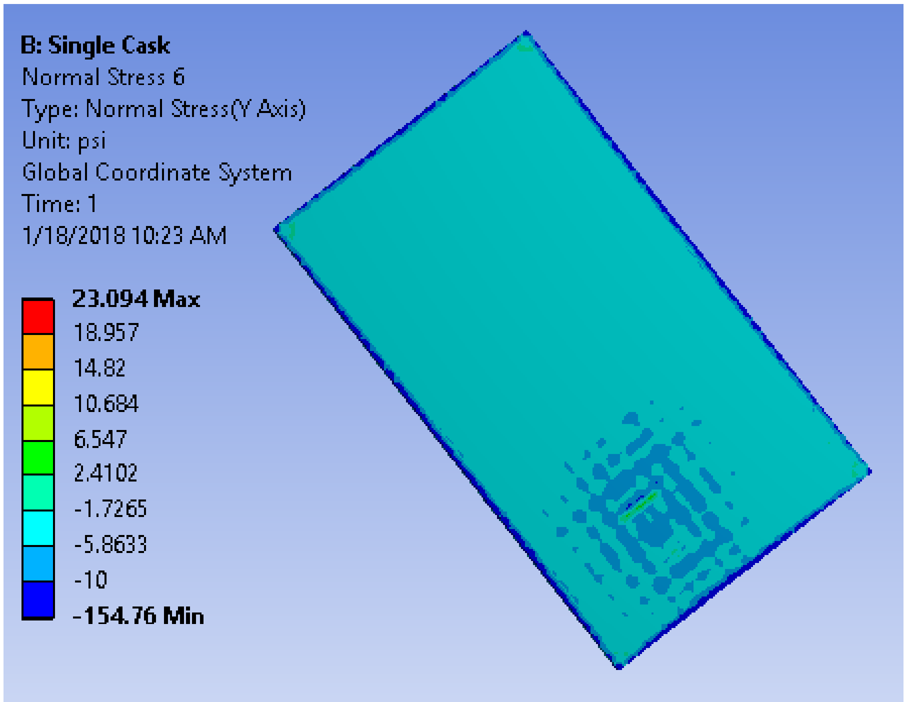


Figure AS-5 Phase 1 single loaded cask system static case – Normal Stress in Y-direction

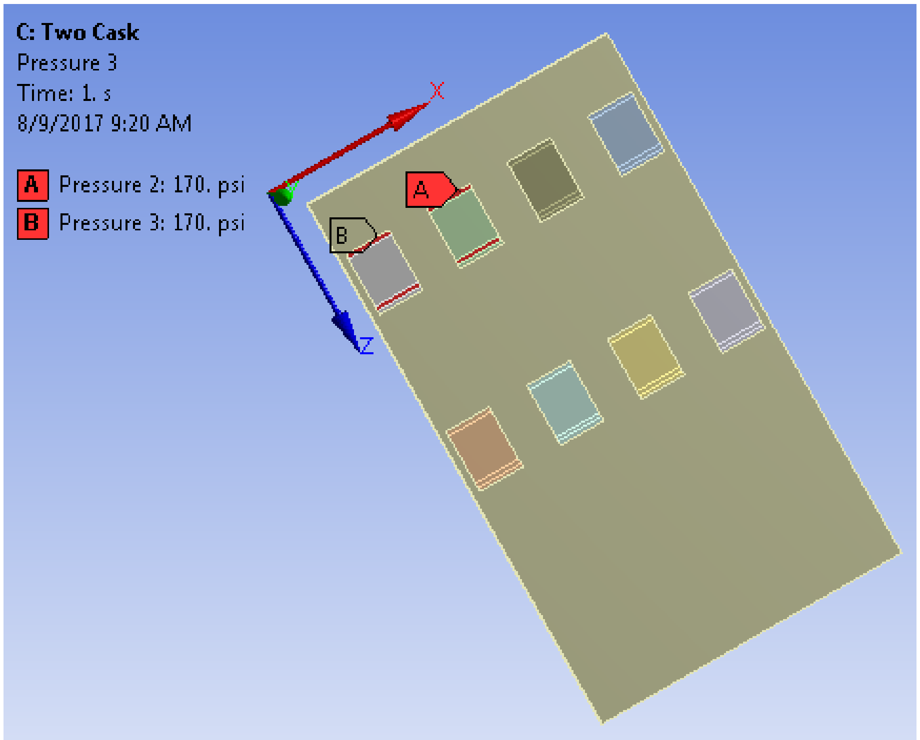
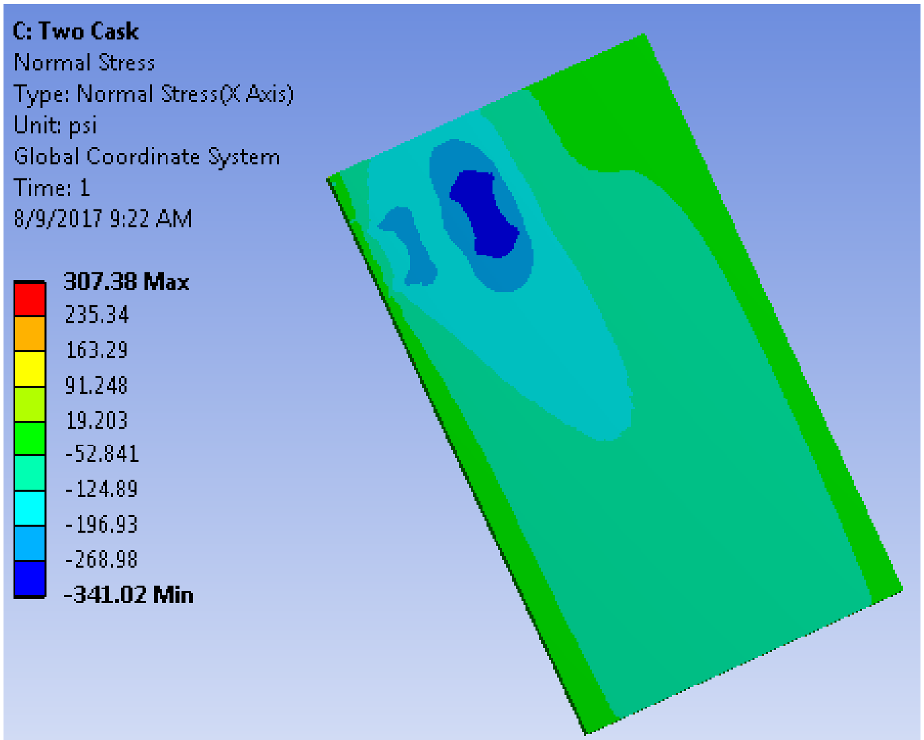


Figure AS-6 Phase 1 two loaded cask system static case – Factored live pressure load



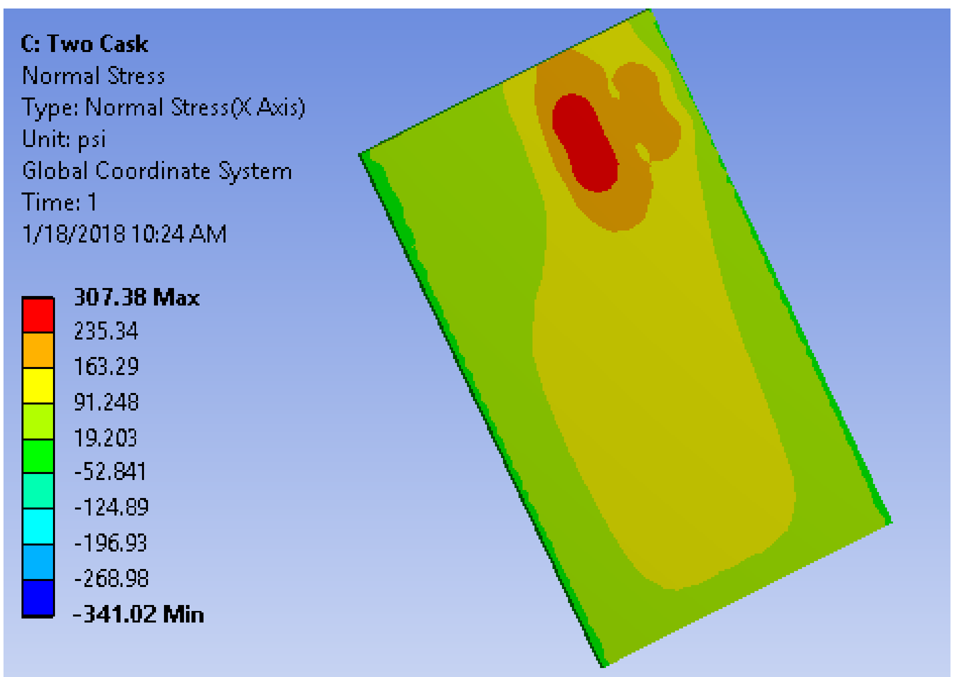


Figure AS-7 Phase 1 two loaded cask system static case – Normal Stress in X-direction

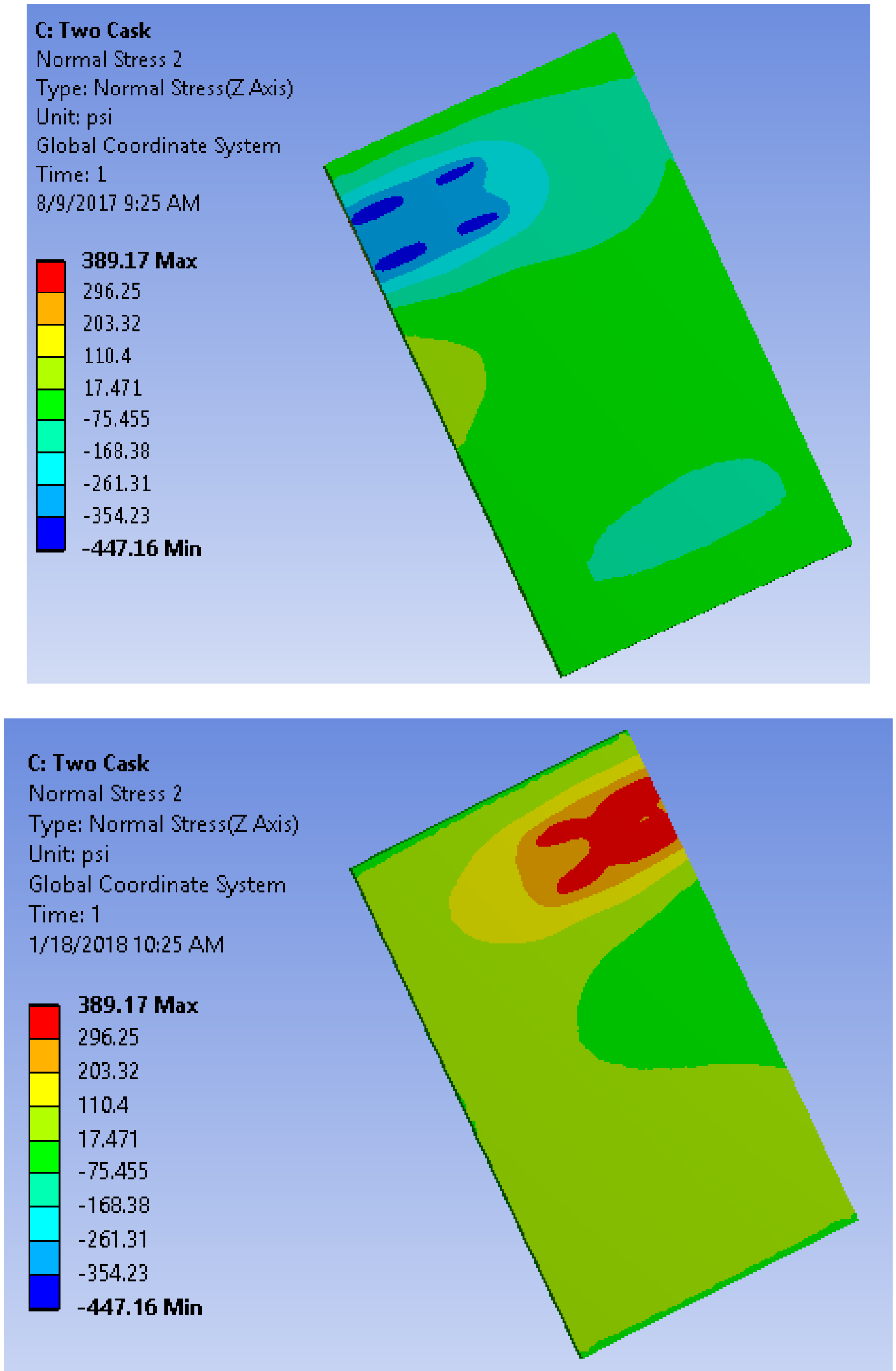


Figure AS-8 Phase 1 two loaded cask system static case – Normal Stress in Z-direction

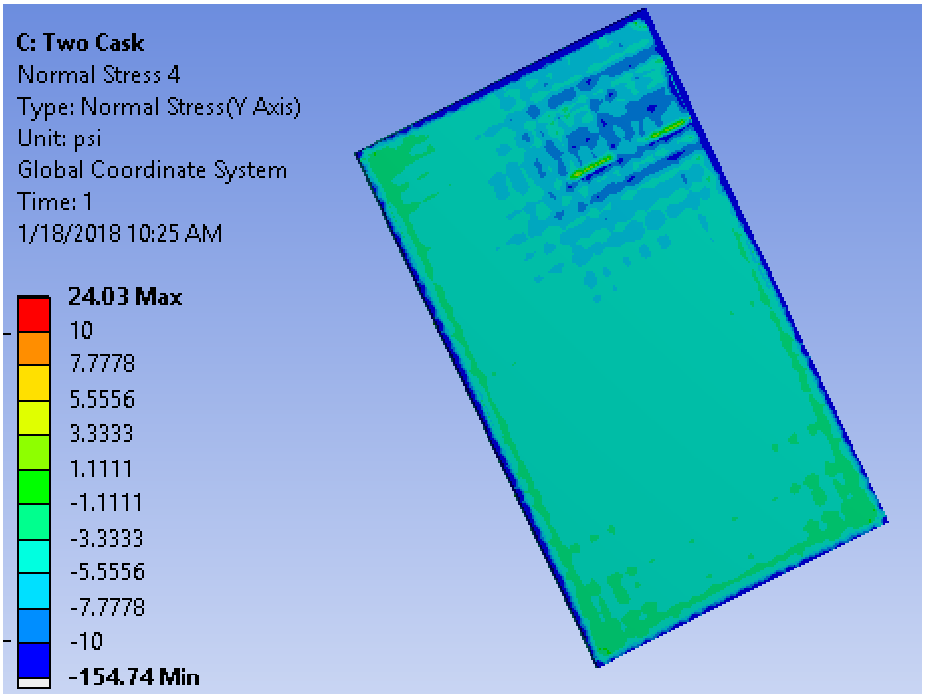


Figure AS-9 Phase 1 two loaded cask system static case – Normal Stress in Y-direction

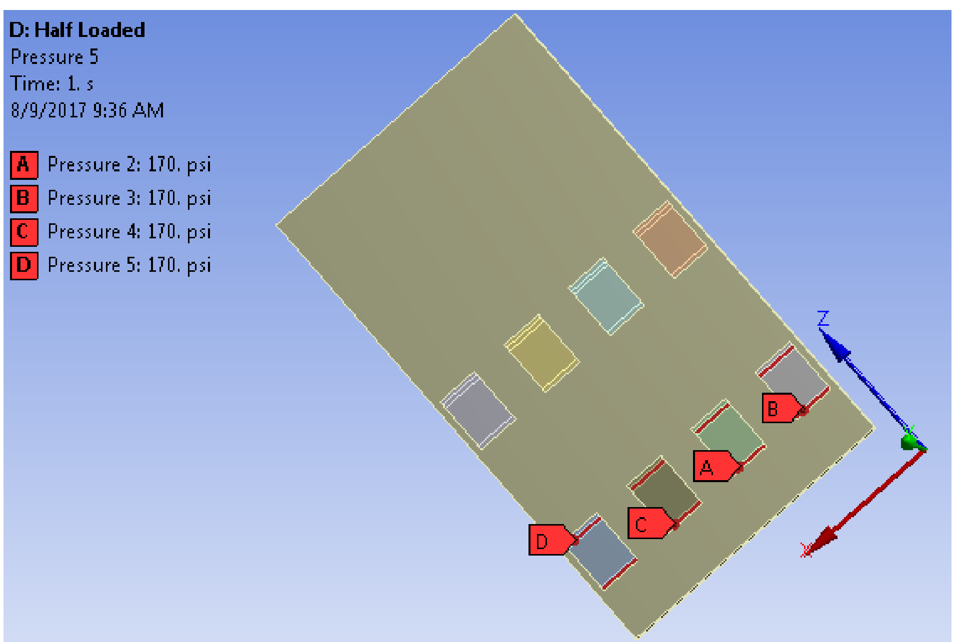
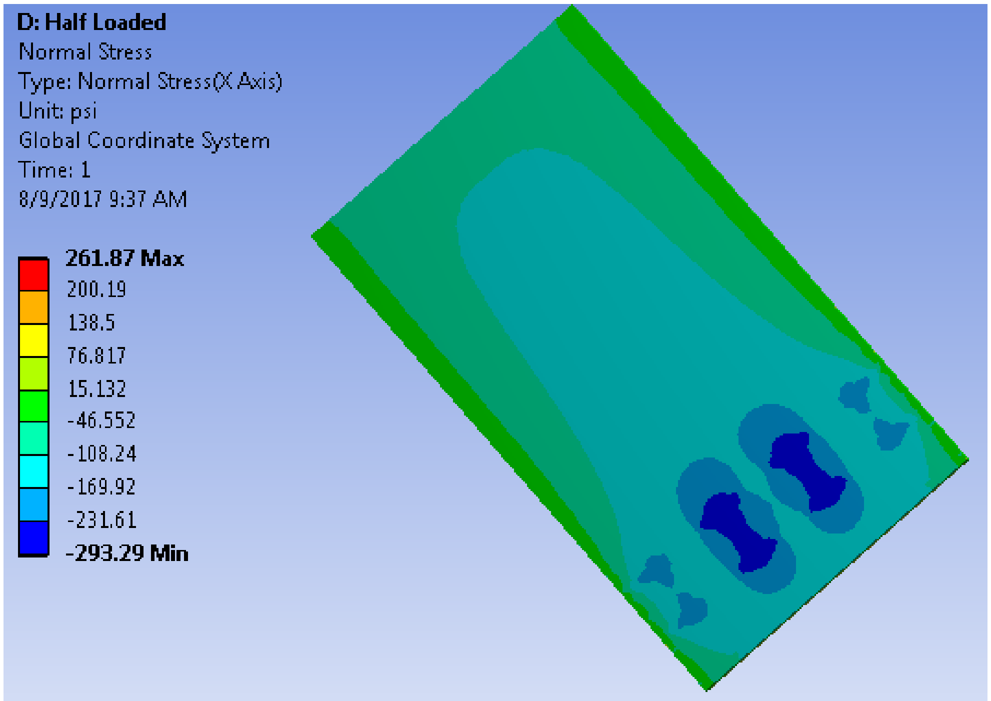


Figure AS-10 Phase 1 half loaded cask system static case – Factored live pressure load



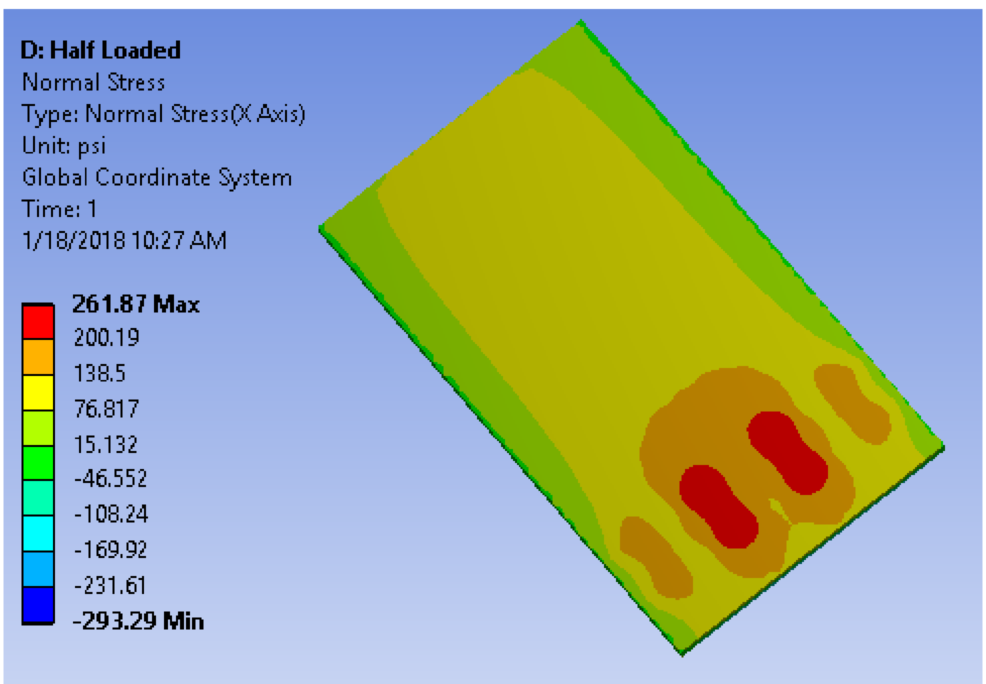
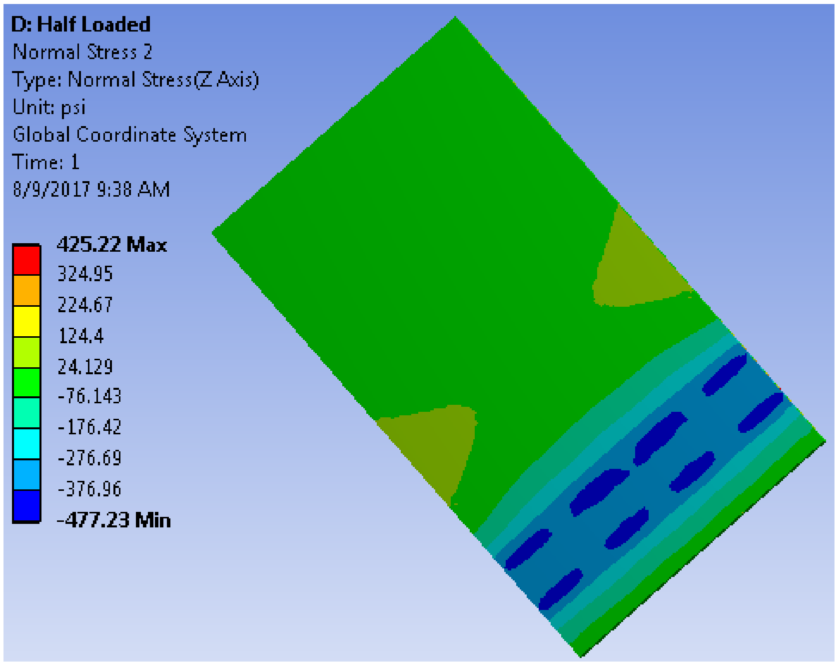


Figure AS-11 Phase 1 half loaded cask system static case – Normal Stress in X-direction



