HOLTEC
INTERNATIONAL

Holtec Center, One Holtec Drive, Marlton, NJ 08053
Telephone (856) 797- 0900
Fax (856) 797 - 0909

STRUCTURAL CALCULATION PACKAGE FOR HI-STORE CIS FACILITY

FOR

HOLTEC

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11.	SUPP 10	PN	3/27/17	678835						
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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:

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 in the N-drive of 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 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".

HOLTEC SAFETY SIGNIFICANT DOCUMENTS

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 has been 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 referencable sources. Any assumed input data is so identified.
- All significant assumptions are stated.
- The analysis methodology is consistent with the physics of the problem.
- Any computer code and its specific versions used in the work have been formally admitted for use within the company's QA system.
- The format and content of the document is in accordance with the applicable Holtec quality procedure.
- The material content of the report 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 report, 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 NRC 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.

Supplement No. 1 - HI-TRAC CS Lifting Analysis (14 pages including cover page)
Supplement No. 2 - HI-TRAC CS Tornado Wind and Missile Analyses (28 pages including cover page)
Supplement No. 3 - HI-STAR 190 Lift Yoke Stress Analysis (21 pages including cover page)
Supplement No. 4 - HI-TRAC CS Lift Yoke Stress Analysis (21 pages including cover page)
Supplement No. 5 - HI-TRAC CS Stack-up Analyses at CTF and UMAX (47 pages including cover page)
Supplement No. 6 - VCT, HI-TRAC CS and HI-STAR 190 Seismic Stability Evaluations (27 pages including cover page)
Supplement No. 7 - MPC Lift Attachment Stress Analysis (14 pages including cover page)
Supplement No. 8 - MPC Lift Attachment Connector Stress Analysis (16 pages including cover page)
Supplement No. 9 - HI-STAR 190 Horizontal Lift Beam Stress Analysis (35 pages including cover page)

Supplement No. 10 - Fatigue Evaluation of HI-TRAC CS and Lifting Ancillaries (17 pages including cover page)
Supplement No. 11 - CTB Slab and CTF Foundation Slab Structural Evaluations (27 pages including cover page)
Supplement No. 12 - HI-TRAC CS Lift Links Stress Analysis (9 pages including cover page)
Supplement No. 13 - HI-STAR 190 Tilt Frame and Saddle Stress Analyses (56 pages including cover page)
Supplement No. 14 - Evaluation of CTB Collapse on HI-TRAC CS and HI-STAR 190 (17 pages including cover page)

REVISION LOG

Revision 0 – Original Issue

PREFACE

This Calculation Package has been prepared pursuant to the provisions of Holtec Quality Procedures (HQPs) 3.0, 3.2 and 3.3, which require that all analyses utilized in support of the design of a safety-related or important-to-safety structure, component, or system be fully documented such that the analyses can be reproduced at *any time in the future* by a specialist trained in the discipline(s) involved. HQPs 3.2 and 3.3 set down a rigid format structure for the content and organization of Calculation Packages that are intended to create a document that is complete in terms of the exhaustiveness of content. The Calculation Packages, however, lack the narration smoothness of a Technical Report, and are not intended to serve as a Technical Report.

This Calculation Package acts as a compendium of all calculations supporting HI-STORE Consolidated Interim Storage (CIS) Facility that require supporting documentation that is not part of a stand-alone report. These calculations may support statements or summaries made in the Licensing Report on the HI-STORE CIS Facility (HI-2167374, Chapters 4 or 5 or 15). A discussion of the technical work included may later be incorporated in the SAR as applicable. Each calculation is self-contained and has a cover sheet that briefly identifies the purpose of the calculation and ties it to any associated electronic change order (ECO). Assumptions, references to finite element work, etc. are within the individual calculation. Therefore, this report contains no "list of files" and its storage location is per the footer on this page. The HQP requirements for calculation packages are followed to the extent practical within each calculation.

It is intended that updates to the report, in the form of supplements containing one or more individual calculations, will occur at reasonable intervals to maintain the document current. No new calculation may be referenced until it is officially made part of a supplement in this report and the report revision is updated.

Revisions shall be made, as necessary, to maintain the report as a living document.

1.0 INTRODUCTION AND SCOPE

This Calculation Package is compiled to provide archival information to supplement the material presented in the HI-STORE CIS Facility SAR [11.2.1]. In particular, this Calculation Package contains structural and seismic calculations related to HI-TRAC CS transfer cask, HI-STAR 190 transport cask, Vertical Cask Transporter (VCT), Cask Transfer Building (CTB) slab and related ancillary equipment. The material presented in this Calculation Package is not needed to comprehend the material presented in the above-mentioned Technical Report (which is a self-contained document in full compliance with the USNRC regulations), unless the reader wishes to examine the computational details. Herein, only specific “singular” calculations that support a specific SAR result are documented. Where a large body of calculations is necessary to support a SAR conclusion, this calculation package may be supplemented by other specialized reports that deal exclusively with the single topic requiring a substantial calculation effort. The results from these specialized calculation packages are simply summarized in the SAR.

Because of its function as a repository of analyses performed on the subject of its scope, this document will be revised only if an error is discovered in the computations or the equipment design is modified. Additional analyses in the future, supporting either a new SAR (or FSAR) amendment or a change supported by a 72.48 evaluation, will 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.)