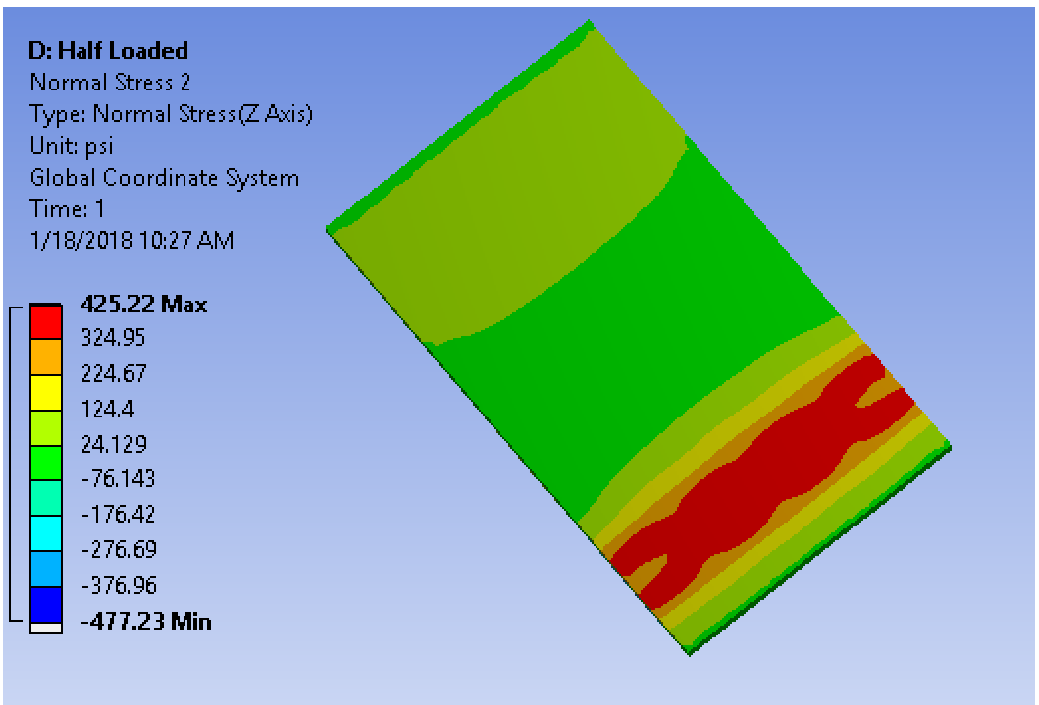


Figure AS-12 Phase 1 half loaded cask system static case – Normal Stress in Z-direction

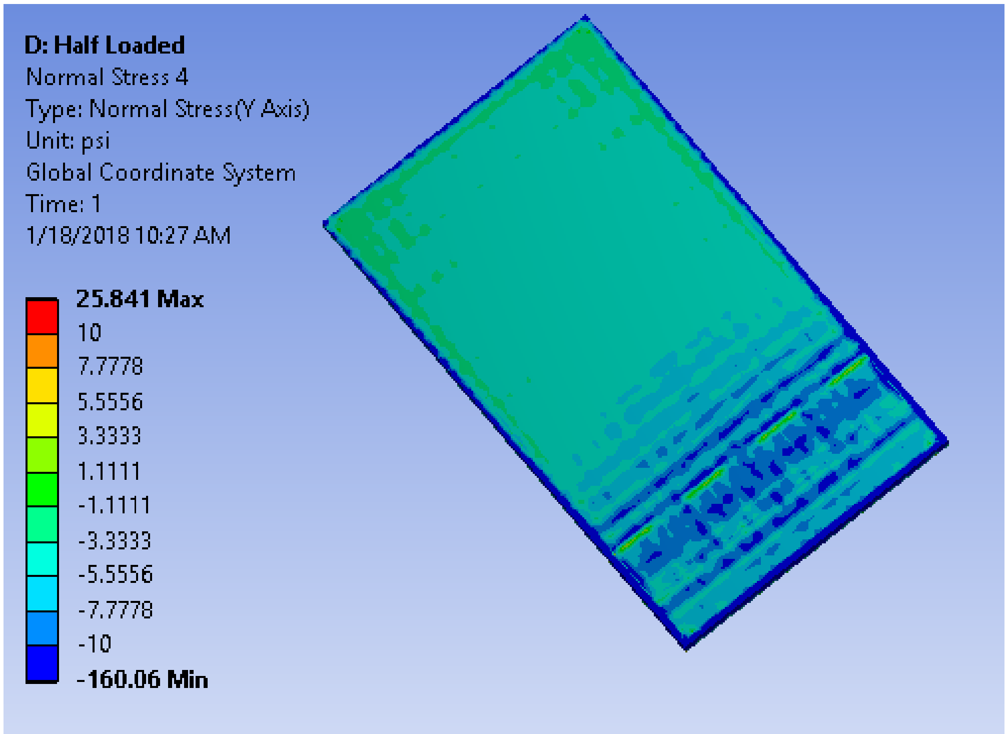


Figure AS-13 Phase 1 half loaded cask system static case – Normal Stress in Y-direction

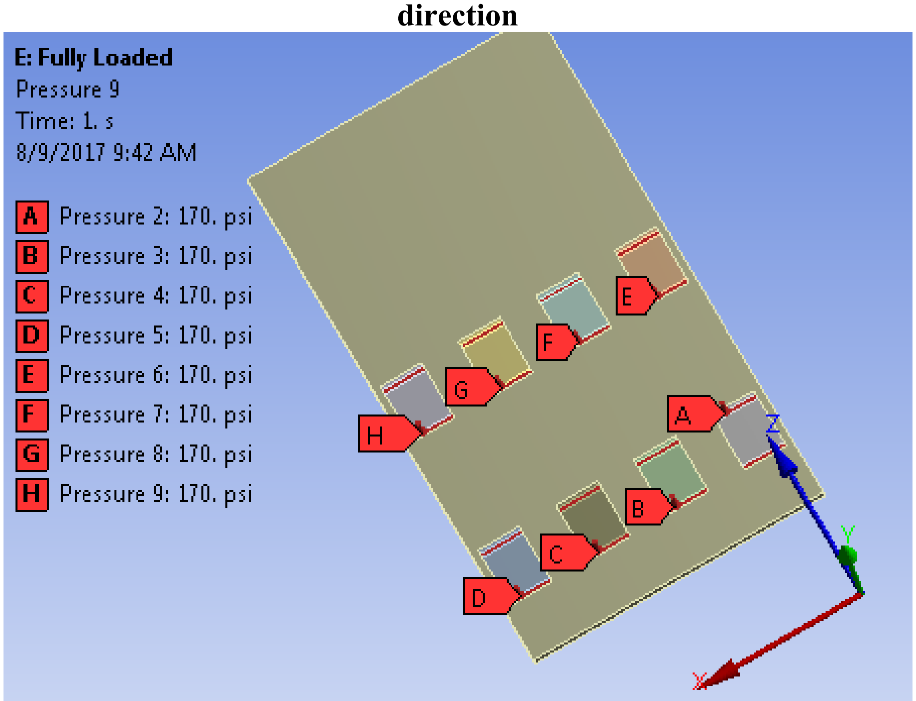
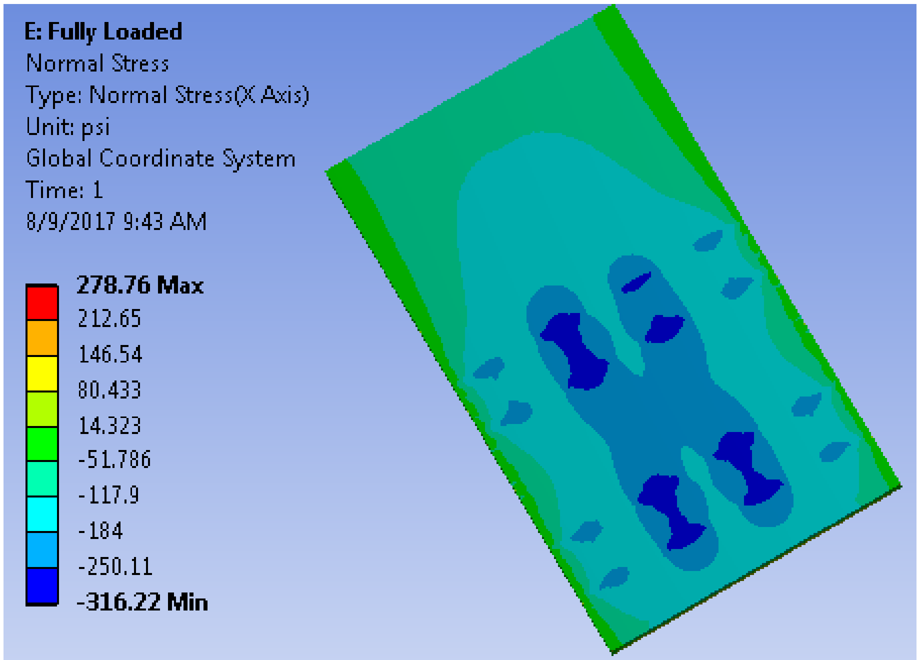


Figure AS-14 Phase 1 full loaded cask system static case – Factored live pressure load



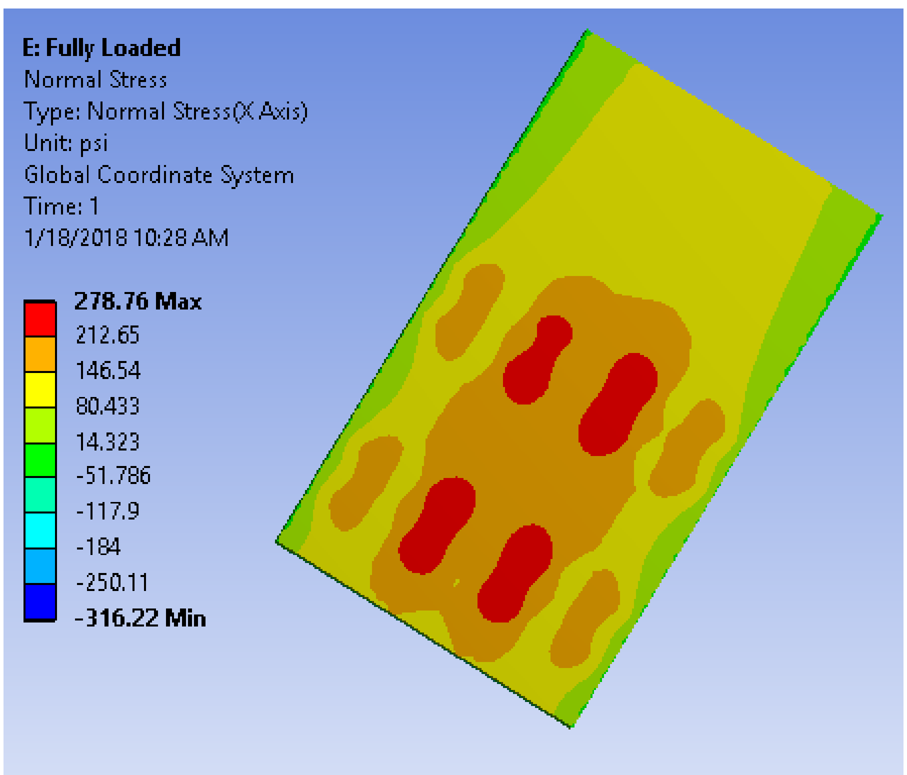
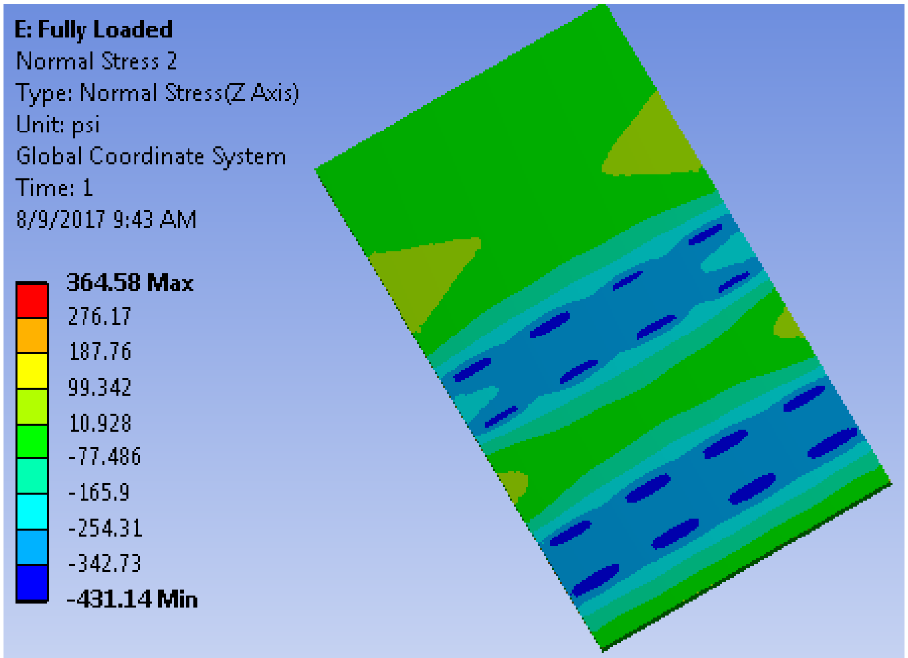


Figure AS-15 Phase 1 full loaded cask system static case – Normal Stress in X-direction



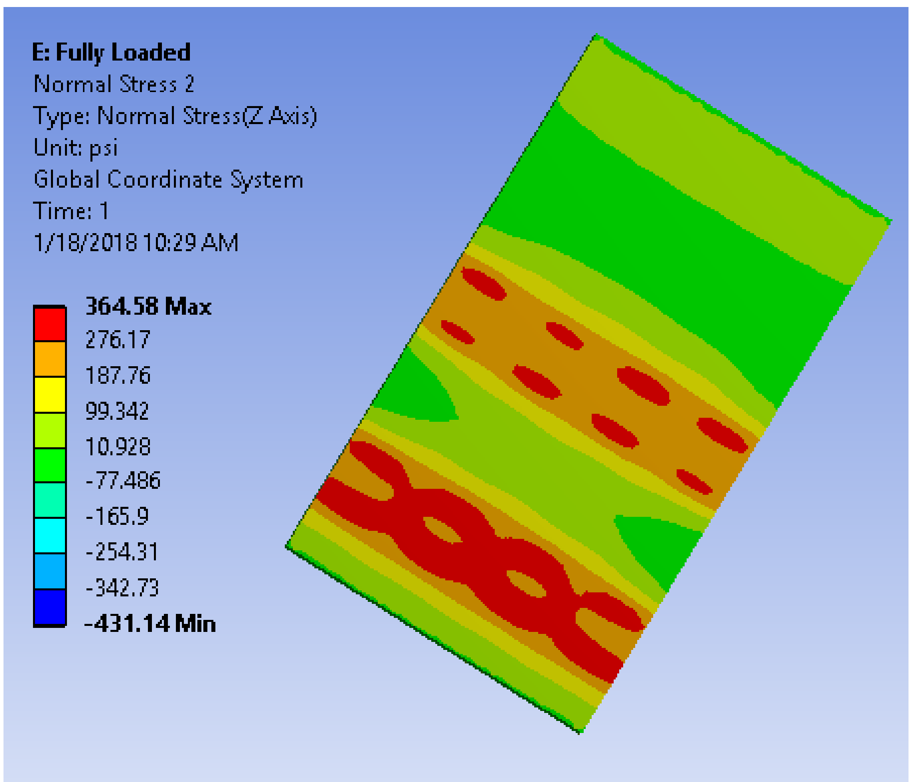


Figure AS-16 Phase 1 full loaded cask system static case – Normal Stress in Z-direction

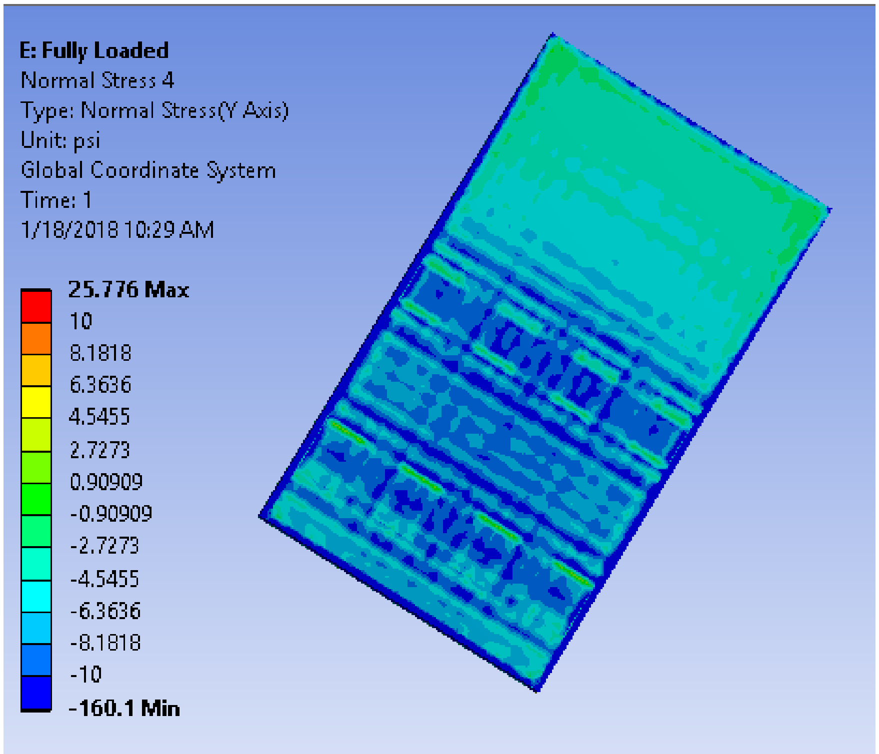


Figure AS-17 Phase 1 full loaded cask system static case – Normal Stress in Y-direction

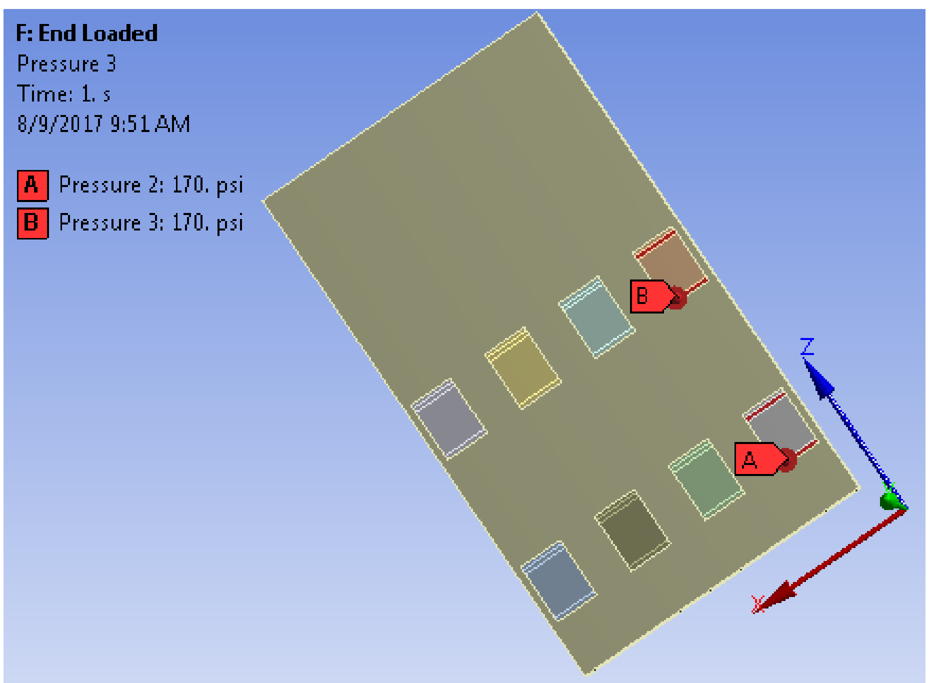
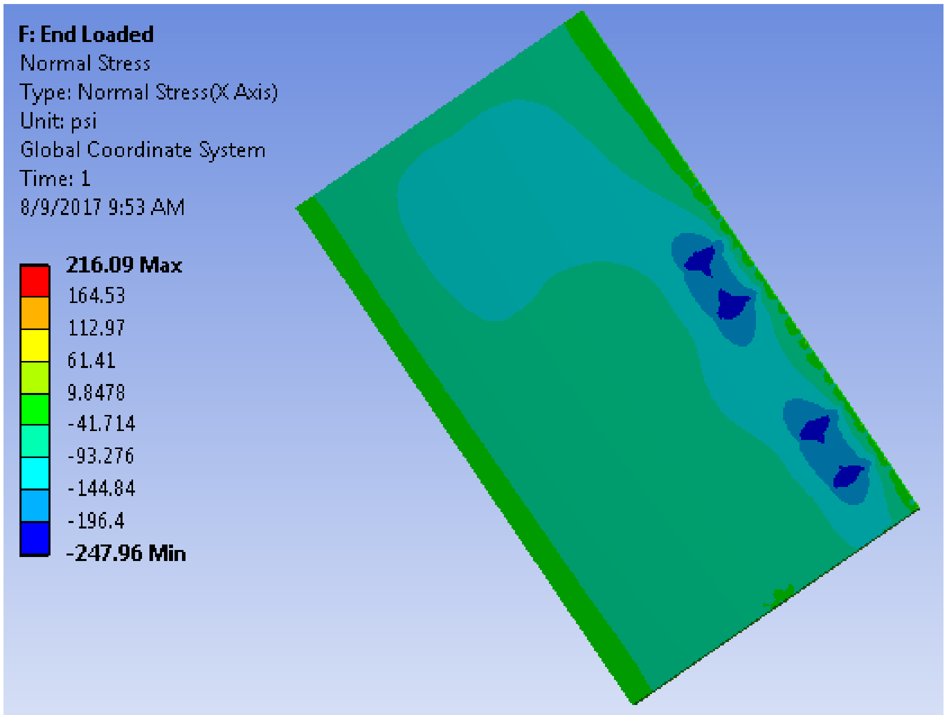


Figure AS-18 Phase 1 end loaded cask system static case – Factored live pressure load



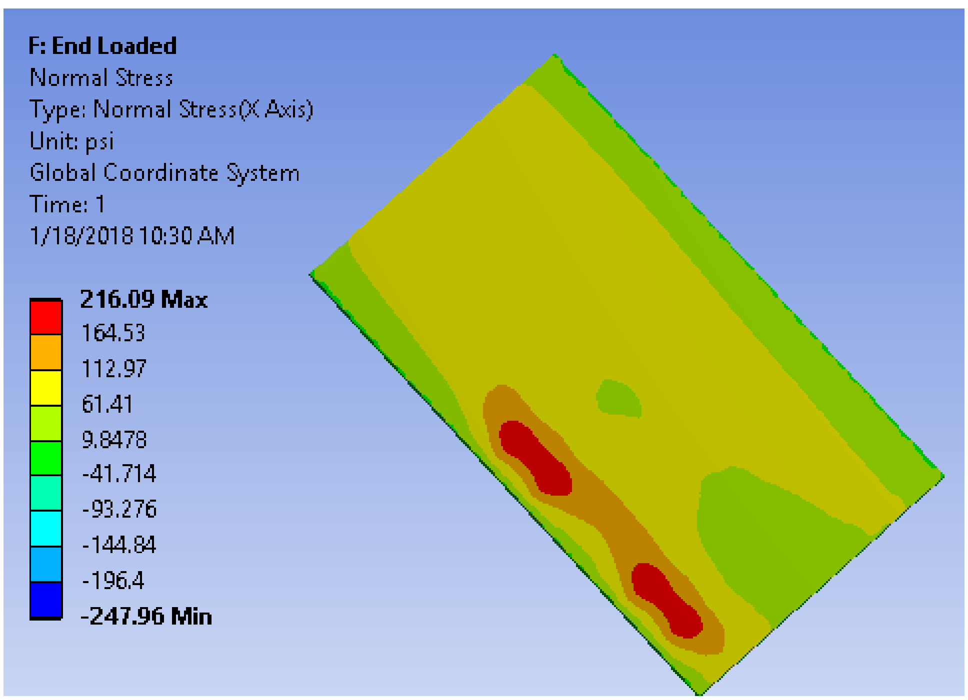
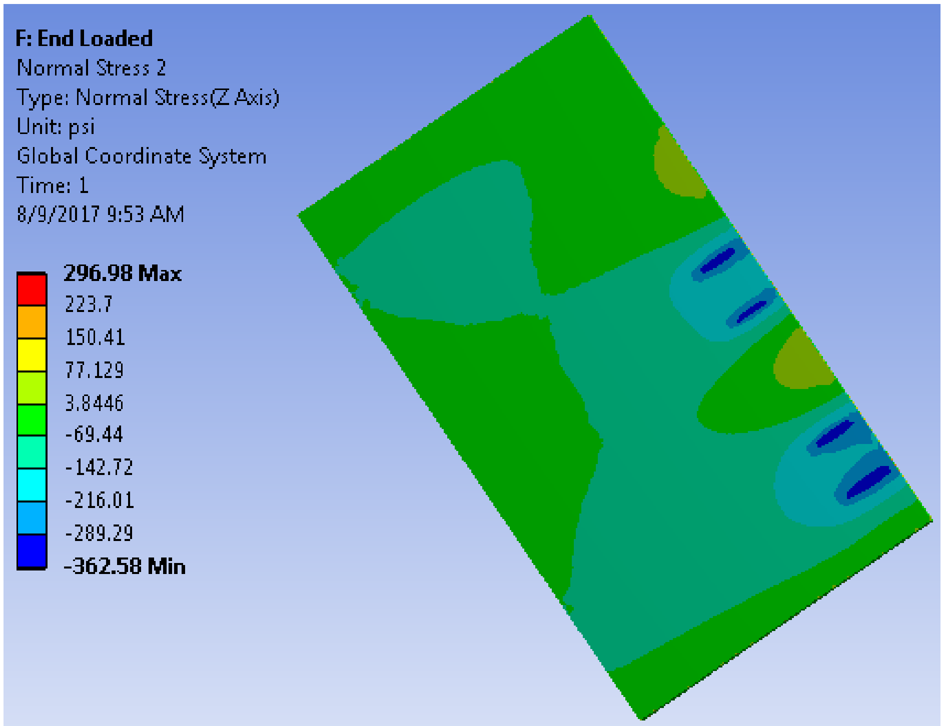


Figure AS-19 Phase 1 end loaded cask system static case – Normal Stress in X-direction



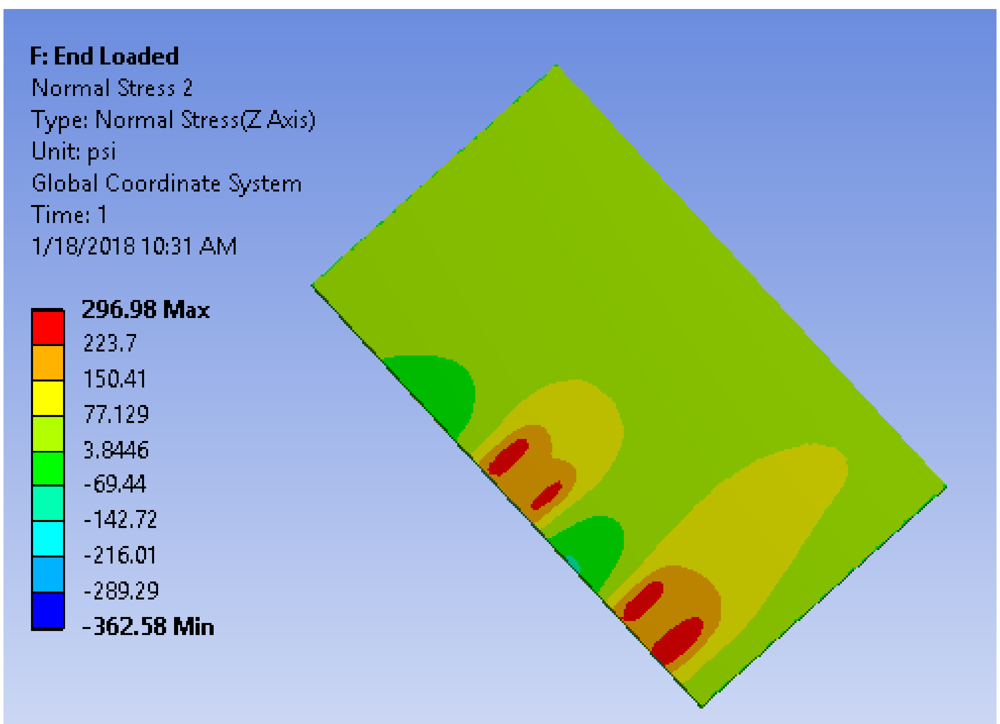


Figure AS-20 Phase 1end loaded cask system static case – Normal Stress in Z-direction

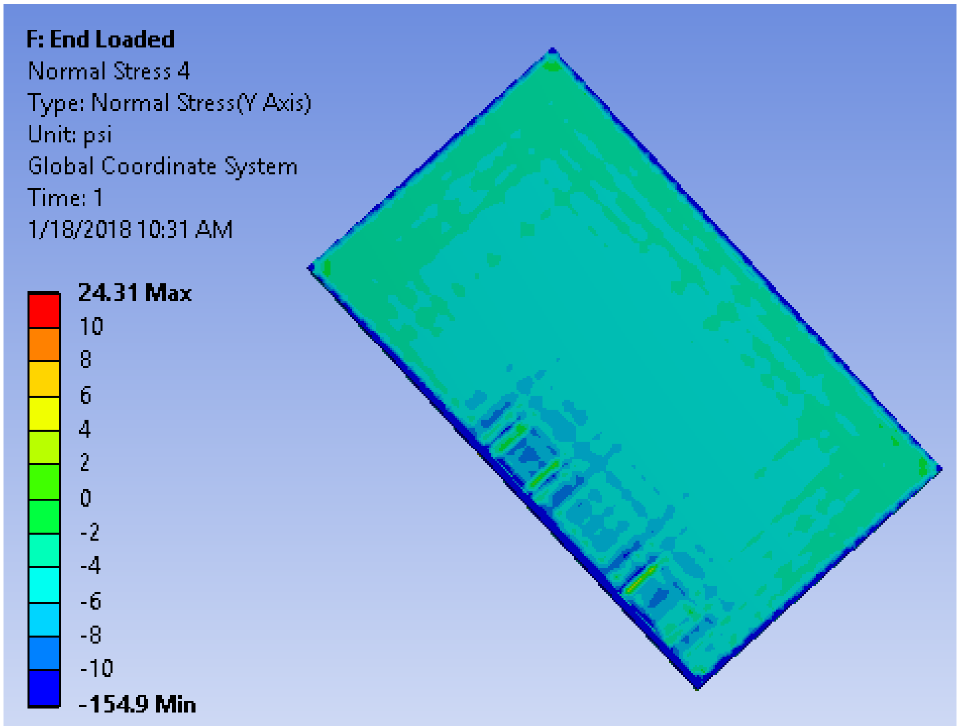


Figure AS-21 Phase 1 end loaded cask system static case – Normal Stress in Y-direction

Phase 2 Static Loading

Unlike Phase 1 results above, only the bounding case results for Phase 2 are presented in this appendix. The results for all other cases are stored on the Holtec network.

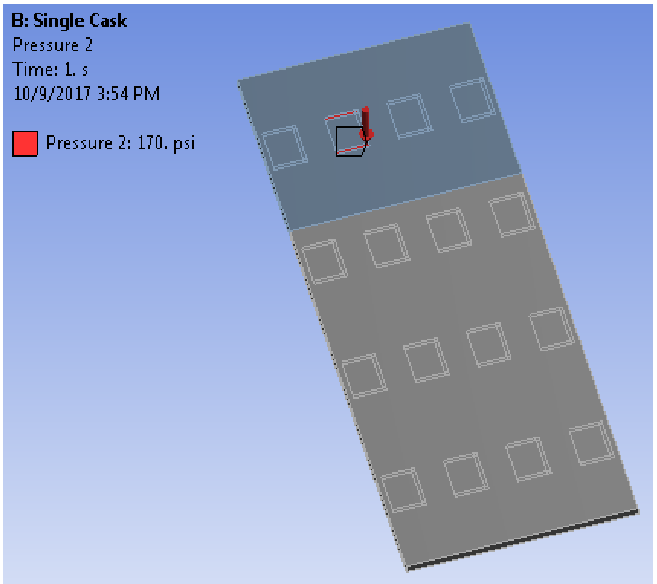
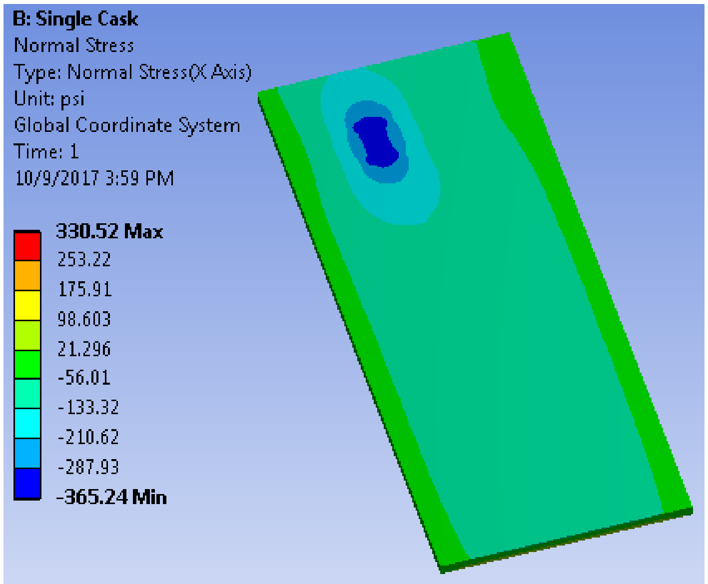


Figure AS-22 Phase 2 single loaded cask system static case – Factored live pressure load



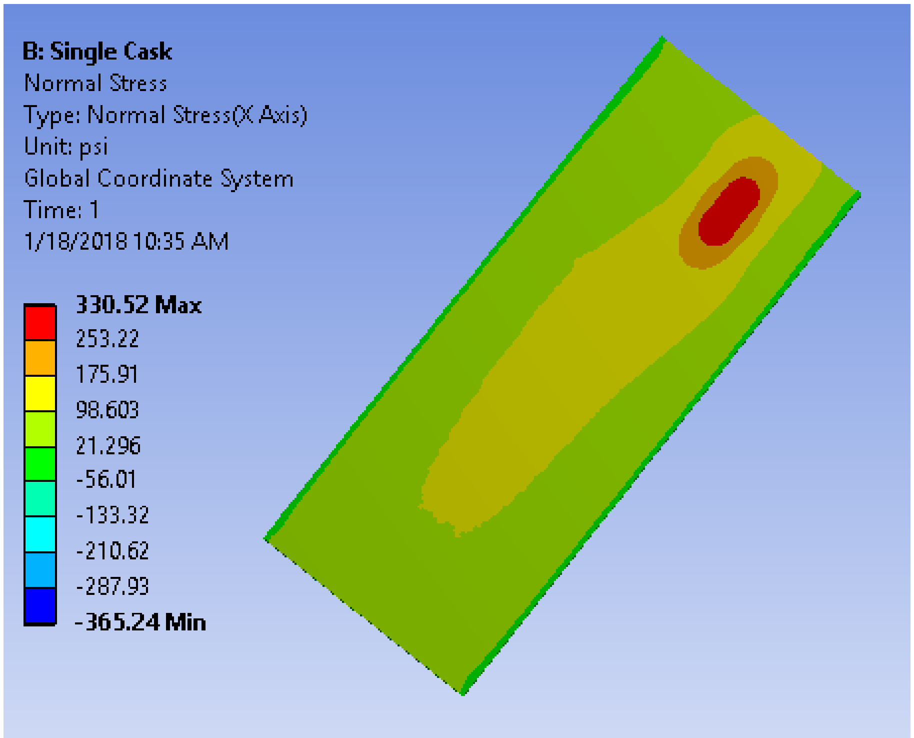
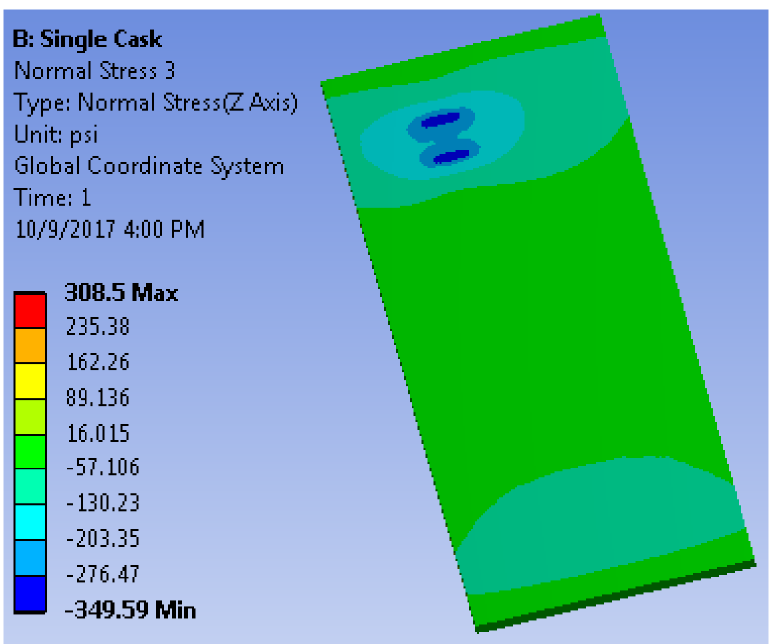


Figure AS-23 Phase 2 single loaded cask system static case – Normal Stress in X-direction



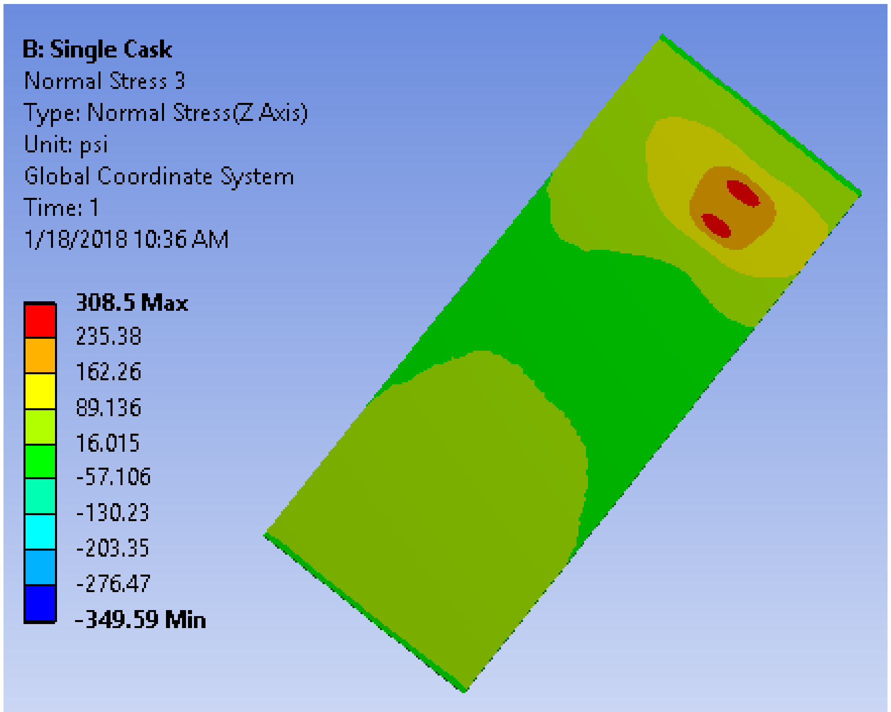


Figure AS-24 Phase 2 single loaded cask system static case – Normal Stress in Z-direction

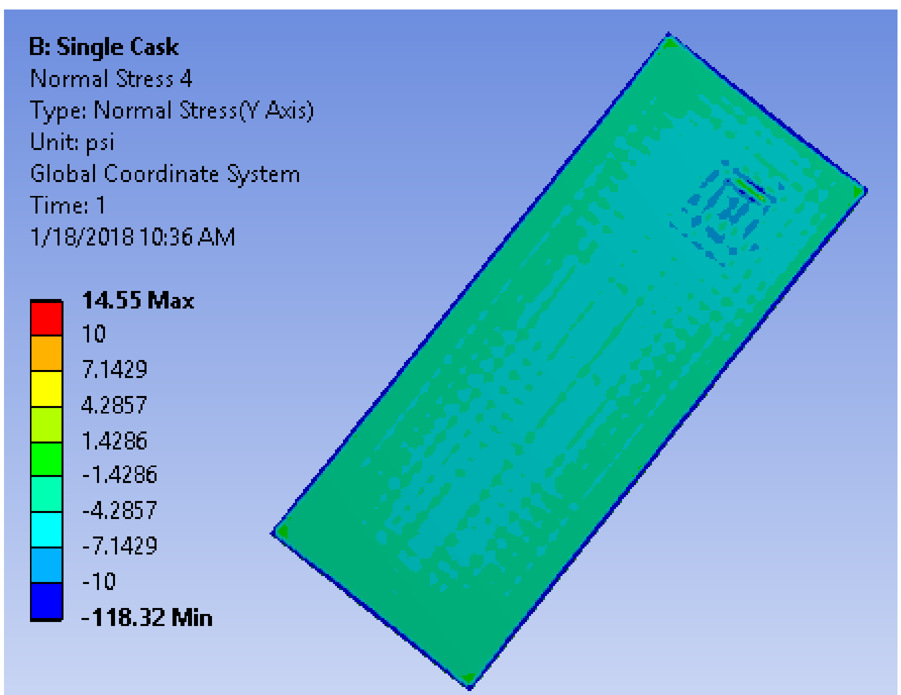


Figure AS-25 Phase 2 single loaded cask system static case – Normal Stress in Y-direction

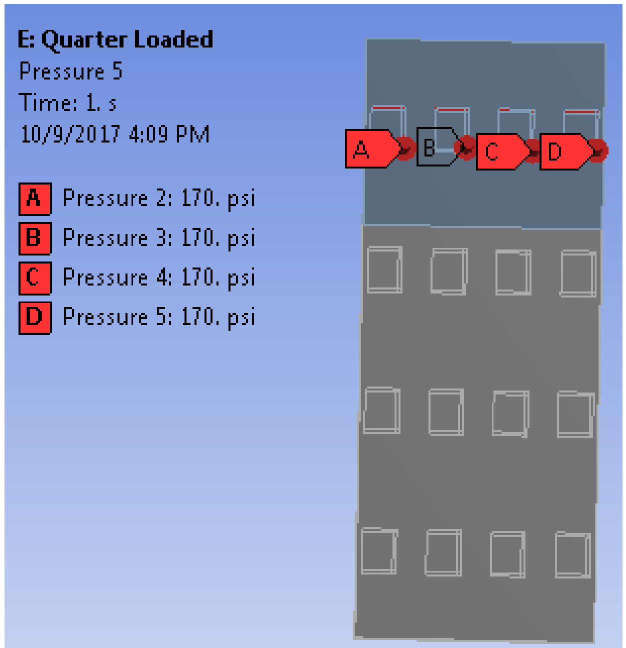
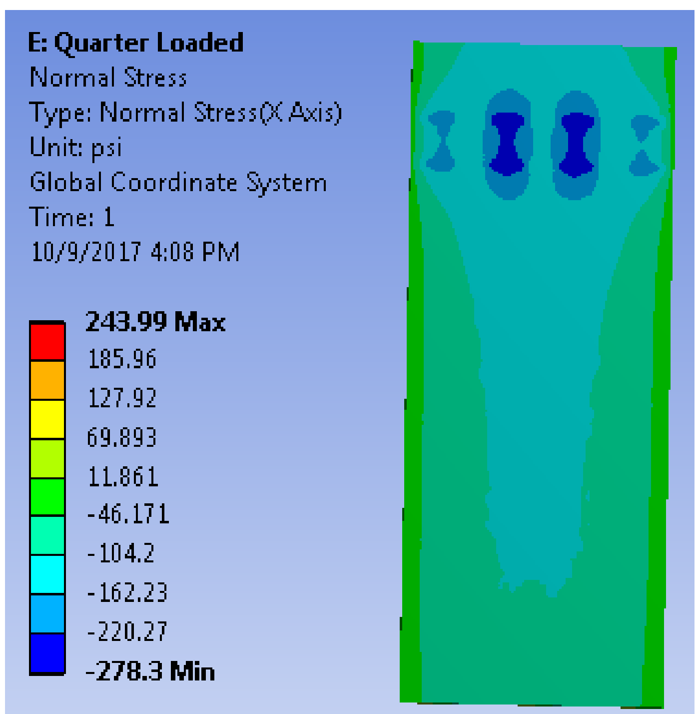


Figure AS-26 Phase 2 quarter loaded cask system static case – Factored live pressure load



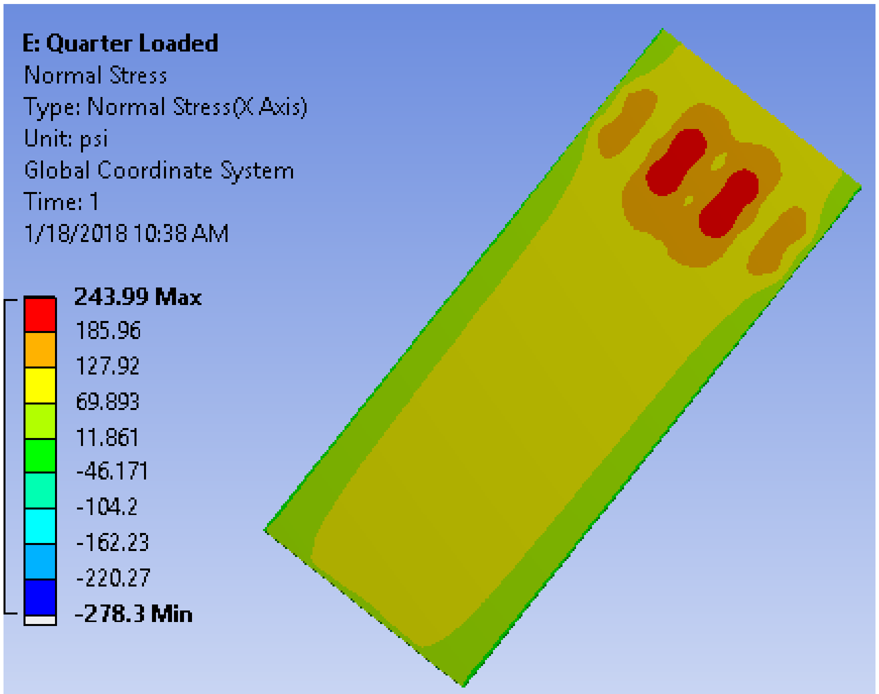
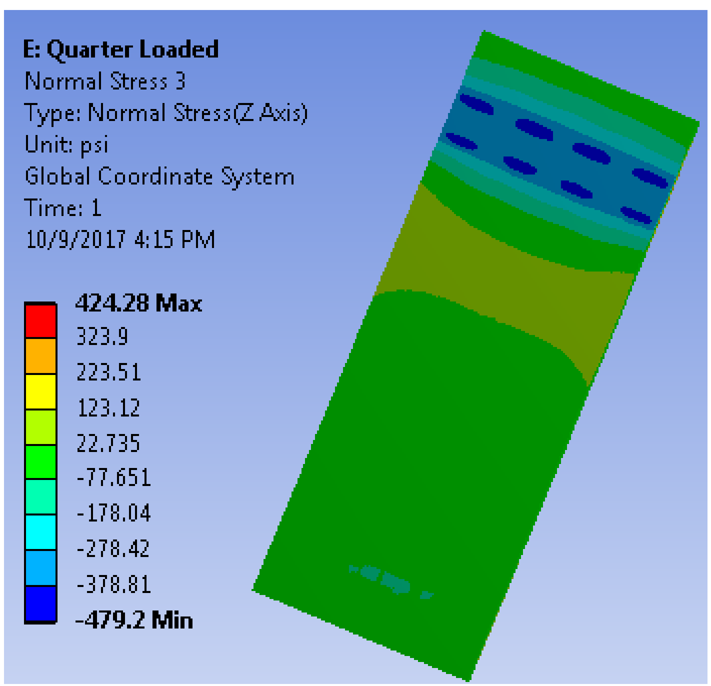


Figure AS-27 Phase 2 quarter loaded cask system static case – Normal Stress in X-direction