In order to fully understand the format and layout of this Calculation Package, it is necessary to understand its two key attributes. First, unlike most calculation packages, this package contains a multitude of discrete analyses, all of which share a common body of input data, but are otherwise entirely distinct in their methods, models, and computer simulations. This calculation package is in fact a compendium of an array of distinct calculations.

All new SAR and FSAR submittals requiring structural calculations are supported by the work herein and by other specialized calculation packages.

2.0 METHODOLOGY

Calculation specific supplements are attached to this report. In general, the problem descriptions are provided in the introductory section of each calculation in the HI-STORE CIS Facility Licensing Report [11.2.1]. The problem descriptions, unique to each calculation, include the description of the component to be analyzed, the nature and source of the applied loading on the component, and the acceptance criteria. Where the calculation performed does not yet appear in summary form in the Technical Report, the calculation itself is complete insofar as having a full description of the problem, methodology, etc.

All structural and seismic calculations are either based on classical strength of materials solutions, or are based on finite element numerical analysis. Each calculation contains detailed explanation of the analysis methods. As noted earlier, this Calculation Package contains supporting calculations for results that may only be summarized in the HI-STORE SAR [11.2.1].

3.0 ACCEPTANCE CRITERIA

This calculation package contains one or more supplements that deal with specific calculation items. If acceptance criteria are different for the individual calculations, then the appropriate acceptance criteria associated with each individual calculation are stated within the specific supplement.

The design criteria are compiled in Chapter 4 of the HI-STORE SAR [11.2.1]. The design criteria represent the basis for the acceptance criteria for the design of the systems, structures and components (SSCs) at HI-STORE CIS Facility. The applicable stress limits for the primary steel structures at the HI-STORE CIS Facility are listed in Chapter 4 of HI-STORE SAR [11.2.1]. The components of HI-TRAC CS are designed to meet the stress limits of ASME Code, Section III, Subsection NF [11.1.6] per Chapter 4 of [11.2.1]. The material properties of all steel structures used in the evaluations in this calculation package are obtained from one of the following:

i. Section 3.3 of HI-STORM FW FSAR [11.2.3]
ii. Section 3.3 of HI-STORM UMAX FSAR [11.2.2]
iii. ASME Code, Section II, Part A [11.1.3] and/or Part D [11.1.4]
iv. ASTM Standards, ASTM International (specific standard will be referred to in applicable supplements)
v. Material manufacturers' catalog for special materials (referred to in applicable supplements)

4.0 ASSUMPTIONS

In general, each calculation in this package contains a unique set of conservative analysis assumptions. In most cases these assumptions are listed under a separate section in each of the calculations; for some calculations that supplement work already detailed in the SAR or in another calculation, references are made to the originating document section for the assumptions.

5.0 INPUT DATA

Input data is provided in the calculation supplements as needed for the specific analysis**.** Data input requirements for geometry, material properties, design and acceptance criteria, and applicable load combinations along with their references are provided in individual supplements.

The sources of the input data that are repetitively used are listed as references in Section 11.

6.0 COMPUTER CODES

The main section of this report is written using Microsoft Word, while the calculation supplements are prepared using Mathcad and/or Microsoft Word, and contain manual calculations and/or finite element results. The computer codes used are documented and referenced within each supplement.

All computer codes used for the analysis and design of SSCs at HI-STORE CIS Facility are approved under Holtec's QA program. A complete listing of Holtec Approved Computer Program List is provided in [11.1.10].

7.0 ANALYSES

Analyses to support the SAR are contained in the form of supplements. As new supporting calculations are added, the revision log and the table of contents will note the additions or modifications to this document.

8.0 COMPUTER FILES

All relevant computer files associated with this calculation package are archived on the Holtec Server at: *G:\Projects\5025\REPORTS\Structural Reports\HI-2177585 (HI-STORE CISF Calc Package)*.

A directory listing appropriate to the supplements is included within each supplement.

9.0 RESULTS OF ANALYSES

All calculations are documented, as appropriate, in Chapter 5 of HI-STORE SAR [11.2.1] along with a brief description of the analysis. The analysis evaluation contains details of the analysis results and the comparison of the result to the applicable code allowables. The design adequacy is also conclusively demonstrated by the computation of the positive margins of safety. The specific calculations within each supplement also evaluate, if applicable, the margins of safety and the results where applicable.

10.0 SUMMARY AND CONCLUSIONS

This Calculation Package supports the structural integrity evaluations of the SSCs for HI-STORE CIF Facility required by the 10CFR72 Submittal. All analysis calculations and documentation meet Holtec's QA requirements and procedures.

11.0 REFERENCES

11.1 Generic References

A comprehensive list of all references that may be applicable to some or all of the specific calculations performed within this document are given below. Not all references need to be cited within this document to be contained in this comprehensive listing.

[11.1.1] NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants", United States Nuclear Regulatory Commission, July 1980.

[11.1.2] ANSI N14.6-1993, "American National Standard for Special Lifting Devices for Shipping Containers Weighing 10000 Pounds (4500 kg) or More for Nuclear Materials", American National Standards Institute, Inc.

[11.1.3] ASME Boiler & Pressure Vessel Code, Section II, Part A, 2010.

[11.1.4] ASME Boiler & Pressure Vessel Code, Section II, Part D, 2010.

[11.1.5] American Concrete Institute, "Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05)".

[11.1.6] ASME Boiler & Pressure Vessel Code, Section III, Subsection NF, 2010.