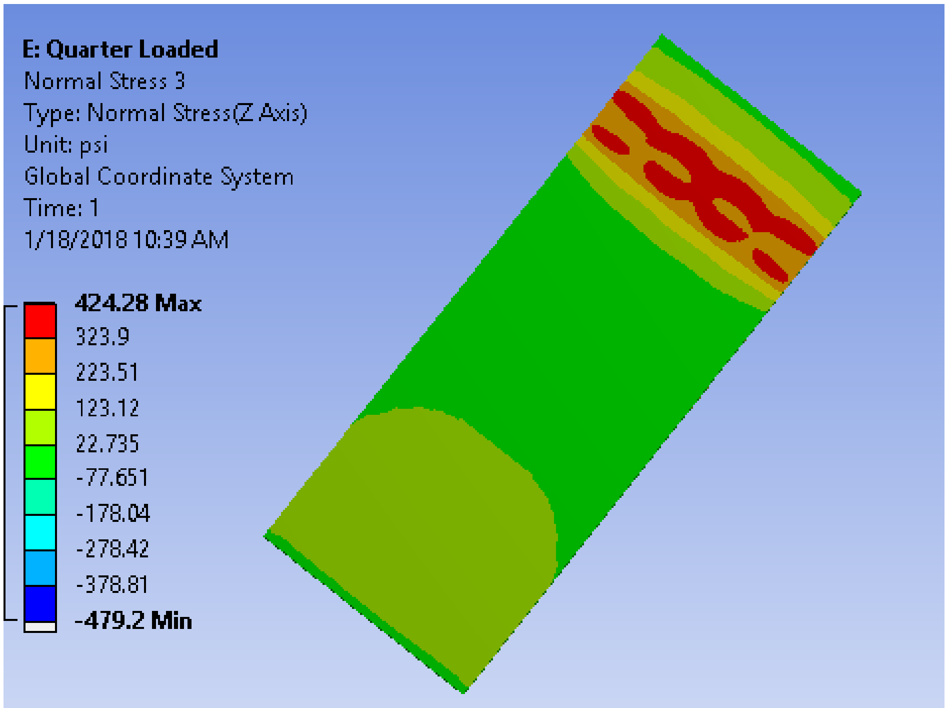


Figure AS-28 Phase 2 quarter loaded cask system static case – Normal Stress in Z-direction

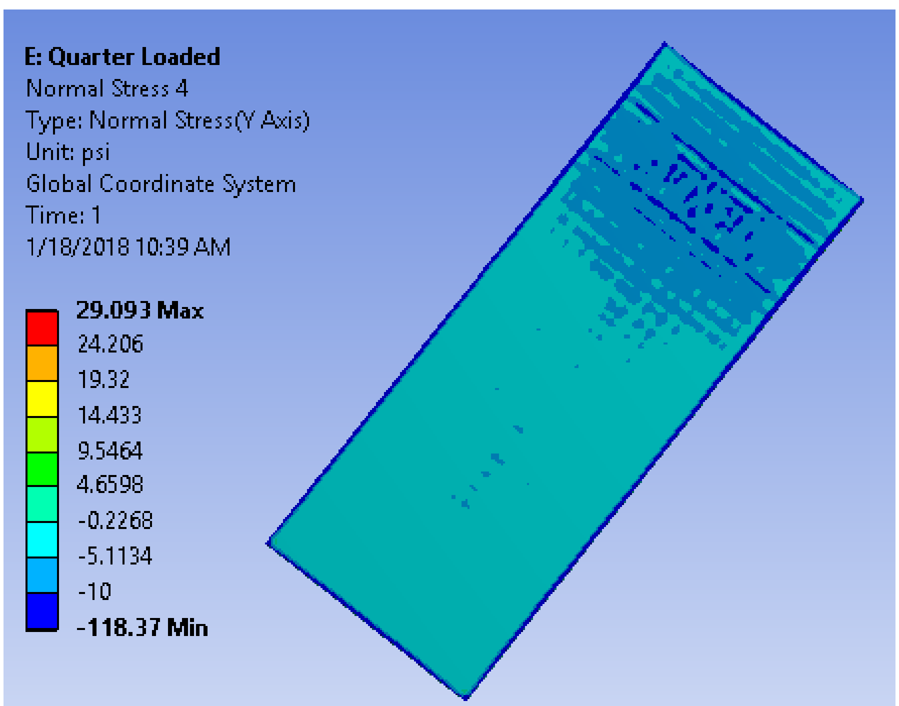


Figure AS-29 Phase 2 quarter loaded cask system static case – Normal Stress in Y-direction

APPENDIX B: MISCELLANEOUS INFORMATION

MOMENT CALCULATIONS FOR ISFSI PAD

SCOPE: This appendix calculates the pure bending capacity of the ISFSI pad. The following provides the moment capacity based on the limiting rebar location and to be conservative this value is used in both the direction.

$h := 36 \cdot in$ Nominal ISFSI pad thickness [5]

The modulus of elasticity of concrete can be obtained per 8.5.1 of [9]:

$f_{cc} := 4000 \cdot psi$ Bounding Minimum Concrete Strength [5]

$E_{cu} := 57000 \cdot \sqrt{f_{cc} \cdot psi}$ $E_{cu} = 3.605 \times 10^6 \cdot psi$

Since the pad is assumed to be half-cracked, the young's modulus is reduced by 50% of its nominal value per the guidance in Section 3.4 of [7].

$$E_c := \frac{E_{cu}}{2} = 1.802 \times 10^6 \cdot psi$$

$$f_{c'} := \frac{E_c^{\,2}}{57000^2 \cdot psi} = 1 \times 10^3 \cdot psi$$

$f_{c'} = 1000 \cdot psi$ Calculated concrete compressive strength for a cracked section

$f_y := 450MPa = 6.527 \times 10^4 \cdot psi$ Rebar yield strength [13]

$d_{bar} := 1.5 \cdot in$ Diameter of Y40 (equivalent #12) rebar [9]

$A_{bar} := 1.76 \cdot in^2$ Cross sectional area of Y40 (equivalent #12) rebar [9]

$spacing := 225mm = 8.858 \cdot in$ Rebar spacing (top and bottom) [5]

$cover := 75mm$ Concrete cover on botom surface of pad [5]

$b := 12 \cdot in$ Assumed width

The capacity of the pad is calculated using the following relations obtained from [22].

$A_s := \frac{A_{bar} \cdot b}{spacing}$ $A_s = 2.384 \cdot in^2$

$a := \frac{A_s \cdot f_y}{0.85 \cdot f_{c'} \cdot b}$ $a = 15.256 \cdot in$

$d := h - cover - 1.5 \cdot d_{bar}$ $d = 30.797 \cdot in$

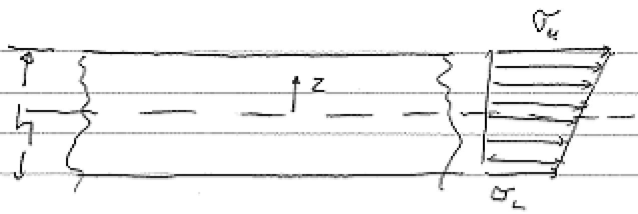
$M_c := A_s \cdot f_y \cdot \left(d - \frac{a}{2}\right)$ $M_c = 3.605 \times 10^6 \cdot lbf \cdot in$

$\phi := 0.75$ Conservative ACI Strength reduction factor for flexural loads [9]

$M_{cu} := \frac{\phi \cdot M_c}{b} = 225336 \cdot lbf \cdot \frac{in}{in}$ Pure moment capacity per unit width

Derivation of Relations Between Stress and Section Force and Moment

DERIVATION OF RELATIONS BETWEEN STRESS AND SECTION FORCE AND MOMENT



$$\boxed{\sigma = \frac{\sigma_u + \sigma_l}{2} + (\sigma_u - \sigma_l)\,\frac{z}{h}}$$

$$N = \int_{-\frac{h}{2}}^{\frac{h}{2}} \sigma \, dz = \left(\frac{\sigma_u + \sigma_l}{2}\right) h$$

$$M = \int_{-\frac{h}{2}}^{\frac{h}{2}} z \, \sigma_z \, dz = \int_{-\frac{h}{2}}^{\frac{h}{2}} \left(\frac{\sigma_u - \sigma_l}{h}\right) z^2 \, dz$$

or

$$M = \frac{(\sigma_u - \sigma_l)}{h} \, \frac{1}{3} \left[\left(\frac{h}{2}\right)^3 - \left(-\frac{h}{2}\right)^3 \right]$$

$$\boxed{M = \frac{\sigma_u - \sigma_l}{3h} \, \frac{h^3}{4} = \frac{(\sigma_u - \sigma_l)}{12} h^2}$$

Appendix C: Supporting Calculations for KNPS

1. Properties of Pad and Substrate

This report analyzes the pad under seismic Dynamic Loading (impact under SSE event) and Static Loading (dead weight of casks). The substrate have different material properties under dynamic loading and static loading and they are calculated as follows. Per [3] and Table A.2 of [1], the soil profile at the ISFSI site is as follows:

Depth from ground surface: 0 ft to 75.5 ft Sand Layer

ISFSI Pad

$f_{cc} := 4000 \cdot psi$ Bounding Minimum Concrete Strength [5]

$\gamma_{conc} := 155 \cdot \frac{lbf}{ft^3}$ Bounding concrete density

The modulus of elasticity of concrete can be obtained per 8.5.1 of [9]:

$E_{cu} := 57000 \cdot \sqrt{f_{cc} \cdot psi}$ $E_{cu} = 3.605 \times 10^6 \cdot psi$ Young's modulus

Since the pad is assumed to be half-cracked, the Young's modulus is reduced by 50% of its nominal value per the guidance in Section 3.4 of [7]. It is noted that the use of cracked-section properties in both dynamic and static analyses of ISFSI pad leads to conservative results.

$$E_c := \frac{E_{cu}}{2} = 1.802 \times 10^6\, psi$$

This modulus of elasticity is used in both the Dynamic Loading and the Static Loading.

Engineered Fill

$E_{fill} := 5000psi$ [5] $\gamma_{fill} := 100 \cdot \frac{lbf}{ft^3}$ main body

Sand Layer

Dynamic Loading

From Depth 0 ft to Depth 75.5 ft, there is Sand Layer. Table C2 calculates the average Best Estimate Young's Modulus E from the five Shake analysis performed in [1]. The final strain compatible properties are used to calculate the average value in two horizontal directions for each set and is reported in Table C2 below. The naming convention used in the table below is consistent with what was used in [1]. The strain compatible shear modulus for all the five sets in H1 and H2 directions is also reported in Table C1. The average of these values is then used in Table C2. The elastic modulus is then calculated using the following relation;

E=G*2*(1+v)

Table C1: Best Estimate (BE) Strain Compatible Shear Modulus from Shake Analysis [1]

Layer No.	Set-1	(KSF)	Set-2	(KSF)	Set-3	(KSF)	Set-4	KSF	Set-5	(KSF)
	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
1	3418.4	3424.3	3414.1	3497.7	3437	3454.3	3321.3	3379.2	3482.5	3361.4
2	895.7	905.2	933.1	998.3	909	929.8	792.1	884.7	984.5	852.1
3	478.7	505.1	533.5	568.8	498	513	409.2	501	589.7	461.4
4	468	559.5	575.3	592.6	527.8	535.6	440.8	566.8	615.8	494.2
5	290.1	340.3	413.9	390.3	342.2	320.8	317.8	476.3	462.5	323.8
6	399.9	620	653.5	616.8	673	573.2	669.3	760.8	689	649
7	797.5	983.7	1005.4	957.1	1073.8	921.5	1104.6	1153.5	1044	1055.4
8	246.9	325.4	329.4	308.4	359.1	286.5	383.1	361.7	345.2	364.5
9	832.8	1069.4	1062.9	998.2	1173.6	881.6	1271.6	1151.6	1128.5	1270.3
10	967	1205.1	1171.3	1115.8	1290	929	1419.3	1261.6	1279.2	1564.5
11	2810.4	3260.5	3169.6	3080.3	3362.4	2713.5	3513.9	3306.9	3440.7	3795.1
12	949.6	1225.3	1154.4	1133.1	1264.4	876	1343.3	1215	1330.9	1580.3

Table C2: Best Estimate (BE) Strain Compatible Modulus E (psi) from Shake Analysis [1]

Layer No.	Thickness (Ft.)	Density (pcf)	Set-1	Set-2	Set-3	Set-4	Set-5	E (Average)
			(ksf)	(ksf)	(ksf)	(ksf)	(ksf)	(psi)
1	6.6	104	3421.35	3455.9	3438.625	3350.25	3421.95	63131
2	6.6	104	900.45	965.7	933.075	838.4	918.3	16832
3	6.6	104	491.9	551.15	521.525	455.1	525.55	9403
4	6.6	104	513.75	583.95	548.85	503.8	555	9995
5	6.6	104	315.2	402.1	358.65	397.05	393.15	6894
6	3.3	104	509.95	635.15	572.55	715.05	669	11459
7	6.6	103	890.6	981.25	935.925	1129.05	1049.7	18422
8	3.3	103	286.15	318.9	302.525	372.4	354.85	6040
9	9.8	103	951.1	1030.55	990.825	1211.6	1199.4	19889
10	9.8	103	1086.05	1143.55	1114.8	1340.45	1421.85	22561
11	6.6	103	3035.45	3124.95	3080.2	3410.4	3617.9	60105
12	3.3	103	1087.45	1143.75	1115.6	1279.15	1455.6	22468

The listed moduli along with the density values are used in Appendix A for Dynamic Loading cases.

Static Loading

Appendix E derives the Sand layer properties under long-term settlement. The Young's modulus used in Finite Element Model for the Static Loading is:

$E_{fill\_static\_phase1} := 2827psi$ from Appendix E for Phase 1 analysis

$E_{fill\_static\_phase2} := 3332psi$ from Appendix G for Phase 2 analysis

2. Input Loads (Section 5.0 of this report)

Dynamic Loading (SSE)

$V_{s1} := 1040000 \cdot lbf$ Bounding Vertical Impact Load used in the Phase 1 analysis

$V_{s2} := 1075000 \cdot lbf$ Bounding Vertical Impact Load used in the Phase 2 analysis

For the cask diameter at the interface, use [11].

$W_{cask\_system} := 286000 \cdot lbf$ Bounding weight (Section 5.0 of main report)

$A_{cask\_system} := 2 \cdot \left(118 + \frac{5}{32}\right) in \cdot \left(12 + \frac{5}{32}\right) in = 2.873 \times 10^{3} \cdot in^{2}$ Full cask system area at the interface under normal conditions (from [23])

The above A_{cask_system} is very conservative as it ignores additional area at the cask/pad interface.

Under "Live Load" only, the vertical pressure is:

$p_{live} := \frac{W_{cask\_system}}{A_{cask\_system}}$ $p_{live} = 99.559 \cdot psi$

The "Dead Load" on the pad is from the dead weight of the pad:

$h := 36 \cdot in$ — pad thickness [5]

$\gamma_{conc} = 155 \cdot \dfrac{lbf}{ft^3}$ — concrete density [15]

$ZPA_{SSE} := 0.47 = 0.47$ (g) — Bounding vertical SSE at top of grade from Table A-1 in [1]

Therefore, an adder to the pressure due to dead load under seismic event is

$$\Delta p_1 := h \cdot \gamma_{conc} \cdot \left(1 + ZPA_{SSE}\right) = 4.747 \cdot psi$$

Also, an adder due to the dead weight is

$$\Delta p_2 := h \cdot \gamma_{conc} = 3.229\ psi$$

Seismic amplification on pad is

$$\Delta p_3 := \Delta p_1 - \Delta p_2 = 1.518\ psi$$

3. Results

Results from finite element load cases for stress differences at most limiting locations are post processed in an Excel Spreadsheet. The following calculations provide the applied loads in Appendix A.

Dynamic Loading (D+L+E)

The SSE load "E" on the pad is comprised of two components, "E_{cask}" and "E_{pad}". They are the SSE load contribution from the cask system and the SSE load contribution from the pad, respectively. Therefore, "D+L+E" is further broken into two components, "D_{pad}+E_{pad}" and "L+E_{cask}". The load "D_{pad}+E_{pad}" is calculated above as uniform pressure Δp_1 over the whole pad.

For Phase 1: The load "L+E_{cask}" is the total cask load on the pad from [1] and Appendix D applies the load as linear varying pressure over a reduced Craddle baseplate area. For Phase 1, the linearly varying pressure (from 0 psi to 1103 psi) as calculated in Appendix D is applied.

For Phase 2: The load "L+E_{cask}" is the total cask load on the pad from [1] and Appendix D applies the load as linear varying pressure over a reduced Craddle baseplate area. For Phase 2, the linearly varying pressure (from 0 psi to 1140 psi) as calculated in Appendix D is applied.

In summary, the loads in Dynamic Loading cases are applied as "D_{pad}+E_{pad}" and "L+E_{cask}" simultaneously in the finite element analysis in Appendix A.

Static Loading (1.4D+1.7L)

The dead load of the pad is calculated above as uniform pressure Δp_2 over the whole pad. The live load on the pad is calculated above as uniform pressure p_{live} over the cask/pad interfaces. In summary, the loads in Static Loading cases (for both Phase 1 and Phase 2) are applied as the factored dead load and live load simultaneously in the finite element analysis in Appendix A.

$1.4 \cdot \Delta p_2 = 4.521 \cdot psi$ on the whole pad

$1.7 \cdot p_{live} = 169.25 \cdot psi$ on cask system locations

Appendix D: CALCULATION OF PARTIAL CONTACT AREA OF CASK SYSTEMS

The seismic impact load between the cask system and the top surface of the ISFSI pad is applied over a reduced Cask system baseplate area, which is calculated in this appendix.

In reality, under a seismic event, per the design of the cradle assembly, the load will be transferred to the slab at least over a smaller area if not the entire plan area of the baseplate. The area over which the load is acting is dependent on the direction in which the cask system (Cask and Cradle assembly) can tip over. In a seismic event, the cask system (cask and craddle assembly) will possibly tip over in the short-axis direction. This could lead to the load being transferred to the slab via one of the two I-beams (item 2 of [23]). It is also noted that the maximum load will be at the ends of Item 2 of [23], where the end saddle plates are present. Therefore, it is reasonable to assume that the load will be transferred to the slab via the Item 2 of [23] over a small patch equal to width x length of the item 2 of [23]. Furthermore, since the load will be maximum at the ends where the end saddle plates are present, the load is applied over the width of the I-beam flange (item 2 of [23]) with a triangular distribution over the length of item 2 of [23], which means the load at the centre of the beam is zero and maximum at the two ends of the beam (as shown in the sketch below). The varying pressure to be applied in ANSYS model in Appendix A is calculated below.

<u>Contact Area Between Cask System and ISFSI Pad for Phase 1</u>

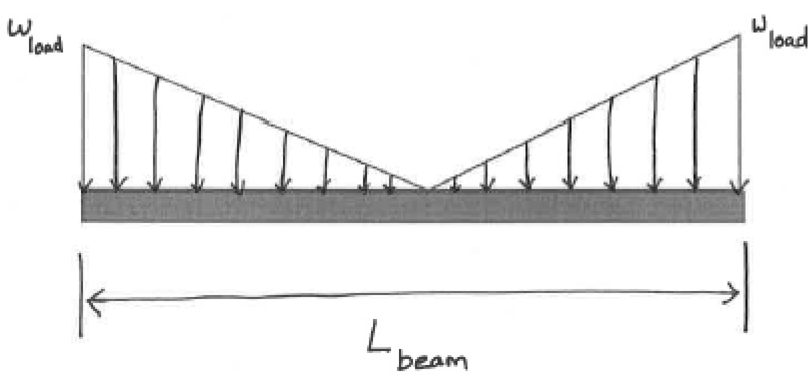
$P_{v1} := 1040000 \cdot \text{lbf}$ Bounding mean vertical impact force under SSE event (from [1])

$W_{beam} := \left(12 + \frac{5}{32}\right) \text{in}$ [23], width of item 2

$L_{beam} := \left(155 + \frac{1}{8}\right) \text{in}$ Sheet 5 of [23]

For a triangular distributed load, the resultant force is $0.5P_v := \frac{1}{2} \cdot w_{load} \cdot 0.5L_{beam}$

$w_{load} := \text{Press} \cdot W_{beam}$



$$\text{Press1} := \frac{0.5P_{v1}}{\left(\frac{1}{2} \cdot W_{beam} \cdot 0.5L_{beam}\right)} = 1103 \cdot \text{psi}$$

'Press1' is the maximum pressure at ends of the I-beam and diminishes to zero at the center of the beam (1/2 L_{beam}).

The partial contact area over which the linear varying pressure calculated above is applied

$$\text{Area} := W_{beam} \cdot 0.5L_{beam} = 943 \cdot \text{in}^2$$

In the ANSYS model described in the main body of the report, the linearly varying pressure gradient, with a maximum pressure of 1103 psi at the two ends of the beam, is applied over a partial contact area of 943 sq. inches (from one end of the beam to center of the beam) similar to Figure AD.6 of Appendix A.

<u>Contact Area Between Cask System and ISFSI Pad for Phase 2</u>

The pressure is calculated similar to Phase 1 with only change is the peak impact vertical load for Phase 2.

$P_{v2} := 1075000 \cdot \text{lbf}$ Bounding mean vertical impact force under SSE event (from [1])

$$\text{Press2} := \frac{0.5P_{v2}}{\left(\frac{1}{2} \cdot W_{beam} \cdot 0.5L_{beam}\right)} = 1140 \cdot \text{psi}$$

'Press2' is the maximum pressure at ends of the I-beam and diminishes to zero at the center of the beam (1/2 L_{beam}).

The partial contact area over which the linear varying pressure will be applied is listed above.

In the ANSYS model described in the main body of the report, the linearly varying pressure gradient, with a maximum pressure of 1140 psi at the two ends of the beam, is applied over a partial contact area of 943 sq. inches (from one end of the beam to center of the beam) similar to Figure AD.6 of Appendix A.

Appendix E: Calculation of Settlement under Phase 1 ISFSI Pad

1. SCOPE

This calculation uses information from site-specific soil tests (Ref. [3]) to compute estimates of settlement under a loaded ISFSI pad. Also calculated are the static substrate Young's Modulus. The methodology used in this appendix is from Holtec position paper DS-338 [21].

2. INPUT DATA

Ref. [3] establishes the soil profile at the ISFSI site.

The generalized soil profile around the ISFSI pad area consists of approximately 75 ft of sand. The following calculation calculates settlement upto the bedrock depth (75.5 ft.) consistent with Ref. [1].

2.1 Sand

Per [3], the sand at Koeberg can be described as dry, cream to off-white and grey, medium dense to dense calcareous silty sand with mudstone and calcrete pebbles and inclusions.

The specific gravity for the sand is provided in [17].

Specific Gravity is $G_s := 2.66$ (Ref. [17])

From [1] & [17], dry density for the soil (Conservatively using lower bound value)

$$\gamma_{dry} := 103 \cdot \frac{lbf}{ft^3} \qquad \gamma_{water} := 62.4 \cdot \frac{lbf}{ft^3}$$

From Ref. [3], the measured % moisture is averaged from all borings and a simple average is computed:

$w_{sand} := 15.66$ water content, an average for sand layers from Ref. [3]

$$\gamma_{wet} := \gamma_{dry} \cdot \left(1 + \frac{w_{sand}}{100}\right) \qquad \gamma_{wet} = 119.13 \cdot \frac{lbf}{ft^3}$$

Void Ratio $e := G_s \cdot \frac{\gamma_{water}}{\gamma_{dry}} - 1$ $e = 0.611$

To maximize the compression index, governing soil properties from [8] are used.

$$C_{c\_sand} := a \cdot (e - b)$$

Per Table 5-1 of [8], the reasonable value for 'a' for the type of Sand at Koeberg is

$$a := 0.12$$

Per Table 2-3 of [8], the reasonable value for 'b' for the type of Sand at Koeberg is

$$b := 0.20$$

$$C_{c\_sand} := a \cdot (e - b) \qquad C_{c\_sand} = 0.049$$

3.0 CALCULATION OF SETTLEMENT

The maximum uniform settlement is calculated based on the following formula for one-dimensional compression of a soil layer.

$$\Delta H := H \cdot \frac{C_c}{1 + e} \cdot \log\left(1 + \frac{\Delta p}{p_i}\right)$$ Ref. [8], Sec. 5-20

in which

ΔH = change in layer thickness due to one-dimensional vertical compression
H = original layer thickness
e = in-place void ratio of material in compressible layer prior to loading
C_c = compression index
Δp = anticipated increase in stress due to proposed loading
p_i = initial stress in layer due to weight of existing overburden

For a layered soil foundation, the total settlement is computed as the sum of the ΔH values for each participating layer.

The cask system layout and pad dimensions are shown in Figure E-1 .

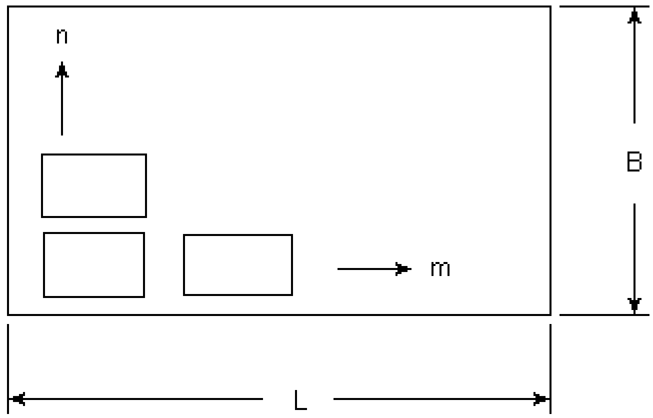


Figure E-1 - ISFSI Pad Layout

Length of pad	$L := 41385\text{mm} = 41.385\,\text{m}$	[5]
Thickness of pad	$t_{pad} := 36\text{in}$	[5]
Width of pad	$B := 21000\text{mm} = 826.772\cdot\text{in}$	[5]
Thickness of structural fill (beneath pad)	$t_{fill} := 36\text{in}$	[5]

Number of cask system $mn := 8$ for Phase 1 ISFSI pad, per sheet 2 of [5]

The maximum weight of a fully loaded cask system is

$W := 286000\cdot\text{lbf}$ (bounding per Ref. [1])

3.1 Increase in Pressure Due to Proposed Loading

The construction of the ISFSI pad and the eventual loading of the pad with storage cask systems will cause an increase in pressure on the underlying soil. The following calculations determine the total magnitude of the increase, including the pressure contributions from the loaded casks, the concrete pad, and the structural fill.

Based on the total number of cask systems and the maximum cask weight, the average pressure on the top surface of the ISFSI pad is calculated as follows:

$$p_{cask} := \frac{mn\cdot W}{L\cdot B} \qquad p_{cask} = 1.7\cdot\text{psi}$$

The pressure on the underlying soil due to the dead weight of the concrete ISFSI pad, which has a bounding weight density (γ_c) of 155 pcf, is

$\gamma_c := 155 \cdot \text{pcf}$

$p_{pad} := \gamma_c \cdot t_{pad}$ $\qquad$ $p_{pad} = 3.23 \cdot \text{psi}$

The structural fill beneath the ISFSI pad produces an additional load on the soil, which is equal to

$\gamma_{fill} := 100 \cdot \dfrac{\text{lbf}}{\text{ft}^3}$ (Section 4 of the report) $\qquad$ $p_{fill} := \gamma_{fill} \cdot t_{fill}$ $\qquad$ $p_{fill} = 2.08 \cdot \text{psi}$

Thus, the total increase in pressure on the soil due to the construction and loading of the ISFSI pad is

$\Delta p := p_{cask} + p_{pad} + p_{fill}$ $\qquad$ $\Delta p = 7.01 \cdot \text{psi}$

Using this pressure, the total load that acts to displace the substrate (over and above the initial overburden pressure of the native soil) is:

$P := \Delta p \cdot L \cdot B$ $\qquad$ $\boxed{P = 9444386 \cdot \text{lbf}}$

3.2 Maximum Uniform Settlement for Sand

As stated above, the total settlement is computed as the sum of the ΔH values for each soil layer. In its integral form, the equation for ΔH is written as:

$$\Delta H := \frac{C_c}{1 + e} \cdot \int_{d_1}^{d_2} \log\left(1 + \frac{\alpha(x) \cdot \Delta p}{p_i}\right) dx \qquad [14]$$

in which

$h_{exc} := t_{pad} + t_{fill} = 72 \cdot \text{in}$ $\qquad$ excavation depth

$$\alpha(x) := \frac{L \cdot B}{(L + 1.155x) \cdot (B + 1.155x)}$$

$\Delta p := \dfrac{P}{L \cdot B} = 7.011 \cdot \text{psi}$

$p_{sand} := \Delta p = 7.011 \cdot \text{psi}$

d_1 = depth below ground to top surface of soil layer $d_1 := h_{exc} = 72 \cdot in$

d_2 = depth below ground to bottom surface of soil layer $d_2 := 75.5ft$

Also, the x coordinate axis is normal to the plane of the soil layer. The function $\alpha(x)$ represents the decrease in pressure with soil depth as the load spreads at roughly a 30 degree angle. On this basis, if the width of the ISFSI pad is B, at a distance x below the pad bottom the load will spread over a width B + 1.155x.

$$\Delta H_{sand} := \frac{C_{c\_sand}}{1+e} \cdot \int_{d_1}^{d_2} \log\left[1 + \frac{\alpha(x) \cdot \Delta p}{\gamma_{wet} \cdot (x - h_{exc}) + \gamma_{wet} \cdot h_{exc}}\right] dx = 1.734 \cdot in$$

This is a conservative result as it neglects the effect of the surrounding unloaded soil.

For added conservatism, a value of 2.5-inches is used which bounds the value calculated above

$$\Delta H_{sand} := 2.5 \cdot in$$

4.0 ESTIMATE STATIC SUBSTRATE YOUNG'S MODULUS TO SIMULATE SETTLEMENT

4.1 Sand

Use the Boussinesq Solution (Section 139 of Ref. [4])

$P = 9.444 \times 10^6 \cdot lbf$ $\frac{L}{B} = 1.971$

Therefore from Table of Factors in above reference, $m := 0.92$

The spring constant is $k := \frac{P}{\Delta H_{sand}}$ $k = 3.778 \times 10^6 \cdot \frac{lbf}{in}$

Assume $\nu := 0.33$

Then the relation between k and the substrate Young's Modulus can be obtained from the reference as

$$E_{sand} := m \cdot k \cdot \frac{(1 - \nu^2)}{\sqrt{L \cdot B}}$$ $$E_{sand} = 2.668 \times 10^3 \cdot psi$$

APPENDIX F: PUNCHING SHEAR & BEARING EVALUATION

PUNCHING SHEAR EVALUATION

Per Appendix D, during a seismic event the cask system could potentially tip over the short-axis direction. This will lead to the entire load shifting on one side. Therefore, conservatively the punching shear perimeter is calculated assuming the load is transferred to the slab via one I-beam (item 2 of [23]). Furthermore, as noted in Appendix D, a triangular load distribution is assumed with majority of the load being transferred to the slab via. the ends of the beam. Therefore, for the punching shear evaluation, the loaded area is considered to be width of the item 2 x length of item 2 (reasonably upto the centroid of triangular distribution from the end of beam) as shown in Figure F-1 below.

Compute the punching shear safety factor following Section 11.12 of the ACI Code [9]

length of beam $L_{beam} := \left(155 + \frac{1}{8}\right)in$ $L_{beam} = 3.94\,m$ from Appendix D

width of beam $W_{beam} := \left(12 + \frac{5}{32}\right)in$ $W_{beam} = 0.309\,m$ from Appendix D

ISFSI pad thickness $h := 36in$ from main body

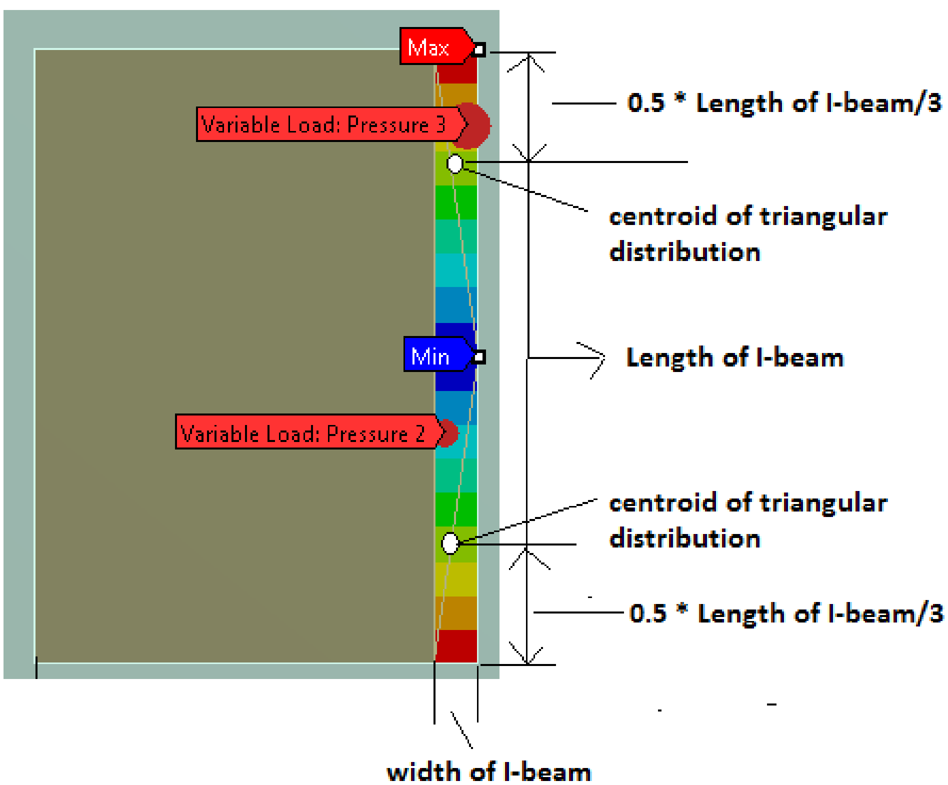


Figure F-1 Sketch of triangular load distribution (listed in Appendix D) in ANSYS for seismic case (not to scale, for illustrative purposes only) distance from extreme fiber to centroid of tension reinforcement per [5]

$$d := h - 75 \cdot mm - \frac{1.5 \cdot in}{2} = 2.691 \cdot ft$$

For punching shear, it is recognized that the most limiting condition occurs for a cask system at the corner. The corner cask system is adjacent to neighboring casks with a minimum pitch of 18.569'; to one free edge with a minimum cask system center to pad edge distance of 6.5945'. The shear perimeter is used to develop the allowable punching shear load in the pad. The shape of the shear perimeter depends on the distance of the cask system to its adjacent cask systems and boundary. For this specific cask system at the corner, the shear perimeter happens to be a rectangle defined per Section 11.12.1.2 of the ACI Code [9].

For Phase 1:

The cask system surface distance between the corner cask system and the adjacent cask system is 18.569' - 10.172' = 8.39', which is greater than 2*d = 5.39'. So the contribution from the adjacent cask side (with a pitch of 18.569') is 100%.

The cask center to pad edge (one side) distance between the corner cask and free edges is 6.5945', so the minimum distance between the cask system surface and free edges is approximately 6.5945' - 5.086' = 1.5085'. This is less than d = 2.695'. Therefore full shear cannot develop. Based on geometry consideration, the contribution to the effective perimeter should be reduced by the factor (6.5945' - 5.086')/2.695' = 0.559.

Therefore, assuming only 55% contribution from the one free edge adjacent to the cask system; the other free edge is more than d therefore 100% contribution is available.

For Phase 2:

The distances calculated above are same or bounding for Phase 2. Therefore, the effective perimeters calcualted below are applicable for both, Phase 1 and Phase 2.

Perimeter calculation for Seismic Case:

Half of the seismic load will be supported on the perimeter calculated below (under seismic case)

$$b_{o\_seismic} := \left(\frac{L_{beam}}{6} + d \cdot 100\%\right) + \left(W_{beam} + d \cdot 55\%\right) \ldots + \left(\frac{L_{beam}}{6} + d \cdot 100\%\right) + \left(W_{beam} + d \cdot 100\%\right)$$

$$b_{o\_seismic} = 15.89 \cdot ft$$

Perimeter calculation for Normal Case:

Half of the load will be supported on the perimeter calculated below (under normal case)

length of beam $L_{beam1} := \left(118 + \frac{5}{32}\right) in - 2 \cdot \left(12 + \frac{5}{32}\right) in = 93.844 \cdot in$ conservative, from Sheet 5 of [23]

$$L_{beam1} = 2.384\,m$$

$$b_{o\_normal} := \left(W_{beam} + d\cdot 100\%\right) + \left(L_{beam1} + d\cdot 55\%\right) \dots + \left(W_{beam} + d\cdot 100\%\right) + \left(L_{beam1} + d\cdot 100\%\right) \qquad b_{o\_normal} = 27.221\cdot ft$$

$W_{cask\_system} := 283060lbf$ (from main body of the report)

$P_v := 1075000\cdot lbf$ Bounding mean vertical impact force from Phase 1 and Phase 2 under SSE event (from main body)

Following 11.12.2.1 of the ACI Code [9], the minimum value of Vc from Eqns. 11-33 to 11-35 is

$$r1 := \left(d\cdot\frac{20}{\min\left(b_{o\_normal}, b_{o\_seismic}\right)} + 2\right) \qquad r1 = 5.388$$

$$\beta_c := \max\left(\frac{L_{beam}}{W_{beam}}, \frac{L_{beam1}}{W_{beam}}\right) = 12.761$$

$$r2 := \left(\frac{4}{\beta_c} + 2\right) \qquad r2 = 2.313$$

$$r3 := 4$$

$f_{cc} := 4000psi$ (from main body)

$$V_c := \min(r1, r2, r3)\cdot\sqrt{f_{cc}\cdot psi}\cdot\min\left(b_{o\_normal}, b_{o\_seismic}\right)\cdot d \qquad V_c = 9.011\times 10^5\cdot lbf$$

It is noted that the bounding vertical seismic load $V_s := 0.5P_v$ is greater than the factored live load $1.7\cdot 0.5\cdot W_{cask\_system} = 2.406\times 10^5\cdot lbf$

Therefore, the seismic load should be used to evaluate the punching shear of the pad. The factored live load is with respect to the normal (or static) load combination.

$$SF_{shear} := \frac{V_c\cdot 0.75}{\max\left(V_s, \frac{1.7\cdot W_{cask\_system}}{2}\right)} \qquad \boxed{SF_{shear} = 1.257}$$

where the strength reduction factor 0.75 comes from Section 9.3.2.3 of the ACI Code [9].

Half of the total load is used to calculate punching shear safety factor as the permieter calculated above only includes half the total perimeter that supports the load.

Aditionally, it should be noted that the instantaneous peak mean vertical seismic impact load is used to calculate the punching shear safety factor. This is very conservative as the shear load, if obtained directly from LS-DYNA analysis in [1] will be significantly lower as the pad is completely supported by the soil underneath.

CALCULATION OF CONCRETE BEARING PRESSURES

Calculated load at top of pad

$$P_{live} := 1.7W_{cask\_system} = 4.812 \times 10^{5} \cdot lbf$$ Factored live load

$$P_{SSE} := V_s = 5.375 \times 10^{5} \cdot lbf$$ Maximum Vertical Load from SSE

$Pad\_Thickness := h = 36 \cdot in$

$Area\_Cask\_Sytem := 2873in^2$ $\quad Area\_Cask\_Sytem = 19.951 \cdot ft^2$ from Appendix C

The above $Area\_Cask\_Sytem$ is conservative as it ignores additional area at the cask/pad interface.

$Area\_Cask\_Sytem\_seismic := 1886in^2$ $\quad Area\_Cask\_Sytem\_seismic = 13.097 \cdot ft^2$ from Appendix D

Calculate the bearing on the pad:

Normal Condition

$$p_{cask\_normal} := \frac{P_{live}}{Area\_Cask\_Sytem} \qquad p_{cask\_normal} = 167.491 \cdot psi$$

SSE Condition

$p_{cask\_sse} := 1140psi$ from Appendix D

$f_{cc} = 4 \times 10^{3} \cdot psi$ (from main body)

Allowable bearing pressure in concrete

$p_{all} := 0.65 \cdot .85 \cdot f_{cc}$ $\quad p_{all} = 2.21 \times 10^{3} \cdot psi$ (conservative)

The allowable is calculated per Section 10.17.1 of [9]. The factor of 0.65 is the strength reduction factor for bearing on concrete per Section 9.3.2.4 of [9]. It is noted that the allowable bearing capacity is much greater than the pressure under SSE and normal condition.

Furthermore, the bearing strength can be multiplied by $\sqrt{\frac{A_2}{A_1}}$ but not more than 2. Here A_1 is the loaded area and A_2 is the area assuming a 45 degree load spread. For this case $\sqrt{\frac{A_2}{A_1}}$ comes out to be 2.0. However, conservatively 1.5 is used to calculate the margin of safety.

$$SF_{concrete\_bearing} := \frac{1.5p_{all}}{\max(p_{cask\_normal}, p_{cask\_sse})}$$ $$\boxed{SF_{concrete\_bearing} = 2.908}$$

The bearing check is more appropriate for a static load acting over an area for a longer duration. However, in this evaluation conservatively the instantaneous peak load from the seismic event is also considered and assumed to act over a smaller area calculated in Appendix D.

Appendix G: Calculation of Settlement under Phase 2 ISFSI Pad

1. SCOPE

This calculation uses information from site-specific soil tests (Ref. [3]) to compute estimates of settlement under a loaded ISFSI pad. Also calculated are the static substrate Young's Modulus. The methodology used in this appendix is from Holtec position paper DS-338 [21].

2. INPUT DATA

Ref. [3] establishes the soil profile at the ISFSI site.

The generalized soil profile around the ISFSI pad area consists of approximately 75 ft of sand. The following calculation calculates settlement upto the bedrock depth (75.5 ft.) consistent with Ref. [1].

2.1 Sand

Per [3], the sand at Koeberg can be described as dry, cream to off-white and grey, medium dense to dense calcareous silty sand with mudstone and calcrete pebbles and inclusions.

The specific gravity for the sand is provided in [17].

Specific Gravity is $G_s := 2.66$ (Ref. [17])

From [1] & [17], dry density for the soil (Conservatively using lower bound value)

$$\gamma_{dry} := 103 \cdot \frac{lbf}{ft^3} \qquad \gamma_{water} := 62.4 \cdot \frac{lbf}{ft^3}$$

From Ref. [3], the measured % moisture is averaged from all borings and a simple average is computed:

$w_{sand} := 15.66$ water content, an average for sand layers from Ref. [3]

$$\gamma_{wet} := \gamma_{dry} \cdot \left(1 + \frac{w_{sand}}{100}\right) \qquad \gamma_{wet} = 119.13 \cdot \frac{lbf}{ft^3}$$

Void Ratio $e := G_s \cdot \frac{\gamma_{water}}{\gamma_{dry}} - 1$ $\quad e = 0.611$

To maximize the compression index, governing soil properties from [8] are used.

$$C_{c\_sand} := a \cdot (e - b)$$

Per Table 5-1 of [8], the reasonable value for 'a' for the type of Sand at Koeberg is

$$a := 0.12$$

Per Table 2-3 of [8], the reasonable value for 'b' for the type of Sand at Koeberg is

$$b := 0.20$$

$$C_{c\_sand} := a \cdot (e - b) \qquad C_{c\_sand} = 0.049$$

3.0 CALCULATION OF SETTLEMENT

The maximum uniform settlement is calculated based on the following formula for one-dimensional compression of a soil layer.

$$\Delta H := H \cdot \frac{C_c}{1 + e} \cdot \log\left(1 + \frac{\Delta p}{p_i}\right) \qquad \text{Ref. [8], Sec. 5-20}$$

in which

- ΔH = change in layer thickness due to one-dimensional vertical compression
- H = original layer thickness
- e = in-place void ratio of material in compressible layer prior to loading
- C_c = compression index
- Δp = anticipated increase in stress due to proposed loading
- p_i = initial stress in layer due to weight of existing overburden

For a layered soil foundation, the total settlement is computed as the sum of the ΔH values for each participating layer.

The cask system layout and pad dimensions are shown in Figure E-1 .

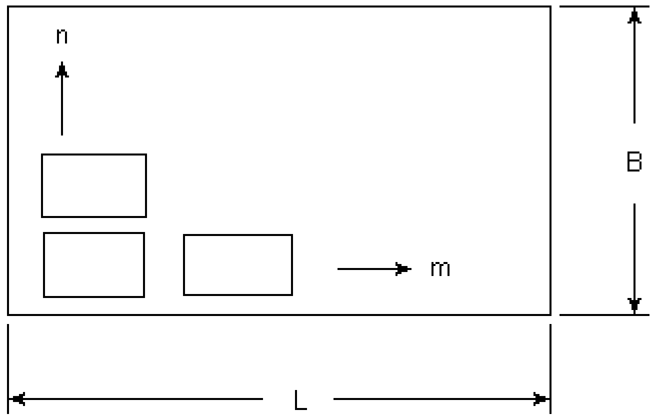


Figure E-1 - ISFSI Pad Layout

Length of pad	$L := 57750\text{mm} = 57.75\text{ m}$	[5]
Thickness of pad	$t_{pad} := 36\text{in}$	[5]
Width of pad	$B := 21000\text{mm} = 826.772\cdot\text{in}$	[5]
Thickness of structural fill (beneath pad)	$t_{fill} := 36\text{in}$	[5]
Number of cask system	$mn := 16$	for Phase 2 ISFSI pad, per sheet 4 of [5]

The maximum weight of a fully loaded cask system is

$W := 286000\cdot\text{lbf}$ (bounding per Ref. [1])

3.1 Increase in Pressure Due to Proposed Loading

The construction of the ISFSI pad and the eventual loading of the pad with storage cask systems will cause an increase in pressure on the underlying soil. The following calculations determine the total magnitude of the increase, including the pressure contributions from the loaded casks, the concrete pad, and the structural fill.

Based on the total number of cask systems and the maximum cask weight, the average pressure on the top surface of the ISFSI pad is calculated as follows:

$$p_{cask} := \frac{mn\cdot W}{L\cdot B} \qquad p_{cask} = 2.43\cdot\text{psi}$$

The pressure on the underlying soil due to the dead weight of the concrete ISFSI pad, which has a bounding weight density (γ_c) of 155 pcf, is

$$\gamma_c := 155\cdot\text{pcf}$$

$$p_{pad} := \gamma_c\cdot t_{pad} \qquad p_{pad} = 3.23\cdot\text{psi}$$

The structural fill beneath the ISFSI pad produces an additional load on the soil, which is equal to

$\gamma_{fill} := 100 \cdot \frac{lbf}{ft^3}$ (Section 4 of the report) $p_{fill} := \gamma_{fill} \cdot t_{fill}$ $p_{fill} = 2.08 \cdot psi$

Thus, the total increase in pressure on the soil due to the construction and loading of the ISFSI pad is

$\Delta p := p_{cask} + p_{pad} + p_{fill}$ $\Delta p = 7.75 \cdot psi$

Using this pressure, the total load that acts to displace the substrate (over and above the initial overburden pressure of the native soil) is:

$P := \Delta p \cdot L \cdot B$ $P = 14562258 \cdot lbf$

3.2 Maximum Uniform Settlement for Sand

As stated above, the total settlement is computed as the sum of the ΔH values for each soil layer. In its integral form, the equation for ΔH is written as:

$$\Delta H := \frac{C_c}{1+e} \cdot \int_{d_1}^{d_2} \log\left(1 + \frac{\alpha(x) \cdot \Delta p}{p_i}\right) dx \qquad [14]$$

in which

$h_{exc} := t_{pad} + t_{fill} = 72 \cdot in$ excavation depth

$$\alpha(x) := \frac{L \cdot B}{(L + 1.155x) \cdot (B + 1.155x)}$$

$$\Delta p := \frac{P}{L \cdot B} = 7.747 \cdot psi$$

$$p_{sand} := \Delta p = 7.747 \cdot psi$$

d_1 = depth below ground to top surface of soil layer $d_1 := h_{exc} = 72 \cdot in$

d_2 = depth below ground to bottom surface of soil layer $d_2 := 75.5ft$

Also, the x coordinate axis is normal to the plane of the soil layer. The function $\alpha(x)$ represents the decrease in pressure with soil depth as the load spreads at roughly a 30 degree angle. On this basis, if the width of the ISFSI pad is B, at a distance x below the pad bottom the load will spread over a width B + 1.155x.

$$\Delta H_{sand} := \frac{C_{c\_sand}}{1+e} \cdot \int_{d_1}^{d_2} \log\left[1 + \frac{\alpha(x)\cdot\Delta p}{\gamma_{wet}\cdot(x - h_{exc}) + \gamma_{wet}\cdot h_{exc}}\right] dx = 1.969\cdot in$$

This is a conservative result as it neglects the effect of the surrounding unloaded soil.