[11.1.7] ASME Boiler & Pressure Vessel Code, Section III, Appendices, 2010.

[11.1.8] AISC, "Manual of Steel Construction", 9th Edition or later.

[11.1.9] J. Shigley and C. Mischke, "Mechanical Engineering Design", 5th Edition or later, McGraw-Hill.

[11.1.10] Holtec Approved Computer Program List (ACPL), Revision 342.

11.2 Specific References

In addition to the comprehensive reference list provided in Section 11.1, additional specific references are cited below. Additional references, where applicable, are cited in the respective supplements.

[11.2.1] Licensing Report on the HI-STORE CIS Facility, HI-2167374, Revision 0.

[11.2.2] Final Safety Analysis Report on the HI-STORM UMAX Canister Storage System, HI-2115090, Revision 3.

[11.2.3] Final Safety Analysis Report on the HI-STORM FW MPC Storage System, HI-2114830, Revision 4.

[11.2.4] Holtec Drawings:

10868, HI-TRAC CS Licensing Drawing, Revision 0.

10875, HI-STORM UMAX Vertical Ventilated Module, Version C, Revision 0.

10889, MPC Lifting Device Extension Licensing Drawing, Revision 1.

10891, MPC Lift Attachment Licensing Drawing, Revision 1.

10894, Transport Cask Horizontal Lift Beam Licensing Drawing, Revision 0.

10895, Canister Transfer Facility (CTF) Licensing Drawing, Revision 0.

10899, Tilt Frame and Saddle Licensing Drawing, Revision 0.

10900, Lift Yoke for HI-TRAC CS Licensing Drawing, Revision 1.

10901, HI-TRAC CS Lift Link Licensing Drawing, Revision 0.

10902, Lift Yoke for HI-STAR 190 Licensing Drawing, Revision 1.

10912, Cask Transfer Building Floor Slab, Revision 0.

9841, HI-STAR 190 Cask Assembly Licensing Drawing, Revision 0.

12.0 LIST OF SUPPLEMENTS

Supplement No.	Description	In Support of	Revision	Specific Locations in SAR†
1	HI-TRAC CS Lifting Analysis	HI-STORE SAR	0	Subsection 5.4.2 Table 5.4.2
2	HI-TRAC CS Tornado Wind and Missile Analyses	HI-STORE SAR	0	Subsection 5.4.2 Table 5.4.3 Figure 5.4.2
3	HI-STAR 190 Lift Yoke Stress Analysis	HI-STORE SAR	0	Subsection 5.4.4 Table 5.4.4
4	HI-TRAC CS Lift Yoke Stress Analysis	HI-STORE SAR	0	Subsection 5.4.6 Table 5.4.6
5	HI-TRAC CS Stack-up Analyses at CTF and UMAX	HI-STORE SAR	0	Subsection 5.4.2 Table 5.4.1 Figure 5.4.1
6	VCT, HI-TRAC CS and HI-STAR 190 Seismic Stability Evaluations	HI-STORE SAR	0	Subsections 5.4.2 and 5.5.2 Tables 5.4.7 and 5.5.2
7	MPC Lift Attachment Stress Analysis	HI-STORE SAR	0	Subsection 5.4.5 and Table 5.4.5
8	MPC Lift Attachment Connector Stress Analysis	HI-STORE SAR	0	Subsection 5.4.6 and Table 5.4.6
9	HI-STAR 190 Horizontal Lift Beam Stress Analysis	HI-STORE SAR	0	Subsection 5.4.6 and Table 5.4.6
10	Fatigue Evaluation of HI-TRAC CS and Lifting Ancillaries	HI-STORE SAR	0	Subsections 5.4.2 and 5.4.6 Tables
11	CTB Slab and CTF Foundation Slab Structural Evaluations	HI-STORE SAR	0	Subsections 5.3.2 and 5.3.3 Table 5.3.2
12	HI-TRAC CS Lift Links Stress Analysis	HI-STORE SAR	0	Subsection 5.4.6 and Table 5.4.6
13	HI-STAR 190 Tilt Frame and Saddle Stress Analyses	HI-STORE SAR	0	Subsection 5.5.1 Table 5.5.1
14	Evaluation of CTB Collapse on HI-TRAC CS and HI-STAR 190	HI-STORE SAR	0	Subsection 5.4.2 Figures 5.4.3 to 5.4.6

†Where minor changes to a design parameter result in an insignificant effect on the computed safety factors, a revision of the results and associated data in the tables of the HI-STORE SAR [11.2.1] is not mandatory. The Unconditionally Safe Threshold (UST) value, as defined in Chapter 1 of HI-STORE SAR [11.2.1], is set at 1.20 for all structural evaluations, i.e., only if a safety factor drops below 1.20 because of a design change, a revision to the results in the SAR is mandatory.

HOLTEC CALCULATION

Title: ____________________HI-TRAC CS Lifting Analysis________________________

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**1**

CALCULATION SUMMARY INFORMATION

Scope: This calculation involves the stress analysis of the lifting trunnions and the bottom lid of the HI-TRAC CS.

Method: The lifting trunnions and the bottom lid are analyzed using a mechanics of materials method with the trunnions considered as short beams and the bottom lid considered as a plate.

FSAR LOCATIONS

Text (Chapter): Subsection 5.4.2

Tables: 5.4.2

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	ASK 03/16/2017	ARK & VRP 03/24/2017
1		
2		

The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

This Calculation is archived in the above-referenced Calculation Package as a labeled supplement. This document may be shared as an autonomous piece of work with external organizations and revised, if necessary, to secure their concurrence to the proposed change.

Note 1: All analyses performed to respond to a query or to initiate a design change are archived in a new Calculation Package or added to an existing Calculation Package as a Supplement and the revision number of the Calculation Package is advanced. A supplement to a Calculation Package may consist of one analysis or several discrete analyses (each containing this cover sheet) supporting several ECOs.

SUPPLEMENT 1 - HI-TRAC CS LIFTING ANALYSIS

1.1 Introduction and Description

This Appendix documents the structural analysis of the HI-TRAC CS under lifting conditions. The objective of this analysis is to demonstrate that under any lifting condition, the primary stresses in the lifting trunnions do not exceed allowable limits per [2.1]. In addition, the calculation also analyzes the HI-TRAC CS bottom lid under lifting loads. The Appendix is self contained; all references cited are listed in Section 1.5. All input dimensions are obtained from [1.5].

The HI-TRAC CS is equipped with four trunnions (2 at top & 2 at bottom). The top two trunnions are used for lifting and they must be capable of supporting a fully loaded HI-TRAC CS in a vertical orientation (i.e., a 2-point vertical lift). The bottom two trunnions are used only for rotation during up-ending or down-ending the HI-TRAC CS.

The lifting trunnions are inserted into the hole on the cask which is welded to the body of the cask. The trunnions are welded to the cask shell, the ribs and the inner shell which prevents the trunnions from backing out.

The bottom lid is designed to withstand the weight of loaded MPC during lifting process.The uniquely designed bottom lid slides and allow the loaded MPC to be transferred from HI-TRAC CS cask.

This Appendix is written using the Mathcad computer code [1.1]. The notation ":=" represents the equal sign for a defined calculation. The notation "=" represents a computed response or answer.

1.2 Methodology and Acceptance Criteria

Methodology

The lifting trunnions are analyzed using mechanics of materials method with the trunnions considered as short beams. Stresses in both the trunnions and in the HI-TRAC CS cask are calculated under the specified load.

Classical formulae of strength of materials and for plate stress are used for bottom lid.

Acceptance Criteria

The two upper lifting trunnions shall be designed to the meet the increased safety factors per ANSI N14.6 (i.e, lesser of Sy/6 and Su/10). Considering de sing safety factors against the material yield strength is conservative and is not mandated for the lifting attachments or points per [2.1].

All other steel members, including welded connections, shall meet the Level A stress limits per ASME Section III, Subsection NF.

The two bottom trunnions shall meet the stress limits per ASME, Section III, Subsection NF.

1.3 Materials and Material Properties [1.6]

The trunnions are made of SA-564 Gr. 630 H1100 material.
The HI-TRAC CS cask material is A516 GRADE 70 material.
The shield gate spacer support material is A36.

The trunnion material yield strength,@350°F [1.8] $S_y := 100.0 \cdot ksi$

The trunnion material ultimate strength,@350°F [1.8] $S_u := 138.0 \cdot ksi$

The trunnion material young modulus,@350°F [1.8] $E := 29000 \cdot ksi$

The cask material yield strength,@350°F (Table 3.3.2 [1.6]) $S_{yc} := 33.05 \cdot ksi$

The cask material ultimate strength,@350°F (Table 3.3.2 [1.6]) $S_{uc} := 70.00 \cdot ksi$

The shield gate support material yield strength,@350°F (Table 3.3.6 [1.6]) $S_{ys} := 31.30 \cdot ksi$

The shield gate support material ultimate strength,@350°F (Table 3.3.6 [1.6]) $S_{us} := 58.00 \cdot ksi$

1.3.1 Allowable stress

1.3.1.1 Allowable stress per ANSI N14.6 [1.2] for trunnion (stress limits against material yield strength is conservatively considered).

$$\sigma_{allowable} := \min\left(\frac{S_y}{6}, \frac{S_u}{10}\right) = 13800 \cdot psi$$

1.3.1.2 Allowable stress per ASME, Section III, Subsection NF [1.7] for Cask

Bending, $\sigma_{all\_ben} := 0.6 S_{yc} = 19830 \cdot psi$

Shear, $\sigma_{all\_shear} := 0.40 S_{yc} = 13220 \cdot psi$

Weld allowable, $\sigma_{all\_weld1} := \min(0.4 \cdot S_{yc}, 0.3S_{uc}) = 13220 \cdot psi$

$$\sigma_{all\_weld2} := \min(0.4 \cdot S_{ys}, 0.3S_{us}) = 12520 \cdot psi$$

1.4 Assumptions

Y

NPMNPGCR?PW GLDMPK?RGML UGRF FCJB GL ?AAMPB?LAC UGRF /.ADP0,17.

[

1.5 References

[1.1] MATHCAD 15.0, Parametric Technology Corporation, 2011.

[1.2] ANSI N-14.6, Special Lifting Devices for Loads Over 10000 lbs.in Nuclear Plants, 1993.

[1.3] Crane Manufacturers Association of America (CMAA), Specification #70, 1988, Section 3.3.

[1.4] J. Shigley and C. Mischke, Mechanical Engineering Design, McGraw-Hill, 5th Edition, 1989.