For added conservatism, a value of 2.5-inches is used which bounds the value calculated above

$$\Delta H_{sand} := 2.5\cdot in$$

4.0 ESTIMATE STATIC SUBSTRATE YOUNG'S MODULUS TO SIMULATE SETTLEMENT

4.1 Sand

Use the Boussinesq Solution (Section 139 of Ref. [4])

$P = 1.456 \times 10^{7}\cdot lbf$ $\qquad \frac{L}{B} = 2.75$

Therefore from Table of Factors in above reference, $m := 0.88$

The spring constant is $k := \frac{P}{\Delta H_{sand}}$ $\qquad k = 5.825 \times 10^{6}\cdot\frac{lbf}{in}$

Assume $\nu := 0.33$

Then the relation between k and the substrate Young's Modulus can be obtained from the reference as

$$E_{sand} := m\cdot k\cdot\frac{\left(1-\nu^2\right)}{\sqrt{L\cdot B}}$$

$$E_{sand} = 3.332 \times 10^{3}\cdot psi$$

APPENDIX H: RESULTS FROM PHASE 2 ISFSI PAD ANALYSIS

The results presented in this appendix are specific to Phase 2 ISFSI pad analysis. The results for Phase 1 ISFSI pad are documented in main body this report. Therefore, the results and associated discussion below are specific to Phase 2 ISFSI pad analysis.

Using the actual input load combinations, the appropriate surface pressure can be computed assuming that all loads are applied as pressures on the whole or partial area representing the cask system interface with the ISFSI pad. The dead weight of the slab plus vertical seismic adder is incorporated as a pressure on the whole area of the ISFSI pad in the –Y direction. The calculations to compute the actual pressures applied on the rectangular interface areas are performed in Appendix C.

Tables H.1 through H.10 present results for the condition where the maximum and minimum surface stresses are used *without regard for location on the ISFSI pad*. This approach maximizes the computed section bending moment that is compared to the allowable moment. The allowable moment is the bending capacity for concrete section from Appendix B, which outputs the section properties based on the specified reinforcement.

Table H.11 summarizes the results of computed bending moments for all ten loading case scenarios of Phase 2 ISFSI pad and the bounding results are identified. Table H.12 establishes the margin of safety based on the bounding results in Table H.11. The margin of safety is defined as the allowable bending moment divided by the calculated bending moment.

Ten loading case scenarios are evaluated and the bounding bending moments in the pad in the long and short directions are identified. Based on the bounding results, the margin of safety of the bending of the pad are calculated and they are shown to be above 1.0 in Table H.12. The minimum computed margin of safety for the Phase 2 ISFSI pad for static loading condition (1.4 D + 1.7L) is **2.31**. Per Table H.12, the minimum computed margin of safety for the dynamic loading condition (D + L + E) is **1.38**, which is based on a peak vertical load of 1,075,000 lbf per [1].

To address the concern about the uplifting of the pad under the partial loading, the Normal Y stress (perpendicular to the pad bottom surface) contours are plotted on the bottom surface of the concrete pad for all loading cases. The stress contours do not show consistent tension along the edge of the pad, which assures the uplifting of the pad is not a concern and the bonded connection used in the model is appropriate.

Appendix D calculates the linearly varying pressure over a partial contact area of cradle baseplate under seismic conditions to be used in the finite element simulations in Appendix A. Appendix G specifies conservative "effective elastic constants" that are to be used in the finite element simulation of the subgrade to represent the effect of settlement based on the soil characteristics at ISFSI site.

TABLE H.1 – RESULTS SUMMARY FROM FEA REPORTED IN APPENDIX A for Phase 2 ISFSI Pad (Dynamic Loading, 1 Cask System)

KOEBERG STRUCTURAL EVALUATION (Dynamic Loading, 1 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	SHORT DIRECTION BENDING
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.27	-865.18	647.98	**-163421.3**
ABSOLUTE VALUE			163421.3
Z-FACE		36	LONG DIRECTION BENDING
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.28	-662.16	449.43	**-120051.7**
ABSOLUTE VALUE			120051.7

Note:
- Tables 9.1 through 9.10 calculate the unit moments in the long and short directions of the pad. The pad thickness is 36 inches.
- Tables 9.1 through 9.10 use the surfaces stresses “SU” and “SL” from the two load cases (described in Section 9.0) in the finite element analysis (Appendix A) to calculate the unit moment “M” for the two perpendicular sections of pad which are normal to Figure 9.1’s X-axis (short direction of the pad) and Z-axis (long direction of the pad), respectively. The surfaces stresses are reported in plain font and the source figures from Appendix A are also provided.
- Tables 9.1 through 9.10 present the maximum and minimum surface stresses without regard for their location on the ISFSI pad.

TABLE H.2 – RESULTS SUMMARY FROM FEA REPORTED IN APPENDIX A for Phase 2 ISFSI Pad (Dynamic Loading, 8 Cask System)

KOEBERG STRUCTURAL EVALUATION (Dynamic Loading, 8 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
	-775.47	517.34	**-139623.5**
ABSOLUTE VALUE			**139623.5**
Z-FACE		36	**LONG DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
	-717.93	488.73	**-130319.3**
ABSOLUTE VALUE			**130319.3**

TABLE H.3 – RESULTS SUMMARY FROM FEA REPORTED IN APPENDIX A for Phase 2 ISFSI Pad (Dynamic Loading, 4 Cask System)

KOEBERG STRUCTURAL EVALUATION (Dynamic Loading, 4 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.31	-774.75	514.53	**-139242.2**
ABSOLUTE VALUE			**139242.2**
Z-FACE		36	**LONG DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AD.32	-749.95	523.02	**-137480.8**
ABSOLUTE VALUE			**137480.8**

TABLE H.4 – RESULTS SUMMARY FROM FEA REPORTED IN APPENDIX A for Phase 2 ISFSI Pad (Dynamic Loading, 16 Cask System)

KOEBERG STRUCTURAL EVALUATION (Dynamic Loading, 16 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
	-786.22	521.75	**-141260.8**
ABSOLUTE VALUE			**141260.8**
Z-FACE		36	**LONG DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
	-717.63	487.74	**-130180.0**
ABSOLUTE VALUE			**130180.0**

TABLE H.5 – RESULTS SUMMARY FROM FEA REPORTED IN APPENDIX A for Phase 2 ISFSI Pad (Dynamic Loading, 4 Cask System (End loading))

KOEBERG STRUCTURAL EVALUATION (Dynamic Loading, 4 END CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
	-859.72	611.17	**-158856.1**
ABSOLUTE VALUE			**158856.1**
Z-FACE		36	**LONG DIRECTION BENDING**
SSE (V)			
Normal Pressure	SU	SL	M(in-lb/in)
	-642.22	408.83	**-113513.4**
ABSOLUTE VALUE			**113513.4**

TABLE H.6 – RESULTS SUMMARY FROM FEA REPORTED IN APPENDIX A for Phase 2 ISFSI Pad (Static Loading, 1 Cask System)

KOEBERG STRUCTURAL EVALUATION (Static Loading, 1 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.23	-365.24	330.52	**-75142.1**
ABSOLUTE VALUE			**75142.1**
Z-FACE		36	**LONG DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.24	-349.59	308.5	**-71073.7**
ABSOLUTE VALUE			**71073.7**

TABLE H.7 – RESULTS SUMMARY FROM FEA REPORTED IN APPENDIX A for Phase 2 ISFSI Pad (Static Loading, 8 Cask System)

KOEBERG STRUCTURAL EVALUATION (Static Loading, 8 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
	-288.93	256.93	**-58952.9**
ABSOLUTE VALUE			**58952.9**
Z-FACE		36	**LONG DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
	-427.08	373.88	**-86503.7**
ABSOLUTE VALUE			**86503.7**

TABLE H.8 – RESULTS SUMMARY FROM FEA REPORTED IN APPENDIX A for Phase 2 ISFSI Pad (Static Loading, 4 Cask System)

KOEBERG STRUCTURAL EVALUATION (Static Loading, 4 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.27	-278.3	243.99	**-56407.3**
ABSOLUTE VALUE			**56407.3**
Z-FACE		36	**LONG DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
FIG. AS.28	-479.2	424.28	**-97575.8**
ABSOLUTE VALUE			**97575.8**

TABLE H.9 – RESULTS SUMMARY FROM FEA REPORTED IN APPENDIX A for Phase 2 ISFSI Pad (Static Loading, 16 Cask System)

KOEBERG STRUCTURAL EVALUATION (Static Loading, 16 CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
	-297.06	265.95	**-60805.1**
ABSOLUTE VALUE			**60805.1**
Z-FACE		36	**LONG DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
	-417.1	367.14	**-84697.9**
ABSOLUTE VALUE			**84697.9**

TABLE H.10 – RESULTS SUMMARY FROM FEA REPORTED IN APPENDIX A for Phase 2 ISFSI Pad (Static Loading, 4 Cask System (End loading))

KOEBERG STRUCTURAL EVALUATION (Static Loading, 4 END CASK SYSTEM)			
COMPUTE FACTORED MOMENTS IN TWO DIRECTIONS			
X-FACE		36	**SHORT DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
	-237.41	212.13	**-48550.3**
ABSOLUTE VALUE			**48550.3**
Z-FACE		36	**LONG DIRECTION BENDING**
1.7L+1.4D			
Normal Pressure	SU	SL	M(in-lb/in)
	-334.97	290.28	**-67527.0**
ABSOLUTE VALUE			**67527.0**

Table H.11 – SUMMARY OF MOMENTS FROM TABLE H.1 TO TABLE H.10 FOR PHASE 2 ISFSI Pad

		1 Cask System	8 Cask System	4 Cask System	16 Cask System	4 Cask System (End Loading)
Dynamic Loading	X-Face Moment (in-lb/in)	**163421**	139623	139242	141261	158856
	Z-Face Moment (in-lb/in)	120052	130319	**137481**	130180	113513
Static Loading	X-Face Moment (in-lb/in)	**75142**	58953	56407	60805	48550
	Z-Face Moment (in-lb/in)	71074	86504	**97576**	84698	67527

The highlighted results in the above table are the results from Table H.1 through Table H.10. Therefore, to calculate margin of safety in Table H.12 under static and dynamic loading for Phase 2 ISFSI pad, results from Table H.11 are used.

Table H.12 – MARGIN OF SAFETY ON BENDING MOMENT COMPUTED USING BOUNDNG RESULTS IN TABLE H.11 FOR PHASE 2 ISFSI PAD

LOCATION	ALLOWABLE MOMENT (in.-lb./in)*	COMPUTED MOMENT (in.-lb./in.)**		MARGIN OF SAFETY***	
		Dynamic Loading	Static Loading	Dynamic Loading	Static Loading
Face Normal to X (Bending in Short Direction)	225,336	163,421	75,142	**1.38**	**3.00**
Face Normal to Z (Bending in Long Direction)	225,336	137,481	97,576	**1.64**	**2.31**

*Appendix B calculates the unit section capacities for ISFSI pad after applying a conservative reduction factor of 0.75 from [9].
**The computed moments are the factored moments based on combination of V (D+L+E) for the Dynamic Loading cases and 1.7L+1.4D for Static Loading cases.
*** The Margin of Safety is defined as SF = (allowable moment)/(computed moment). A SF > 1.0 means that the configuration is acceptable.

APPENDIX I: ISFSI PAD EVALUATION UNDER LOADED TRAILER

In this appendix, the pressure on ISFSI pad from loaded transporter is calculated and shown to be less than the pressure calculated in Appendix D of this report, for ISFSI pad structural qualification.

For trailer design shown in [26]

Weight of trailer $W_{trailer} := 44474 \cdot kgf = 9.805 \times 10^4 \cdot lbf$ [26]

Weight of cask with cradle on trailer $W_{cask\_cradle} := 130000 \cdot kgf = 2.866 \times 10^5 \cdot lbf$ [26]

Weight of trailer with loaded mass $W := W_{trailer} + W_{cask\_cradle} = 3.846 \times 10^5 \cdot lbf$

CG of the cask with cradle from base of trailer [26] $CG_{cradle} := 1789 \cdot mm + 1175 \cdot mm = 116.693 \cdot in$

The CG of the trailer with cask and cradle is calculated below assuming that the CG of the trailer (without cask and cradle) is at 3/4th height of the trailer. This is reasonable as the CG of the trailer is expected to be above the trailer tires but below the top deck.

$$H_{centroid} := \frac{W_{cask\_cradle} \cdot CG_{cradle} + W_{trailer} \cdot \left(\frac{3}{4} \cdot 1175mm\right)}{W} = 95.791 \cdot in$$

It is not expected that the loaded trailer will be left on the ISFSI pad for an extended duration of time before or during the cask loading operation. The loaded trailer will be on the pad for a short duration of time during the cask loading operation and hence the evaluation of loaded trailer on the ISFSI pad is not warranted. Conservatively, an operating basis earthquake (OBE), which has a higher possibility of occurrence than safe shutdown earthquake (SSE) or design extended condition (DEC) earthquake, can be considered for the evaluation of the loaded trailer on the ISFSI pad for this short term operation. However, the analysis for the loaded trailer on ISFSI pad is performed below very conservatively by assuming the SSE input motion [27]. The detailed calculation to demonstrate stability (rocking and sliding) of loaded trailer will be performed in a separate calculation.

Reference [27], provides free field surface motion for SSE (also know as D&M earthquake). The free field ZPA's under SSE event in both, horizontal and vertical, directions are

Horizontal ZPA (g) $\varepsilon_H := 0.47$ [27]

Vertical ZPA (g) $\varepsilon_V := 0.5$ [27]

The trailer tire span about which the trailer would pivot about is

$$Track\_Span := 3000mm = 118.11 \cdot in \qquad [26]$$

Assuming that one side of trailer lifts up under the earthquake and the entire load of the trailer is supported by only a line of two tires [26], the total maximum load on one side of the tires under the seismic event is conservatively estimated as

$$P := W \cdot (1 + \varepsilon_V) + \frac{W \cdot H_{centroid} \cdot \varepsilon_H}{\frac{Track\_Span}{2}} = 8.702 \times 10^5 \cdot lbf$$

Per the Goldhofer catalog, for PST-SL 10 Axle, the tire specification is 215/75 R 17.5. The Michelin tire catalog [28], provides the net contact area of a tire with ground.

Net ground contact area per tire $A_{tire} := 260cm^2$ [28]

From [26], it is noted that there are a total of eight tires per axle (four on each side). However to calculate the pressure on ISFSI pad, conservatively only two tires per axle are credited. There are a total of 10 axles, so the ground contact area of the tire is multiplied by 20.

$Track\_Area := 10 \cdot 2 \cdot A_{tire}$ $Track\_Area = 806.002 \cdot in^2$

$$Pressure_{trailer} := \frac{P}{Track\_Area} = 1.08 \times 10^3 \cdot psi$$

The above calculations are repeated below for trailer design shown in [29]. The two designs are identical, however the loaded weight is different in the two drawings.

For trailer design shown in [29]

Weight of trailer $W_{trailer1} := 45474 \cdot kgf = 1.003 \times 10^5 \cdot lbf$ [29]

Weight of cask with cradle on trailer $W_{cask\_cradle1} := 114700 \cdot kgf = 2.529 \times 10^5 \cdot lbf$ [29]

Weight of trailer with loaded mass $W1 := W_{trailer1} + W_{cask\_cradle1} = 3.531 \times 10^5 \cdot lbf$

CG of the cask with cradle from base of trailer $CG_{cradle1} := 1946mm + 1175mm = 122.874 \cdot in$

The CG of the trailer with cask and cradle is calculated below assuming that the CG of the trailer (without cask and cradle) is at 3/4th height of the trailer. This is reasonable as the CG of the trailer is expected to be above the trailer tires but below the top deck.

$$H_{centroid1} := \frac{W_{cask\_cradle1} \cdot CG_{cradle1} + W_{trailer1} \cdot \left(\frac{3}{4} \cdot 1175mm\right)}{W1} = 97.84 \cdot in$$

Assuming that one side of trailer lifts up under the earthquake and the entire load of the trailer is supported by only a line of two tires [29], the total maximum load on one side of the tires under the seismic event is conservatively estimated as

$$P1 := W1 \cdot \left(1 + \varepsilon_V\right) + \frac{W1 \cdot H_{centroid1} \cdot \varepsilon_H}{\frac{Track\_Span}{2}} = 8.047 \times 10^5 \cdot lbf$$

$$Pressure_{trailer1} := \frac{P1}{Track\_Area} = 998.326 \cdot psi$$

The above calculated pressures on ISFSI pad from the loaded trailer are lower than the maximum pressure on the ISFSI pad under seismic case (per Appendix D).

The maximum pressure on ISFSI pad from Cask on Cradle under seismic event is (from Appendix D)

$$Pressure_{seismic} := 1103psi$$

$$\max\left(Pressure_{trailer}, Pressure_{trailer1}\right) < Pressure_{seismic} = 1$$

1 = true
0 = false

It is noted that the above pressure estimates are reasonable and ensures that the ISFSI pad analyses performed in this report remain bounding for the case when the loaded trailer is on the ISFSI pad for the following reasons.

1) As noted in the calculation above, it is not expected that the trailer will be left on the ISFSI pad for an extended duration of time. The loaded trailer will be on the pad only during the cask loading operation and hence the evaluation of loaded trailer on the ISFSI pad is not warranted. However, the analysis for the loaded trailer on ISFSI pad is performed in this appendix, very conservatively, using the safe shutdown earthquake (SSE) input motion at the top of grade.

2) The pressure under the tires of the loaded trailer on the ISFSI pad will be evenly distributed over a large span on the ISFSI pad as opposed to the pressure from cask and cradle which acts on a smaller span and leads to a more concentrated load on the ISFSI pad, which subsequently leads to higher bending stresses.

3) For the conservative calculations performed in this appendix, a load of ~ 870,000 lbf (which results in an amplification factor of 2.25) is applied over 1/4th support area of trailer. This load is only slightly lower than the maximum peak impact load for the cask on cradle assembly on ISFSI pad reported in the main body of the report. Typically, under an OBE, such a high load amplification is unlikely. Furthermore, there are a total of 80 tires supporting the total mass, which will damp out the instantaneous dynamic loads. These dampers are not credited in these calculations.

4) It is noted that the maximum load will occur during a slap down motion of the trailer. In such an instance, there will be more tires participating in the load distribution than only the two rows of tires considered in this analysis. This will lead to much lower pressures on the ISFSI pad.

Therefore, per the above discussion, it is evident that the static checks performed in this appendix are conservative, and provide assurance that the loaded trailer on the ISFSI pad will not overstress the ISFSI pad. The concrete bearing evaluation presented in Appendix F bounds the case for the loaded trailer on the ISFSI pad and thus it's not repeated here. Furthermore, as noted in Appendix F, the punching shear of ISFSI pad is not credible since the ISFSI pad is well supported by the subgrade underneath. Therefore, no explicit calculations for punching shear and bearing are performed.

ATTACHMENT A3
SAFETY EVALUATION E2017-0019

Eskom

TITLE

SAFETY EVALUATION FORM

Reference No.: KFA-048
Revision: 1 Page 1 of 10
Associated Procedure: KAA-709

No: E2017-0019 Rev. 0

Reason for Revision: *N/A*

CONCLUSION

Based on the attached discussion, does/can this activity/condition:

- involve a USQ ("Yes" to any question in Sections 4, 5, 6, 7, 8)? Justification No: J - YES ☐ NO ☒
- involve a change to the OTS, EOP, SAMG, and/or EP? YES ☐ NO ☒
- require a change or addition to the SAR? YES ☒ NO ☐
- require NNR approval for the proposed activity/condition? YES ☒ NO ☐

If any of the above is answered "Yes", the activity or condition needs to be discussed with the Koeberg Licensing Group before going any further.

Is a special review required by groups other than the group to which the preparer belongs? YES ☒ NO ☐

Groups: *RP, Civil Engineering*

Prepared by:

A Lawrence	A Lawrence	IPD-K	2018-07-26
PRINT NAME	SIGNATURE	GROUP	DATE

RRM REVIEW (SECTIONS 4 / 7 / 8)	ADDITIONAL REVIEW	ADDITIONAL REVIEW
Reviewed by: S Fagan (PRINT NAME)	Reviewed by: K Makhotha (PRINT NAME)	Reviewed by: E Venter / S Pietersen (PRINT NAME)
SFagan (SIGNATURE)	(SIGNATURE)	(SIGNATURE)
	Group: RFE	Group: SDE (Civil) / RP
Date: 2018-07-26	Date: 2018-07-26	Date: 2018-07-26 2018-07-26

INDEPENDENT REVIEWER	KORC APPROVED
Signature:	Signature:
Print Name: John Venter	Print Name: M. Valatham
Date: 2018-07-26	Date: 2018-07-30

No: E2017-0019 Rev. 0

1.0 INTRODUCTION

SAR Safety Evaluation Determination is required for:

☐ *Procedure* ☐ *Temporary Alteration* ☒ *Modification* ☐ *Modification (30% Phase)* ☐ *Test* ☐ *Other*

Activity/Condition No: *07147 DPDRR007*

Title: *Cask Storage Building (CSB) Storage Pad Upgrade*

Brief Description of Activity or Plant Condition:

Eskom is procuring fourteen HI-STAR 100 spent fuel metal casks for storage on the Koeberg site. Analyses were performed to store seven of these casks in the CSB alongside the four existing CASTOR X/28F casks, while the remaining seven will be stored on a transient interim storage facility (TISF), which is yet to be constructed on the Koeberg site. The HI-STAR 100 casks are placed horizontally on transport cradles during storage, similar to the CASTOR X/28F casks.

The current CSB storage area is modified to meet the HI-STAR 100 FSAR requirements in accordance with 10 CFR 72 dry storage regulations, to allow for the safe storage of both the CASTOR X/28F and HI-STAR 100 casks during normal and accident conditions.

The CSB storage pad design as documented in 07147 DPDRR0007 is evaluated herein as follows:

- *The design and installation of the CSB storage pad; and*
- *The storage of casks during the construction activities as described in Section 2.1.*

The lifting, movement and placing of the casks (CASTOR X/28F and HI-STAR 100) during the construction is not evaluated here and is included in the safety case for LCR 1913 which discusses the long term storage of the CASTOR X/28F and HI-STAR 100 casks in the CSB.

2.0 DESCRIPTION

2.1. Describe the activity/condition being evaluated, and its expected effects.

The construction of the CSB pad for storage of seven HI-STAR 100 casks alongside the four CASTOR X/28F casks is implemented in two phases. Phase 1 is the replacement of the existing CSB storage area where the CASTOR X/28F casks are not currently stored, followed by Phase 2 the replacement of the CSB storage area where the CASTOR X/28F casks are stored, as follows:

Phase 1

- *The four CASTOR X/28F casks, 9 PMC 003 BA, 9 PMC 004 BA, 9 PMC 005 BA, and 9 PMC 006 BA are located on the spent fuel cask storage plinths 3, 4, 5, and 6 in a single row at the back of the CSB.*
- *The existing CSB Phase 1 storage area is removed and replaced with a new storage pad in accordance with detailed design 07147 DPDRR007.*

Phase 2

- *The four CASTOR X/28F casks, 9 PMC 003 BA, 9 PMC 004 BA, 9 PMC 005 BA, and 9 PMC 006 BA are located on the new Phase 1 storage pad. Additionally, a maximum of four (of the seven) loaded HI-STAR 100 casks may also have been located on the Phase 1 storage pad.*
- *The existing CSB Phase 2 storage area is removed and replaced with a new storage pad in accordance with detailed design 07147 DPDRR007.*

During the CSB storage pad construction, the area will remain an RP controlled zone. Consequently, for purposes of ALARA, a radiological shield wall is installed to separate the construction zone and the stored casks during construction activities in the CSB. The radiological shield wall, which is constructed of steel and UHMW (polyethylene), does not pose a risk to the casks as the failure thereof cannot result in the failure of the casks to perform their designed safety functions.