[1.5] Holtec drawing 10868, HI-TRAC CS, Latest Revision.

[1.6] Holtec report HI-2114830, HI-STORM FW FSAR, Revision 4.

[1.7] ASME Code, Section III, Division 1, Subsection NF, 2010.

[1.8] ASME Code, Section II, Part D, 2010.

[1.9] Holtec drawing 10901, HI-TRAC CS Lift Link, Latest Revision.

[2.0] S.P Timoshenko, Strength of Materials, Part 1, 3rd Edition, McGraw-Hill, 1958, p.99.

[2.1] NUREG-0612, Control of Heavy Loads at Nuclear Power Plants Resolution of Generic Technical Activity A-36, Section 5.1.6(3), 1993.

1.6 Trunnion Analysis

In this section, stresses in the trunnion and the cask material are determined. Stresses in the lifting trunnions (top trunnion) are compared to allowable strengths per ANSI N-14.6, and stresses in the cask are compared with appropriate allowable strengths from Subsection NF of the ASME Code.

1.6.1 Stresses in the Trunnion

In this subsection, the geometry of the system is defined, and bending and shear stresses in the lifting trunnions are determined. The input lifted load is from Table 3.2.8 of [1.6].

1.6.1.1 Input Data

All input dimensions are obtained from [1.5].

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NPMNPGCR?PWGLDMPK?RGML UGRF FCJBGL ?AAMPB?LAC UGRF /.ADP0,17.

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[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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1.6.1.2 Bending Stress in the Trunnion

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

1.6.1.3 Shear Stress in the Trunnion

Y

NPMNPGCR?PWGLDMPK?RGML UGRF FCJBGL ?AAMPB?LAC UGRF /.ADP0,17.

[

1.7 Analysis of Bottom Trunnions

The bottom two trunnions are used only as rotation trunnions for up-ending or down-ending for the HI-TRAC CS cask. They are not acting as lifting trunnions and therefore they need not be qualified as lifting trunnions per ANSI N14.6 [1.2]. The bottom two trunnions may be used to support loads in excess of 50% (as the cg lies below of Centrex) of the loaded cask weight when it is lifted in a horizontal orientation and they need not be qualified per ASME, Section III, Subsection NF [1.7].

Allowable stress per [1.2] is clearly bounding the allowable stress per [1.7] which is shown in section 1.3.1.

As the design of the top and bottom trunnions is same, hence, calculations for bottom trunnions are not warranted. The calculations for top trunnions presented above bounds for the bottom trunnions.

1.8 Bottom Lid Analysis

In this section, bending stresses in the bottom lid is determined. Stress in the bottom lid is compared to allowable strengths per Subsection NF of the ASME Code.

1.8.1 Input Data for bottom lid [1.5]

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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1.8.2 Calculation of Bottom Lid Pressure Load

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

1.8.3 Calculation of Bottom Lid Stress

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

1.8.4 Weld between cask and shield gate top flange

[

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[

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1.8.5 Weld between shield gate top flange and shield gate spacer support plates

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

2.0 Computer files and locations

G:\Projects\5025\REPORTS\Structural Reports\HI-2177585 (HI-STORE CISF Calc Package)\REV 0\Supplement 1

3.0 Conclusion

The HI-TRAC CS lifting trunnions and bottom lid meet the requirements of ANSI N14.6 and ASME, Section III, Subsection NF for lifting heavy loads in a nuclear plant. Primary stresses in the top trunnions are less than one-tenth of the ultimate strength of the trunnion material.

Also, the stress in the bottom plate region meet the imposed stress limits from ASME section III subsection NF [1.7].

HOLTEC CALCULATION

Title: ______________HI-TRAC CS Tornado Wind and Missile Analyses_______________

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**2**

CALCULATION SUMMARY INFORMATION

Scope: This objective of this calculation is to determine the response of the HI-TRAC CS to the combined load of the wind due to design basis tornado and the large missile impact. It is demonstrated that under this loading condition, the cask will not tip over.

Method: The methodology is described in Section 2.0 of this calculation.

FSAR LOCATIONS

Text (Chapter): Subsection 5.4.2 and Figure 5.4.2

Tables: 5.4.3

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	ASK 03/16/2017	ARK & VRP 03/24/2017
1		
2		

The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

This Calculation is archived in the above-referenced Calculation Package as a labeled supplement. This document may be shared as an autonomous piece of work with external organizations and revised, if necessary, to secure their concurrence to the proposed change.

Note 1: All analyses performed to respond to a query or to initiate a design change are archived in a new Calculation Package or added to an existing Calculation Package as a Supplement and the revision number of the Calculation Package is advanced. A supplement to a Calculation Package may consist of one analysis or several discrete analyses (each containing this cover sheet) supporting several ECOs.

SUPPLEMENT 2 - HI-TRAC CS TORNADO WIND AND MISSILE ANALYSIS

1 Introduction

The objective of this calculation is to determine the response of the HI-TRAC CS to the combined load of the wind due to the design basis tornado and the large missile impact specified in HI-STORM FSAR[4.7]. It is demonstrated that under this loading condition, the cask will not tip over. The case of large missile impact plus the instantaneous pressure drop due to the tornado passing the cask is also considered. The two load cases need not be combined. Impacts from two types of smaller missiles are considered in Supplement 2A.

2 Method

In this calculation, the cask is simultaneously subjected to a missile impact at the top of the cask and either a constant wind force or an instantaneous pressure drop leading to an impulsive adder to the initial angular velocity imparted by a missile strike. The configuration of the system just prior to impact by the missile is shown in Figure1.

The first step of the analysis is to determine the post-strike angular velocity of the cask, which is the relevant initial condition for the solution of the post-impact cask equation of motion. There are certain limiting assumptions that we can make to compute the post-impact angular velocity of the cask. There are three potential limiting options available.

a. Assume a coefficient of restitution (ratio of velocity of separation to velocity of approach) = 1. This assumption results in independent post impact motion of both the cask and the missile with the change in kinetic energy of the missile being entirely transmitted to the cask.

b. Assume a coefficient of restitution = 0. This assumption results in the missile and the cask moving together after the impact with a certain portion of the kinetic energy lost by the missile being dissipated during the collision so that the post impact kinetic energy is less than the energy change in the missile.

c. Assume a coefficient of restitution = mass of missile/mass of cask. This assumption brings the missile to rest after the impact. There is kinetic energy dissipated during the impact process but the kinetic energy acquired by the cask is larger than in case b.

Missile impact tests conducted under the auspices of the Electric Power Research Institute [4.1] have demonstrated that case c above matches the results of testing. Determination of the force on the cask due to the steady tornado wind is the next step. The primary tornado load is assumed to be a constant force due to the wind, acting on the projected area of the cask and acting in the direction that tends to cause maximum propensity for overturning.

The equation of motion of the cask under the wind loading is developed, and using the initial angular velocity of the cask due to the missile strike, the time-dependent solution for the post-impact position of the cask centroid is obtained.

In the second scenario, the missile impact occurs at the same instant that the cask sees the pressure drop due to the passing of the tornado.

3 Assumptions

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

4 References

[4.1] EPRI NP-440, Full Scale Tornado Missile Impact Tests, 1977.

[4.2] USNRC Regulatory Guide 1.76, Rev. 0.

[4.3] Fluid Mechanics with Engineering Applications, Daugherty, Franzini, and Finnemore, McGraw-Hill, 8th Edition, 1985.

[4.4] Hoerner Fluid Dynamics, 1965.

[4.5] Bechtel Topical Report BC-Top-9A, “Design of Structures for Missile Impact”, Rev. 2.

[4.6] Holtec Drawing 10868, HI-TRAC CS, Rev.0.

[4.7] Holtec Report HI-2114830, HI-STORM FW FSAR, Revision 4.

[4.8] Holtec Report HI-2094392,Tornado Missile Analysis for HI-STORM FW System.

5 Input Data

All dimensions and other inputs are taken from [4.6, 4.7& 4.8]. The input data necessary to perform the analysis are as follows:

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6 Solution for Post-Missile Strike Motion of Cask

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7 Calculation of Pressure due to Tornado Wind

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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8 Post Impact Plus Steady Wind Solution

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

9 Results for Impact Plus Steady Wind

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

10 Missile Impact Plus Pressure Drop

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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11 Results for Impact plus Pressure Drop

Once the angular rotation with respect to time is known, the horizontal displacement of the cask centroid can be calculated as:

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

12 Sliding under Large Missile Impact and Wind Load

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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13 Conclusion

As is shown in Figure 2 and Figure 3, the maximum horizontal excursion of the cask midpoint (approximately equal to the cask center of gravity) under the given loading is less than 30 in. (Note that the only valid part of the figures is the region with positive angular movement). In order for a cask tipover accident to occur, the centroid must undergo a horizontal displacement of 53 in. Therefore, the loadings from wind, tornado and missile strike events will not result in HI-TRAC tipover due to excessive sliding.

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Figure 1 Free Body Diagram of Cask for Large Missile Strike/Tornado Event

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Figure 2 Centroid Motion - Impact/Wind

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Figure 3 Centroid Motion - Impact/Pressure Drop

SUPPLEMENT 2A - MISSILE PENETRATION ANALYSES FOR HI-TRAC CS

2A.1 Introduction

In this calculation, deformations and stresses in the HI-TRAC CS due to missile strikes are investigated. The objective of the analysis is to show that deformations in the HI-TRAC CS System due to the missile strike events do not compromise the containment boundary of the system, and that global stresses in the HI-TRAC outer shell that arise from the missile side strikes do not exceed the appropriate limits.

2A.2 References

[2A.1] Holtec Report HI-2167374, HI-STORE SAR, Revision 0.
[2A.2] Young, Warren C., Roark's Formulas for Stress and Strain, 6th Edition, McGraw-Hill,1989.
[2A.3] Holtec Report HI-2114830, HI-STORM FW FSAR, Revision 4.
[2A.4] Holtec Drawing 10868, HI-TRAC CS, Revision 0
[2A.5] Mathcad 15, Parametric Technology Corporation, 2011.
[2A.6] ASME Code, Section III, Appendix F, 2010.
[2A.7] American Concrete Institute, "Building Code Requirements for Structural Concrete", ACI-318-05.

2A.3 Composition

This calculation was created using the Mathcad 15 [2A.5] software package. Mathcad uses the symbol ':=' as an assignment operator, and the equals symbol '=' retrieves values for constants or variables. Mathcad's built-in equation solver is also used.

2A.4 General Assumptions and Bounding Missiles

General assumptions that apply to all analyses in this calculation are stated here. Further assumptions are stated in the subsequent text.