The four CASTOR X/28F casks in the CSB are fitted with a monitoring system to indicate the integrity of the casks. Since the cabling for the casks is attached to the walls of the CSB, it is not expected that the CSB pad construction activities will affect the operability thereof. However, should a failure of the pressure monitoring equipment occur, the repair thereof is performed as soon as possible even if it requires that the CSB pad construction is suspended.

With the implementation of Phase 2 the CSB will have a single storage pad which can accommodate both the HI-STAR 100 and the CASTOR X/28F casks. The Phase 2 storage pad modification need not be implemented if the CASTOR X/28F casks remained located in their current storage configuration on the four plinths at the back of the CSB.

2.2. Identify the parameters and systems affected/potentially affected by the activity/condition (including common mode effects).

The parameters and systems affected and/or potentially affected during the CSB pad construction are:

- *CSB storage pad;*
- *CSB environment (e.g. ventilation, shielding);*
- *CSB structural integrity;*
- *Cask pressure monitoring equipment;*
- *Cask structural integrity;*
- *Cask confinement;*
- *Spent fuel/cask temperature during accidents;*
- *Spent fuel integrity;*
- *Fuel sub-criticality margin;*
- *Fuel retrievability;*
- *Cask surface radiation dose rates;*
- *IAEA monitoring system;*
- *CSB electrical supplies; and*
- *Security system.*

2.3. Identify the credible failure modes associated with the activity/condition.

The following are the credible potential failure modes and their mitigation as described in the CSB storage design package 07147 DPDRR007 [1]:

i) From SAR Section II-8.1.5

- *SAR Section II 8.1.5 d) states that a leaking cask shall be moved to the fuel building for repair as soon as practicable but not later than 6 months from the date the leak was detected.*

Consequently, the failure of the CASTOR X/28F seals is resolved as soon as practicable but not later than 6 months from the date of failure.

The HI-STAR 100 cask does not require pressure monitoring since a leak of the HI-STAR 100 multi-purpose canister is not considered a credible failure as the canister is welded shut in accordance with the requirements of ASME IX with welding qualification in accordance with ANSI N14.5 [14].

ii) Non-Compliance with the Design and Construction Requirements

During the construction of the new storage pad in accordance with the requirements of detailed design 07147 DPDRR007, the following are applicable:

- *Subsidence of the storage pad where the loaded casks are located*

The report HI-2177728 [11], analyses the slope stability of the temporary slopes necessary for construction of the storage pad in the CSB.

During the construction of Phase 1, a 1H:1V temporary slope is maintained at the edge of the existing CASTOR X/28F casks storage area.

On completion of the Phase 1 CSB pad, all the loaded casks are transferred to the Phase 1 CSB pad and the Phase 2 CSB pad construction will commence. For the Phase 2 construction, a temporary 1H:1V slope is maintained during construction.

The Eskom site supervisor ensures that the 1H:1V temporary slope is maintained in accordance with the CSB storage pad detailed design as documented in 07147 DPDRR0007.

- *Fire inside the CSB*

The report HI-2177726 [10] evaluates whether controls are to be imposed to prevent accidental fires due to construction-related equipment during construction that would result in exceeding any licensing basis cask temperature or pressure limits for the HI-STAR 100 casks.

Two classes of combustible materials associated with construction are relevant, namely combustible liquids and combustible solids. The predominant combustible liquids are fuel for internal combustion engines in vehicles or generators and hydraulic fluid for hydraulically-operated equipment. The predominant combustible solids are the rubber tyres on the construction equipment.

The approaches to evaluate fires of these classes of combustible materials are described for two fire scenarios, namely during and after construction of the radiological shielding wall.

The analysis, conclusions, and requirements are as follows:

- *HI-STAR 100 cask after installation of the radiological shield wall*

The HI-STAR 100 casks will continue to perform all their intended safety functions during the postulated construction equipment fire event, provided the distance between the casks and the shield wall is at least 1 500 mm and the total volume of all combustible liquid materials inside the CSB is no more than 6 000 litres.

- *HI-STAR 100 cask during installation of the radiological shield wall*

The HI-STAR 100 casks will continue to perform all their intended safety functions during the postulated construction equipment fire event, provided the total volume of all combustible liquid materials inside the CSB is no more than 1 306 litres, and the total mass of all combustible solid materials inside the CSB is no more than 2 109 kilograms.

The Eskom site supervisor ensures that the construction contractor does not exceed the combustible quantity maximum limits.

The CASTOR X/28F casks have been analysed for fire accidents in the document GNB B 127/95E [7], Topical Safety Analysis Report, par. 6.3. The CASTOR X/28F casks have been shown to be able to withstand a homogeneous heating test of 800°C for 30 minutes. The shielding and confinement capabilities of the cask were not compromised during the test.

The CASTOR X/28F cask heat test has been performed on the cask in the transport configuration and not in the storage configuration. The transport configuration fire analysis is normally less conservative than the storage configuration due to the radiation heat shielding included for transport. However, the homogeneous heating test performed heats all the cask surfaces equally whereas the heat from the postulated fire due to construction is from a single direction, the location of the fire. Therefore, transport configuration fire can be regarded as bounding the postulated site fire (GNB B 127/95E [7]).

The fire pressure analysis in GNB B 127/95E [7] concludes that, for the highest temperature of the cavity medium, i.e. for the maximum mean value resulting from the temperature of the hottest fuel rod and the cavity wall temperature, there is an overall pressure of approximately 354 kPa assuming 100% failed fuel cladding. Therefore, the integrity of the CASTORX/28F cask is not impaired as the fire pressure does not exceed the design pressure for normal operational conditions of 700 kPa.

- Loss of Adequate Cooling to the Casks

The report HI-2177722 [9] describes the evaluation performed to determine whether dust and other airborne debris generated during construction activities and deposited on the cask surfaces, will unacceptably hamper heat transfer from the casks for:

1. Airborne Dust

During the construction, water is used to suppress the generation of excessive clouds of dust. In addition, to ensure worker safety from exhaust fumes caused by internal combustion powered equipment, adequate ventilation is ensured at all times.

The combination of active dust control using water and constant natural ventilation will prevent quantities of airborne dust from reaching concentrations where radiated heat emitted from the cask would be blocked enough to be of concern. Additionally, a high concentration of airborne dust would immediately be visibly detected and the construction activities stopped as the environment will not be safe for the construction personnel.

2. Deposited Dust

Despite actions to limit airborne dust, some amount of construction dust will likely accumulate on the casks in the CSB. Periodic inspection and cleaning of the casks is commensurate with the observed rate of deposition. To ensure the casks are properly cooled between periodic cleanings a thermal analysis for a dust coated cask is performed.

The analysis results obtained, HI-2177722 [9], demonstrate that dust and other airborne debris generated during construction activities and deposited on the cask surfaces will not unacceptably hamper heat transfer.

Included in the installation design [1] is a requirement for the contractor to remove deposited dust from the CASTOR X/28F and the HI-STAR 100 casks at the end of work each day as determined based on the dust deposition rate and ALARA considerations.

The Eskom site supervisor will monitor the periodic inspection and cleaning of the casks and ensure that the CSB door and roof vents are maintained fully open during the construction activities.

- Loss of Electrical Supply

The loss of electrical supply which renders the CASTOR X/28F casks pressure monitoring equipment inoperable can be conservatively enveloped by the failure of the primary and/or secondary lid seal as the leak tightness of these seals is not apparent during this state.

SAR Section II 8.1.5 d) states that a leaking cask shall be moved to the fuel building for repair as soon as practicable but not later than 6 months from the date the leak was detected.

A leak of the HI-STAR 100 multi-purpose canister is not considered a credible failure as the canister is welded shut in accordance with the requirements of ASME IX with welding qualification in accordance with ANSI N14.5 [14]. Consequently, an electrical supply is not required to support its primary safety functions or operational requirements.

- Failure of the Cask Pressure Monitoring System

The failure of the CASTOR X/28F cask inter-lid pressure monitoring system can be conservatively enveloped by the failure of the primary and/or secondary lid seals as the leak tightness of these seals are unknown.

SAR Section II 8.1.5 d) states that a leaking cask shall be moved to the fuel building for repair as soon as practicable but *not later than 6 months from the date the leak was detected.*

Consequently, the failure of the CASTOR X/28F cask inter-lid pressure monitoring system is resolved as soon as practicable but not later than 6 months from the date of failure.

- *Cask Seal Failure*

SAR Section II 8.1.5 d) states that a leaking cask shall be moved to the fuel building for repair as soon as practicable but not later than 6 months from the date the leak was detected.

Consequently, the failure of the CASTOR X/28F seals is resolved as soon as practicable but not later than 6 months from the date of failure.

A leak from the HI-STAR 100 multi-purpose canister is not considered a credible failure as the canister is welded shut in accordance with the requirements of ASME IX with welding qualification in accordance with ANSI N14.5 [14]

- *Damage to Fuel Due to Construction Vibrations*

The repetitive vibrations and shocks experienced by the cask due to construction activities are equivalent to those experienced during normal road, rail, and sea transport, which will lead to significantly lower stresses than those experienced by the cask and its internals during all other design basis loads defined in Reference [3], Subsection 2.1.2.1. It is understood that the vibrations and shocks during construction activities are more frequent than the design basis accidents; however, they are equivalent to the vibratory motions experienced during transport. This loading condition is addressed in Reference [3], Subsection 2.6.5.

The CASTOR X/28F casks are similarly licensed under Reference [28] (IAEA Transportation Regulations).

- *CSB Structural Failure during the Construction of the CSB Pad*

In the CSB storage pad design it is described that geotechnical tests are performed on the soil below the existing CSB storage area to confirm that the design specified soil requirements has been achieved prior to installation of the new CSB storage pad. Consequently, as the foundations of the CSB walls will not be undermined, as they are at a similar level as the bottom of the existing storage area, the seismic capability of the CSB walls is unchanged during the construction of the new CSB storage pad.

- *Sabotage*

The CSB is located within a National Key Point and therefore the security controls are consistent with the National Key Points Act. Keys are controlled by Protective Services and RP for access into the CSB.

- *Human Error*

All industrial safety measures as required by Koeberg Plant Safety Regulations and sound industrial safety, health, and environmental (SHE) principles are incorporated into the overall project planning to meet the requirements of the OH&SA [16] and related regulations.

The health and safety file compiled by the contractor was accepted by Eskom. The file includes SHE requirements, risk assessments, method statement, pre-job briefs, checklists, and personnel qualification.

The risk assessment will discuss risks including hazards associated with each construction activity, consequences of the risk, control measures to prevent the risk, and actions to mitigate the risk.

Pre-job briefings for all activities on site shall be carried out in order to ensure that the details of the work plan are understood and that the appropriate safety measures and level of personal protective equipment are deployed.

2.4. Identify the design basis accidents in the SAR reviewed for impact by the activity/condition.

According to SAR sections III-4.4.5.1 and II-8.1.5, the design basis accidents associated with the casks are:

- Cask drops; and

- Cask seal leaks.

NOTE: The lifting, movement and placing of the casks (CASTOR X/28F and HI-STAR 100) during the construction is not evaluated here and is included in the safety case for LCR 1913.

2.5. Provide references reviewed for this safety evaluation (including SAR chapter references).

[1] 07147 DPDRR007 – Cask Storage Building (CSB) Storage Pad Upgrade

[2] DSG-310-211 Rev 5 – Spent Nuclear Fuel Transport and Storage Metal Casks

[3] Docket 71-9261, Rev 15 – Safety Analysis Report on the HI-STAR 100 Cask System

[4] Docket 72-1008, Rev 4A – Final Safety Analysis Report for the Holtec International Storage, Transport, and Repository

Cask System (HI-STAR 100 Cask System)

[5] Drawing 10988, Rev. 1 – Radiological Shield Wall for Storage Building

[6] Drawing 10941, Rev. 3 – ISFSI Pad Details

[7] GNB B 127/95E – Documents for Application of the Type B(U)F Transport Licence for the Transport and Storage Cask CASTOR X/28F

[8] GNB B 276/92E – Topical Safety Analysis Report for the Transport and Storage for 28 PWR Fuel Assemblies CASTOR X/28F

[9] HI-2177722 Rev 1 – CSB SARCA Cask Thermal Evaluation of Air and Surface Debris

[10] HI-2177726 Rev 1 – CSB SARCA Cask Fire Hazard Evaluation

[11] HI-2177728 Rev 2 – Slope Stability Analysis of the Temporary Slopes during ISFSI Pad Construction

[12] HI-2177743 Rev 1 – Cask Storage Building Safety Analysis Report For Construction Activities (SARCA) – Hazards Analysis

[13] HI-2177774 Rev 1 – Thermal Analyses of Cask Storage in CSB during Construction Activities.

[14] J2016-0001 Rev1 – Compatibility of the HI-STAR 100 Dry Storage Cask for Koeberg Type Spent Fuel

[15] JN603-PSA-001 – Safety Risk Evaluation of Additional Casks on the Koeberg Spent Fuel Storage Cask Assessment's Initiating Event Frequencies

[16] OHSA No 85/93 – Occupational Health and Safety Act No 85 of 1993

[17] PSA-R-T15-05 Rev 4 – Spent Fuel Cask Risk Assessment

[18] PSA-R-T15-08 Rev 2 – Risk Assessment of Additional Metal Casks

[19] RRTI-2556-001 Rev 1 – Seismic Stability and Structural Safety of the four CASTOR Casks During Phase 1 Modifications

[20] SAR Section I-3.2.11 Cask Storage Building

[21] SAR Section II-1.9.0.1 General Description of the Buildings

[22] SAR Section II-1.9.4.4.3 Dropping of a Transport/Storage Cask

[23] SAR Section II-8.1 Storage and Handling of Spent Fuel Shipping Casks

[24] SAR Section III-4.3.4.1 Fuel Handling Accidents

[25] SAR Section III-4.4 Radiological Consequences of Accidents

[26] SAR Section III-4.4.5 Fuel Handling Accident

[27] Deleted

[28] TS-R-1 – IAEA Regulations for the Safe Transport of Radioactive Material

[29] USNRC Certificate of Compliance CoC: 72-1008, Amendment 3 (Proposed)

2.6. Other discussion, if applicable.

None

3.0 IMPACT ON DESIGN / LICENSING BASIS

Is the activity/condition a change to or does it affect any of the following:

3.1.	Operating Technical Specifications?	YES ☐	NO ☒
3.2.	Radiation Protection Licencing Requirements?	YES ☐	NO ☒
3.3.	Emergency Operating Procedures/SAMGs?	YES ☐	NO ☒
3.4.	Emergency Plan?	YES ☐	NO ☒

Discuss any "YES" response(s) from the above:

N/A

4.0 EFFECT ON THE ACCIDENTS AND MALFUNCTIONS PREVIOUSLY EVALUATED IN THE SAR (RRM to Review)

4.1. Does the proposed activity/condition result in more than a minimal increase in the frequency of occurrence of an accident previously evaluated in the SAR? (KGA-025, Appendix 2, Section 2.0)

YES ☐ NO ☒

Explanation:

The accident evaluated in the SAR for dry storage casks is due to cask drops. This proposed activity however excludes lifting, movement and placing of the casks that could lead to dropping a cask causing an accident as evaluated in the SAR. Also, the frequency of all external hazards, including a CSB collapse accident due to an SSE event, is unchanged during the construction of the CSB storage pad.

Therefore, the CSB storage pad modification activities will not result in more than a minimal increase in the frequency of occurrence of an accident previously evaluated in the SAR.

4.2. Does the proposed activity/condition result in more than a minimal increase in the likelihood of occurrence of a malfunction of an SSC important to safety previously evaluated in the SAR? (KGA-025, Appendix 2, Section 3.0)

YES ☐ NO ☒

Explanation:

The relevant important to safety SSC evaluated in the SAR are the dry storage casks stored in the CSB. As presented in Section 2.3, the casks designed safety functions will not be impeded due to the CSB storage pad modification activities; therefore there will not be a more than minimal increase in the likelihood of an occurrence of a malfunction of an important to safety SSC. Additionally, the frequency of all external hazards, including the CSB collapse on the casks due to an SSE event, is unchanged during the construction of the CSB storage pad.

Therefore, the CSB storage pad modification activities will not result in more than a minimal increase in the likelihood of occurrence of a malfunction of an SSC important to safety previously evaluated in the SAR.

4.3. Does the proposed activity/condition result in more than a minimal increase in the consequences of an accident previously evaluated in the SAR? (KGA-025, Appendix 2, Section 4.0)

YES ☐ NO ☒

Explanation:

The accident evaluated in the SAR for dry storage casks is due to cask drops. This accident is however not applicable to this evaluation as the evaluation excludes lifting, movement and placing of the casks as discussed in section 1.0. Also, the CSB walls and roof structural seismic capability are not affected by storage pad construction.

Therefore, the CSB pad modification activities will not result in more than a minimal increase in the consequences of an accident previously evaluated in the SAR.

4.4. Does the proposed activity/condition result in more than a minimal increase in the consequences of a malfunction of an SSC important to safety previously evaluated in the SAR? (KGA-025, Appendix 2, Section 5.0)

YES ☐ NO ☒

Explanation:

The relevant important to safety SSC evaluated in the SAR are the dry storage casks stored in the CSB. As presented in Section 2.3, the casks designed safety functions will not be impeded due to the CSB storage pad modification activities therefore the construction of the CSB slab will not cause a more than minimal increase in the consequences of a malfunction of the dry storage casks. Additionally, the frequency of the CSB collapse on the casks due to an SSE event is unchanged during the construction of the CSB storage pad.

Therefore, the CSB storage pad modification will not result in more than a minimal increase in the consequences of a malfunction of an SSC important to safety previously evaluated in the SAR.

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5.0 IMPACT ON FISSION PRODUCT BARRIERS AS DESCRIBED IN THE SAR

5.1. Does the proposed activity/condition result in a design basis limit of a fission product barrier as described in the SAR being exceeded or altered? (KGA-025, Appendix 2, Section 8.0)

YES ☐ NO ☒

Comments:

Construction activities and storage of casks in the CSB do not affect the fuel cladding design basis parameters listed in KGA-025, as the potential structural and thermal failure modes listed in Section 2.3 have been evaluated in the design package to demonstrate that the design basis limit of a fission product barrier as described in the SAR is not exceeded or altered.

Concerning the casks integrity, the CASTOR X/28F casks primary and secondary seals in conjunction with the interspace pressure monitoring equipment, ensures the cask integrity is ensured. For the HI-STAR 100 cask, the multi-purpose canister (MPC) integrity is ensured as it is welded shut in accordance with the requirements of ASME IX with welding qualification in accordance with ANSI N14.5 [14]. The MPC is then loaded into the HI-STAR 100 overpack which incorporates a dual sealed lid. Also, the cavities of both the CASTOR X/28F and HI-STAR 100 casks are filled with inert helium gas to preclude degradation of the fuel cladding and promote efficient heat transfer.

6.0 IMPACT ON EVALUATION METHODS DESCRIBED IN THE SAR

6.1. Does the proposed activity/condition result in a departure from a method of evaluation described in the SAR used in establishing the design bases or in the safety analysis? (KGA-025, Appendix 2, Section 9.0)

YES ☐ NO ☒

Comments:

The modification to the CSB storage pad does not affect any evaluation methods in the Koeberg SAR.

Note that the evaluations of construction activities, which include the storage of casks as described in Section 2.1, were performed using methods described in the HI-STAR 100 FSAR which is approved by the USNRC, CoC 72-1008. The results of these calculations were verified to be applicable to the CASTOR X/28F casks.

Consequently, the CSB pad modification will not involve a change or departure from any method of evaluation in the SAR.

7.0 IMPACT ON BEYOND-DESIGN-BASIS ACCIDENTS (RRM to Perform)

7.1. Is there a more than minimal increase in baseline risk in the Koeberg Risk Assessment? (KGA-025, Appendix 2, Section 10.0) — YES ☐ NO ☒

Comments:

This safety evaluation deals only with the upgrade of the storage pad in the cask storage building. The Level 1 and Level 2 PSA will not be affected by this activity. However, the Level 3 PSA, specifically the site personnel risk assessment, was assessed as indicated below.

Risk to site personnel present in the cask storage building during the construction could result from (a) cask seal leaks and failures, (b) heavy aircraft crash, and (c) seismic activity during construction.

Note that no catastrophic seal leak leading to immediate depressurisation of the inter-lid space has been recorded to date. The frequency that both seals on a cask will develop slow leaks leading to a possible radioactive release was calculated to be 4.12E-4 per cask per year [18]. The construction activity in the CSB will not result in a change to this frequency. However, given that one slow leak was previously detected, it is required that the operability of the CASTOR X/28F casks inter-lid pressure monitoring system be maintained.

Given that regular checks for cask seal leaks and failures are performed, there will not be a more than minimal increase in the Level 3 PSA.

The frequency of a heavy aircraft crashing into the building, or any seismic activity is unchanged during the construction of the storage pad. For this reason, there will not be a more than minimal increase in baseline risk due to a heavy aircraft crash.

7.2. Is there, or would there be, a more than minimal impact on: (KGA-025, Appendix 2, Sections 11 and 12)

- the Emergency Operating Procedures (EOPs)? — YES ☐ NO ☒
- the Severe Accident Management Guidelines (SAMGs)? — YES ☐ NO ☒
- the Emergency Plan? — YES ☐ NO ☒

Comments: The construction of the storage pad in the cask storage building will have no more than minimal impact on the successful implementation of the above procedures and guidelines.

8.0 POTENTIAL FOR CREATION OF A NEW TYPE OF UNANALYSED EVENT (RRM to Review)

8.1. Does the proposed activity create a possibility for an accident of a type different than that previously evaluated in the SAR? (KGA-025, Appendix 2, Section 6.0) — YES ☐ NO ☒

Comments:

Having considered the credible failure modes associated with this activity as described in Section 2.3 and reviewed the different types of accidents evaluated in the SAR, the CSB pad modification activities will not create a possibility for an accident of a type different than that previously evaluated in the SAR.

8.2. Does the proposed activity create a possibility of a malfunction of an SSC important to safety with a result different to any previously evaluated in the SAR? (KGA-025, Appendix 2, Section 7.0) — YES ☐ NO ☒

Comments:

Having reviewed the SSCs affected by this activity in Section 2.2, and the credible failure modes associated with this activity as described in Section 2.3, the construction activities do not create a possibility of a malfunction of an SCC important to safety with a result different to that previously evaluated in the SAR.

Eskom	TITLE SAFETY EVALUATION FORM	Reference No.: KFA-048	
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		Associated Procedure: KAA-709	

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9.0 SAR REVIEW

SAR Sections Reviewed: *I-3.2.11; I-4.2.2.2; I-6.1.7; II-1-9.4.4.3; II-8.1; III-3.1.3; III-4.4; III-4.4.5; III-5.1.5.6 II-1.9.0.1, II-8.1, III-4.3.1.1.b, III-4.3.4.1 and III-4.4.5.1*

SAR Update Request raised? YES ☒ NO ☐ No: 2422 These SAR updates are implemented under LCR-1913 (pending NNR approval) described in Section 1.0.

Note: NNR approval is required for SAR updates.

10.0 NNR APPROVAL

Is this activity/condition:

- a change to an NIL-01 Licence Condition, LD, RD, or subsequent LCRs? YES ☐ NO ☒
- a change to a document that requires NNR approval as listed in Appendix 6? YES ☒ NO ☐
- a modification that requires NNR approval according to the requirements of LD-1012? YES ☒ NO ☐

Use the NNR Approval Impact Form to assist in answering the above.
Copies of NIL-01, LDs, and RDs can be found on g\\userg\nuclear engineering\design eng\SAFEVAL\Forms.

11.0 SAFETY EVALUATION CONCLUSION

Based upon the evaluation in Sections 4.0 to 10.0, update the CONCLUSION section on page 1.