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2A.5 Impact of a 1-in Diameter Solid Sphere

2A.5.1 Method

The first step in the 1-in. diameter sphere missile impact analysis is an investigation of the elastic behavior of the cask component being impacted. By balancing the kinetic energy of the missile with the work done deforming the impacted surface, it is shown that the missile's energy will not be entirely absorbed by elastic deformation. Therefore, the small missile will dent the cask. The elastic impact of the sphere is treated as a contact problem. The geometry is shown in Figure 2A.1.

For the 1-in Solid Sphere, the following impact is considered

a. the outer shell of HI-TRAC
b. the closure lid of MPC

Following the elastic investigation of the impact, a plastic analysis is performed to determine the depth of the dent.

2A.5.2 Elastic Analysis

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[

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2A.5.3 Plastic Analysis

[

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2A.5.3.a. Strike on HI-TRAC CS outer shell

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2A.5.3.b. Strike on top of MPC closure lid

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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2A.5.4 Conclusion: 1-in. Diameter Sphere Missile Impact

The depth of penetration of the small missile, which is required to absorb all of the impact energy, is less than the thinnest section of material on the exterior surface of the cask and MPC lid. Global stresses in the HI-TRAC that arise from the 1-in. missile strike are assumed to be negligible.

2A.6 Impact of an 8-in. Diameter Rigid Cylinder

2A.6.1 Method

An 8-in. diameter cylindrical missile is postulated to impact the cask at the most vulnerable location, as shown in Figure 2A.2. The deformed shape is shown for the case where a steel shell forming the HI-TRAC outer shell is backed by concrete shielding.

The following two impact locations are investigated:

a. Impact on the outer shell of HI-TRAC CS (with concrete backing)
b. Impact on the closure lid of MPC

Penetration is examined by balancing the kinetic energy of the missile with the work required to punch out a slug of the target material. Both the outer shell and the concrete neutron absorber material are considered to be active in resisting missile penetration in the case of a side strike.

Finally, global stresses in the HI-TRAC due to the 8-in. cylindrical missile impact are considered.

2A.6.2 Determination of Input Kinetic Energy

[

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2A.6.3 Local Penetration

Local penetration is examined by requiring that the impact force developed be balanced by only the resistance force developed in shear along the side area of a plug that would be punched out from an otherwise rigid material. That is, a "shear plug" type of failure mechanism is assumed. The failure mode is based on achievement of the ultimate stress in shear. If the steel plug is backed by additional load resisting material (the concrete shielding), then the confined compressive strength of the backing material also acts to resist the strike. The following two impact locations are examined:

a. Penetration of the outer shell of HI-TRAC CS

b. Penetration of the MPC closure lid

2A.6.3.a Penetration of the outer shell of HI-TRAC CS

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[

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2A.6.3.b. Penetration of the MPC closure lid

Local penetration is examined by requiring that the impact force developed is balanced by only the resistance force developed in shear along the side area of a plug that would be punched out from an otherwise rigid material. That is, a "shear plug" type of failure mechanism is assumed. The failure mode is based on achievement of the ultimate stress in shear.

[

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2A.6.4 <u>Stresses in the HI-TRAC CS Due to 8-in. Rigid Cylinder Missile Strike (beam bending)</u>

Global stresses in the HI-TRAC CS due to the side missile strike is examined in this subsection.

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[

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2A.7 Conclusion

The above calculations demonstrate that the HI-TRAC CS provides an effective containment barrier for the MPC after being subjected to various missile strikes. No missile strike compromises the integrity of the boundary; further, global stress intensities arising from the side missile strikes satisfy ASME Code Level D allowable strengths away from the immediate vicinity of the loaded region.

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Figure 2A.1: Small Missile Impact

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 2A.2: Post Impact Deformation of HI-TRAC CS Outer Shell Backed by Concrete And Impacted by A Horizontal Missile Strike

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 2A.3: Missile Strike at Top of HI-TRAC CS

HOLTEC CALCULATION

Title: ____________________ HI-STAR 190 Lift Yoke Stress Analysis__________________

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**3**

CALCULATION SUMMARY INFORMATION

Scope: This supplement presents the structural qualification of the lift yoke for lifting loaded HI-STAR 190 with its two upper trunnions.

Method: Strength of materials formulations is used for the analysis.

FSAR LOCATIONS

Text (Chapter): Subsection 5.4.4

Tables: 5.4.4

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	YC 03/24/2017	VM 03/24/2017
1		
2		

The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

This Calculation is archived in the above-referenced Calculation Package as a labeled supplement. This document may be shared as an autonomous piece of work with external organizations and revised, if necessary, to secure their concurrence to the proposed change.

Note 1: All analyses performed to respond to a query or to initiate a design change are archived in a new Calculation Package or added to an existing Calculation Package as a Supplement and the revision number of the Calculation Package is advanced. A supplement to a Calculation Package may consist of one analysis or several discrete analyses (each containing this cover sheet) supporting several ECOs.

SUPPLEMENT 3: HI-STAR 190 LIFT YOKE STRESS ANALYSIS

3.1 INTRODUCTION

The purpose of this supplement is to demonstrate that the load bearing parts of the Lift Yoke (LY) for HI-STAR 190 meet all requirements for the in-plant handling of heavy loads.

3.2 METHODOLOGY, ACCEPTANCE CRITERIA AND ASSUMPTIONS

The analyses are carried out using strength of materials formulations for statically determinant components.