ATTACHMENT A4

10941 Rev 3: ISFSI Pad Details Drawing:

REVISIONS				
REV	SUMMARY OF CHANGES/ INCORPORATED ECOS	PREPARED BY	DATE	VIR †
3	ADDED NOTE	DMF	SEE BELOW	SEE BELOW

GENERAL NOTES:

1. ALL MATERIALS AND THEIR INSTALLATION SHALL BE IN ACCORDANCE WITH THIS DRAWING AND THE CONTRACT DOCUMENTS. ALL WORK TO BE DONE IN ACCORDANCE WITH PROJECT PROCEDURES AND SPECIFICATIONS.
2. IN CASE OF CONFLICT BETWEEN THE DRAWINGS, NOTES, DETAILS, AND SPECIFICATIONS, THE CONTRACTOR SHALL CONTACT THE CONSTRUCTION MANAGER FOR INSTRUCTION PRIOR TO PROCEEDING. THE MOST STRINGENT REQUIREMENTS SHALL GOVERN.
3. ALL WORK SHALL BE PERFORMED IN ACCORDANCE WITH SITE SAFETY AND CONSTRUCTION PRACTICES.
4. ALL CONSTRUCTION PERSONNEL MUST RECEIVE ALL PROPER SAFETY TRAINING AND SAFETY ORIENTATION PRIOR TO PERFORMING ANY WORK ON KOEBERG NUCLEAR POWER STATION PROPERTY.
5. EXISTING FOOTINGS AND OTHER PHYSICAL FEATURES ARE BASED ON ORIGINAL DRAWINGS DONE BY BRUINETTE KRUGER STOFFBERG CONSULTING ENGINEERS. THE CONTRACTOR SHALL VERIFY ALL EXISTING CONDITIONS IN THE FIELD PRIOR TO THE START OF CONSTRUCTION. CONSTRUCTION MANAGEMENT WILL INDICATE APPLICABLE PLANT SURVEY MONUMENTATION TO BE USED BY THE CONTRACTOR.
6. THE EXISTENCE OF ALL UNDERGROUND FACILITIES SHALL BE INVESTIGATED AND VERIFIED BY THE CONTRACTOR AND HOLTEC IN THE FIELD PRIOR TO COMMENCING WORK. THE CONTRACTOR SHALL DETERMINE THE EXACT LOCATION AND DEPTH OF ALL UNDERGROUND FACILITIES AND UTILITIES WHETHER IN SERVICE OR ABANDONED, AND SHALL BE RESPONSIBLE FOR ANY AND ALL DAMAGE CAUSED.
7. A MINIMUM OF THREE (3) FEET SEPARATION WITH EXISTING STRUCTURES OR UTILITIES SHALL BE MAINTAINED WHEN USING POWERED EXCAVATING EQUIPMENT. IF THIS SEPARATION CANNOT BE MAINTAINED, POWERED EXCAVATING EQUIPMENT MAY BE USED WITH EXTREME CAUTION, AND PROVIDED THAT ADDITIONAL STEPS ARE TAKEN TO PROTECT THE COMMODITIES UNTIL THEY ARE FULLY EXPOSED AND COMPLETELY LOCATED. THE CONTRACTOR MAY USE HAND EXCAVATING OR HYDRO EXCAVATION TECHNIQUES TO EXPOSE AND COMPLETELY LOCATE THE ITEM PRIOR TO PROCEEDING WITH POWERED EXCAVATION EQUIPMENT. THE CONTRACTOR SHALL BE RESPONSIBLE FOR ALL REQUIRED SHORING AND BRACING, AS NEEDED.
8. DURING CONSTRUCTION, THE CONTRACTOR SHALL PROVIDE MAINTENANCE AND PROTECTION OF EXISTING STRUCTURES OR UTILITIES REGARDLESS OF WHETHER THEY ARE SHOWN ON THE DRAWINGS OR IDENTIFIED BY KOEBERG POWER STATION MANAGEMENT IN THE FIELD.
9. ALL WORK IN THE PROJECT AREA MUST BE COORDINATED WITH KOEBERG POWER STATION TO MINIMIZE ANY INTERRUPTION OF PLANT OPERATIONS.
10. THE CONTRACTOR SHALL NOTIFY THE RESPONSIBLE ENGINEER IMMEDIATELY IF ANY FIELD CONDITIONS ENCOUNTERED DIFFER MATERIALLY FROM THOSE REPRESENTED ON THE DRAWINGS OR IF SUCH CONDITIONS, IN THE CONTRACTOR'S OPINION, WOULD RENDER THE PROPOSED DESIGN INEFFECTIVE AND/OR INAPPROPRIATE.
11. DO NOT SCALE THE DRAWINGS. ADJACENT AND SURROUNDING PHYSICAL CONDITIONS, BUILDINGS, STRUCTURES, ETC. ARE SCHEMATIC ONLY EXCEPT WHERE DIMENSIONS ARE SHOWN THERETO.
12. CONTRACTOR'S BULK STORAGE AND MATERIAL LAYDOWN WILL BE PERMITTED IN SPECIFIED AREAS ON-SITE AS DESIGNATED BY THE CONSTRUCTION MANAGER. THE CONTRACTOR IS RESPONSIBLE FOR THE SECURITY OF MATERIALS AND EQUIPMENT. CLEAN-UP OF THIS AREA WILL BE RETURNED TO "AS FOUND" OR BETTER CONDITION IMMEDIATELY FOLLOWING THE PROJECT.
13. THE CONTRACTOR IS RESPONSIBLE FOR CLEANING ALL ROADS AND PAVED AREAS TO REMOVE DIRT AND CONSTRUCTION DEBRIS CAUSED BY THE WORK. THE CONTRACTOR MAY BE REQUESTED BY KOEBERG POWER STATION MANAGEMENT TO PERFORM CLEAN-UP OUTSIDE OF THE WORK AREA CAUSED DURING CONSTRUCTION AT THE CONTRACTOR'S COST.
14. ALL SUBCONTRACTORS AND TIER SUBCONTRACTORS ARE ALSO SUBJECT TO THE REQUIREMENTS WITHIN THE CONTRACT DOCUMENTS.
15. IT IS MANDATORY AT EACH REVISION TO COMPLETE THE REVIEW & APPROVAL LOG STORED IN HOLTEC'S DIRECTORY N:/PDOXWIN/WORKING/DBAL BY ALL RELEVANT TECHNICAL DISCIPLINES, PM AND QA PERSONNEL. EACH ATTACHED DRAWING SHEET CONTAINS ANNOTATED TRIANGLES INDICATING THE REVISION TO THE DRAWING.
16. THE SAFETY CATEGORY OF A SUB-COMPONENT IS THE HIGHEST SAFETY LEVEL OF ALL PARTS THAT MAKE UP THE SUB-COMPONENT. THE FOLLOWING SAFETY CATEGORIES ARE RECOGNIZED UNDER HOLTEC INTERNATIONAL'S QA PROGRAM:
    - SR = SAFETY RELATED, NSR = NOT SAFETY RELATED
    - ITS-A = IMPORTANT TO SAFETY CATEGORY A
    - ITS-B = IMPORTANT TO SAFETY CATEGORY B
    - ITS-C = IMPORTANT TO SAFETY CATEGORY C
    - NITS = NOT IMPORTANT TO SAFETY
17. THE FOLLOWING MINIMUM ITS CLASSIFICATIONS FOR THE ISFSI PAD SUB COMPONENTS . ARE AS FOLLOWS:

ITEM	ITS CLASSIFICATION
ISFSI PAD CONCRETE	ITS-C
REBAR	ITS-C
REBAR CHAIRS AND STANDEES	NITS
REBAR WIRE TIES	NITS

EARTHWORK:

1. ENGINEERED FILL:
    A. ENGINEERED FILL SHALL CONSIST OF DURABLE, CLEAN, WELL-GRADED SAND AND CRUSHED STONE, REASONABLY FREE OF ORGANIC MATERIAL, LOAM, SILT, CLAY, SNOW, ICE, OR OTHER OBJECTIONABLE MATERIALS. THE BACKFILL SHALL CONFORM TO THE FOLLOWING GRADATION REQUIREMENTS:

SIEVE DESIGNATION	% PASSING BY WEIGHT
75 mm	100
NO. 4 (4.75mm)	45-75
NO. 100 (160um)	0-12
NO. 200 (75um)	0-6

    B. ENGINEERED FILL SHALL HAVE A YOUNG'S MODULUS BETWEEN 35 AND 193 MPA, AND A MINIMUM DENSITY OF 1.6g/cm^3.
    C. IF EXISTING FILL IS CONFIRMED TO MEET THE REQUIREMENTS IN NOTE 1.B (YOUNG'S MODULUS AND DENSITY) ABOVE, IT MAY BE USED AS THE ENGINEERED FILL LAYER.
2. CONTROLLED LOW-STRENGTH MATERIAL (CLSM)
    A. CONTROLLED LOW-STRENGTH MATERIAL (CLSM) FOR THE NON-STRUCTURAL FILL SHALL BE MANUFACTURED USING THE GUIDELINES AS GIVEN IN ACI 229R. THE MINIMUM 28 DAY STRENGTH IS 0.5 MPA.
3. CRUSHED STONE
    A. UNLESS OTHERWISE SPECIFIED, AGGREGATE SHALL BE CRUSHED STONE AND GRADING SHALL COMPLY WITH ASTM D448 #57 GRADATION OR EQUIVALENT SOUTH AFRICAN NATIONAL STANDARD.
4. GEOSYNTHETICS
    A. GEOTEXTILE FABRIC SHALL BE MIRAFI 135N OR AN APPROVED EQUIVALENT.
5. IN GENERAL, STRUCTURAL FILL AND COMMON FILL SHALL BE COMPACTED TO 95 PERCENT MINIMUM OF THE MODIFIED PROCTOR MAXIMUM DRY DENSITY (ASTM D1557 OR EQUIVALENT SOUTH AFRICAN NATIONAL STANDARD).
6. CONTRACTOR SHALL ENSURE THAT ALL FINISHED GRADING AREAS HAVE POSITIVE DRAINAGE AWAY FROM THE PADS AND SLABS. FINISHED GRADE ELEVATIONS SHALL BE WITHIN ±30mm AS INDICATED ON THE DRAWINGS.
7. SPECIAL CARE SHALL BE TAKEN TO NOT DISTURB SOIL BENEATH WALL FOUNDATIONS.

CONCRETE REINFORCEMENT:

1. ALL REINFORCING STEEL SHALL BE MANUFACTURED FROM HIGH STRENGTH BILLET STEEL CONFORMING TO SANS 920:2011 GRADE 450 MPA.
2. CHAIRS, BOLSTERS, BAR SUPPORTS, SPACERS, ETC. SHALL BE SIZED AND SHAPED FOR STRENGTH AND SUPPORT OF REINFORCEMENT DURING CONCRETE PLACEMENT CONDITIONS.
3. SPECIAL CHAIRS, BOLSTERS, BAR SUPPORTS AND SPACERS ADJACENT TO WEATHER EXPOSED CONCRETE SURFACES SHALL BE PLASTIC COATED STEEL, SIZED AND SHAPED AS REQUIRED.
4. REBAR MANUFACTURER SHALL PROVIDE REBAR SHOP DRAWINGS AND BEND SCHEDULE PER SANS 282.
5. REINFORCEMENT INSTALLATION TOLERANCES SHALL BE IN ACCORDANCE WITH ACI 117 UNLESS SPECIFIED BELOW:

    CENTER-CENTER SPACING: +/- 75mm

    CLEAR COVER TOLERANCE: +/- 12mm

CAST IN PLACE CONCRETE:

1. ALL CONCRETE SHALL HAVE A MINIMUM COMPRESSIVE STRENGTH AT 28 DAYS OF 27.6 MPA AND A MAXIMUM OF 41.4 MPA.
2. THE MAXIMUM COMPRESSIVE STRENGTH MAY BE EXCEEDED IF THE HI-STAR 100 CASK IS STORED HORIZONTALLY IN A SECURED CONFIGURATION AND QUALIFIED ACCORDING TO SECTION 2.2.3.2 OF HI-STAR 100 FSAR, REV 4. ESKOM MUST CONFIRM IN WRITING IF THIS REQUIREMENT CAN BE EXCEEDED UPON VERIFICATION THAT THESE LICENSE CONDITIONS ARE MET.
3. PREPARE CONCRETE STRENGTH TEST SPECIMENS AND CURE IN ACCORDANCE WITH ASTM C31. EACH SET SHALL CONSIST OF A MINIMUM OF 9 CYLINDERS FOR 6"x12" CYLINDERS AND 12 CYLINDERS FOR 4"x8" CYLINDERS.
4. THE TOP SURFACE OF THE ISFSI PAD SHALL HAVE A BROOMED FINISH.
5. IF NEEDED, CONSTRUCTION JOINTS SHALL BE COORDINATED WITH THE SITE PROJECT MANAGER OR HIS DESIGNEE. CONSTRUCTION JOINTS SHALL NOT BE PLACED UNDER FUTURE CASK LOCATIONS (PERMANENT OR TEMPORARY). IT IS UP TO THE DISCRETION OF THE PROJECT MANAGER AS TO WHERE THE CONSTRUCTION JOINTS WILL LAY. SEE "CONSTRUCTION JOINT" DETAIL ON SHEET 3.
6. THE ISFSI PAD TOP SURFACE SHALL BE CONSIDERED TO HAVE A "MODERATELY FLAT" SURFACE CLASSIFICATION BY THE MANUAL STRAIGHTEDGE METHOD.
    A. FLATNESS SHALL BE CHECKED BY MANUALLY PLACING A 3m STRAIGHTEDGE ANYWHERE ON THE SLAB AND ALLOWING IT TO REST NATURALLY ON THE TEST SURFACE. THE GAP UNDER THE STRAIGHTEDGE AND BETWEEN THE SUPPORT POINTS SHALL NOT EXCEED THE BELOW CRITERIA.

FLOOR SURFACE CLASSIFICATION	MAXIMUM GAP 90% COMPLIANCE SAMPLES NOT TO EXCEED	MAXIMUM GAP 100% COMPLIANCE SAMPLES NOT TO EXCEED
MODERATELY FLAT	10mm	16mm

LEGEND

ITEM BALLOON (X)

REVISION SYMBOL

FLAG NOTE

UNLESS NOTED OTHERWISE
ALL DIMENSIONS ARE IN INCHES
MILLIMETER DIMENSIONS SHOWN IN [ ]
DIMENSIONING AND TOLERANCING TO BE INTERPRETED PER ASME Y14.5M-1994
ALL SURFACES SHALL HAVE A FINISH OF 250 Ra OR BETTER
REMOVE BURRS & BREAK SHARP EDGES 1/16" CHAMFER OR RADIUS MAXIMUM
DO NOT SCALE OFF DRAWING
TOLERANCES:
FRACTIONAL

<1"	±1/8"
1" TO 6"	±1/4"
6" TO 10'	±1"
>10'	±2"

HOLTEC INTERNATIONAL
NUCLEAR POWER DIVISION
HOLTEC TECHNOLOGY CAMPUS
ONE HOLTEC BOULEVARD
CAMDEN, NJ 08104 (USA)

PROJECT / CLIENT: ESKOM

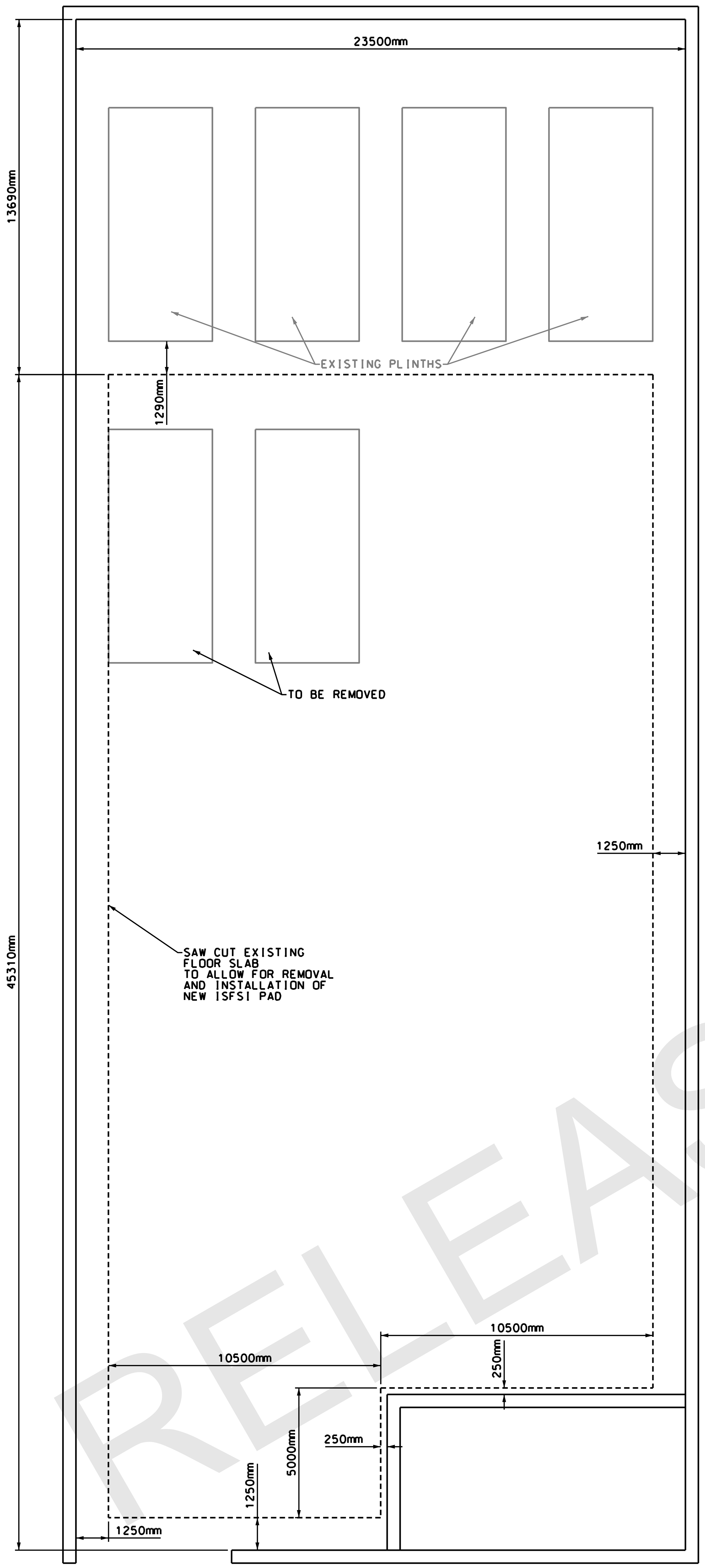
TITLE: ISFSI PAD DETAILS PHASE 1

PO NO.

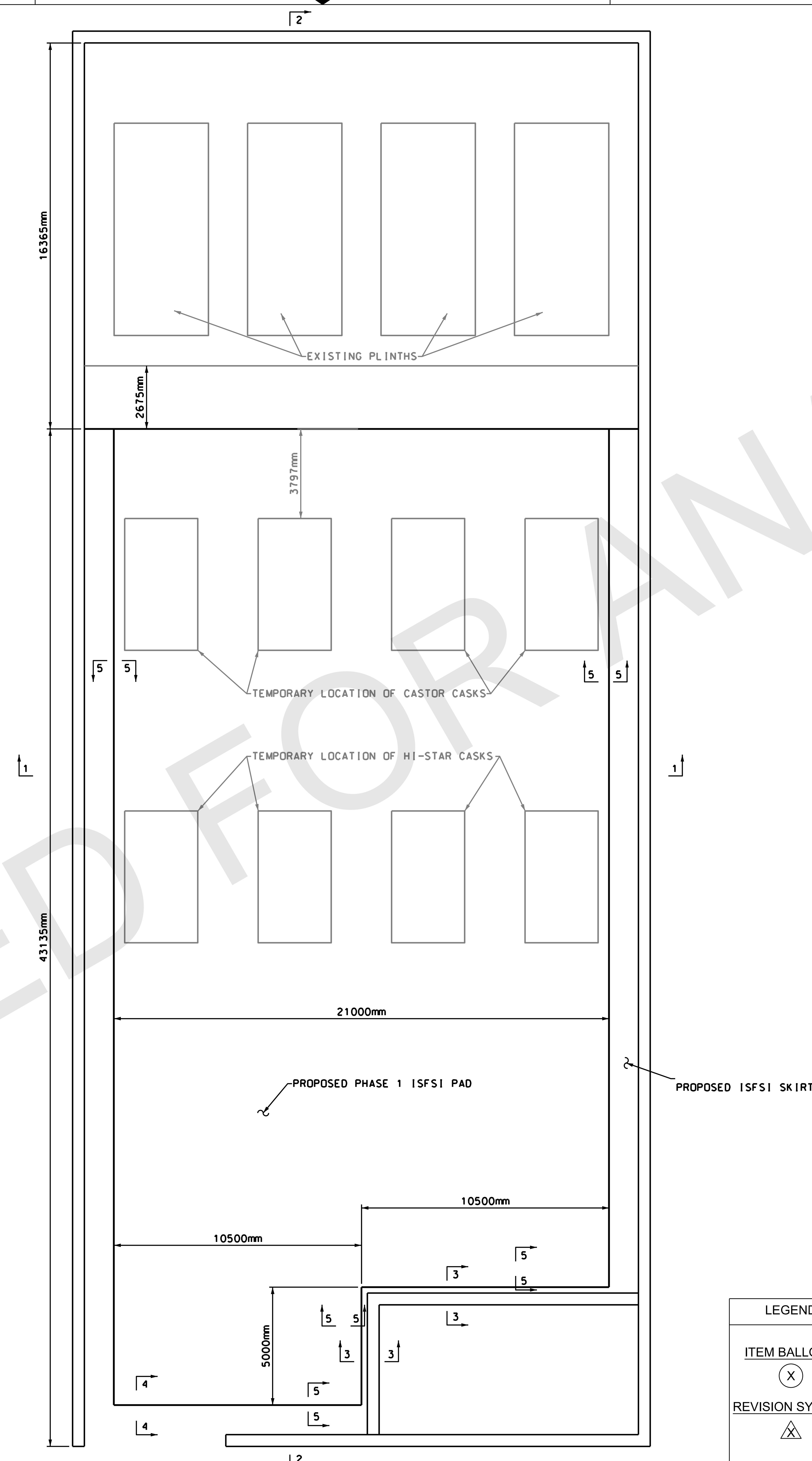
SIZE	PROJECT NO.	DRAWING NO.	SHEET	REV.
D	2556	10941	1 OF 5	3

SCALE: NTS
FILE PATH: ?:\DRAWING PATH

THIS DRAWING HAS BEEN SIGNED OFF IN HOLTEC'S SYSTEM. VIR # =14447 DATED:10/20/2017



PLAN VIEW
PHASE 1 SAW CUT LOCATIONS
NOT TO SCALE



PLAN VIEW
PHASE 1 ISFSI PAD LOCATION
NOT TO SCALE

NOTES:

1. SEE SHEET 1 FOR GENERAL NOTES
2. UPON COMPLETION OF PHASE 1 ISFSI PAD, THE 4 EXISTING CASTOR CASKS, ALONG WITH 4 ADDITIONAL HI-STAR CASKS, WILL BE TRANSFERRED TO PHASE 1 ISFSI PAD AS SHOWN. SPACING OF THE CASKS SHALL MATCH DRAWING 10671 WITH A 3.797m OFFSET FROM THE EDGE OF THE PAD.

LEGEND

ITEM BALLOON

REVISION SYMBOL

FLAG NOTE

UNLESS NOTED OTHERWISE

ALL DIMENSIONS ARE IN INCHES

MILLIMETER DIMENSIONS SHOWN IN [ ]

DIMENSIONING AND TOLERANCING TO BE INTERPRETED PER ASME Y14.5M-1994

ALL SURFACES SHALL HAVE A FINISH OF 250 Ra OR BETTER

REMOVE BURRS & BREAK SHARP EDGES 1/16" CHAMFER OR RADIUS MAXIMUM

DO NOT SCALE OFF DRAWING

TOLERANCES:

FRACTIONAL

<1"	±1/8"
1" TO 6"	±1/4"
6" TO 10'	±1"
>10'	±2"

HOLTEC INTERNATIONAL
NUCLEAR POWER DIVISION
HOLTEC TECHNOLOGY CAMPUS
ONE HOLTEC BOULEVARD
CAMDEN, NJ 08104 (USA)

PO NO.

PROJECT / CLIENT: ESKOM

TITLE: ISFSI PAD DETAILS PHASE 1

SIZE	PROJECT NO.	DRAWING NO.	SHEET	REV.
D	2556	10941	2 OF 5	3

SCALE: NTS | FILE PATH: ?:\DRAWING PATH