For design without redundant load paths, the maximum stress in any load bearing component, per [3.1] and [3.2], shall not exceed the minimum of one-tenth of the material ultimate tensile strength and one-sixth of the material yield strength.

60% of the tensile allowable is used as the shear allowable. There is no limit set on local bearing stress in [3.1] and [3.2] and also it is a secondary stress; the limit on bearing stress is set at yield strength to ensure that there is no change in hole shape during load testing of 3 times the lifted load without dynamic load factor.

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

3.3 REFERENCES

[3.1] U.S. NRC NUREG-0612, Control of Heavy Loads at Nuclear Power Plants, 1980.
[3.2] ANSI N14.6, Special Lifting Devices for Shipping Containers Weighing 10000 Pounds (4500 kg) or More, 1993.
[3.3] HI-STORM FW FSAR, Holtec Report HI-2114830, Revision 4.
[3.4] Holtec Licensing Drawing 10902, Lift Yoke for HI-STAR 190, Revision 1.
[3.5] Holtec Licensing Drawing 9841, HI-STAR 190 Cask Assembly, Revision 0.
[3.6] CMAA Specification #70, Crane Manufacturers of America, 1988.
[3.7] ASME BTH-1-2011, Design of Below-the-Hook Lifting Devices, January 2012.
[3.8] A514/A514M-14, Standard Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding, ASTM International Standard Specification, 2014.
[3.9] ASME Boiler and Pressure Vessel Code, Section II, Part D, Properties, 2010.
[3.10] ASME Boiler and Pressure Vessel Code, Section II, Part A, Materials, 2010.
[3.11] Holtec Report HI-2146286, Thermal Evaluations of HI-STAR 190 System, Revision 3.

3.4 INPUT DATA

3.4.1 Lifted Weight

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.4.2 Material Properties

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.4.3 Dimensions

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3.5 CALCULATIONS

3.5.1 Allowable Stresses

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.2 Strongback Plates

3.5.2.1 Tension in Strongback Plates

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.2.2 Tearout in Strongback Main Pin hole

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3.5.2.3 Bearing stress in Strongback Main Pin hole

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.2.4 Single plane fracture in Strongback Main Pin hole

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.2.5 Strongback bending at Main Pin hole cross-section

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3.5.3 <u>Lift Arm Plates</u>

3.5.3.1 Tension in Lift Arm Plates

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.3.2 Bearing Stress at Lift Arm Trunnion Holes

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3.5.3.3 Single Plane Fracture at Lift Arm Trunnion Holes

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3.5.3.4 Tearout at Lift Arm Trunnion Holes

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3.5.3.5 Shear in Lift Arm Tabs

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.4 Actuator Plates

3.5.4.1 Tension in Actuator Plates

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.4.2 Bearing Stress in Lift Arm Tab hole

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.4.3 Tearout in Lift Arm Tab hole

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.4.4 Tearout in Actuator Pin hole

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.4.5 Single Plane Fracture at the Actuator Pin hole

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

3.5.5 Main Pins

The Main Pins allow the lift yoke to be lifted by a crane hook. The pin is subjected to bending moments and shear forces. The bending stresses are evaluated by conservatively considering the pin as a simply-supported beam with the load acting as a point load at the center of the beam.

3.5.5.1 Main Pin bending stress

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.5.1 Main Pin shear stress

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.6 Actuator Pins

The two Actuator Pins connect the two sets of Actuator Plates to the Strongback and allow the Lift Yoke to support the load. These pins are subjected to bending moments and shear forces. The load is assumed to act as a point load at the center of each Actuator Plate on each pin. The pin is assumed to be simply-supported at the center of the Strongbacks.

3.5.6.1 Actuator Pin bending stress

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.5.6.2 Actuator Pin shear stress

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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3.6 COMPUTER CODES AND COMPUTER FILES

MathCad 15.0 is used to prepare this supplement. The computer files associated with this analysis are stored in Holtec's network at the following location:

G:\Projects\5025\REPORTS\Structural Reports\HI-2177585 (HI-STORE CISF Calc Package)\REV 0\Supplement 3

3.7 FIGURES

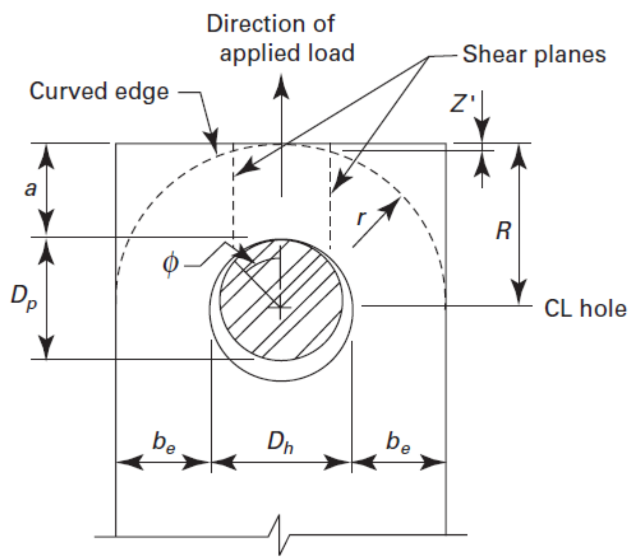

Figure 3.1: Inputs Used for Single Plane Fracture and Double Plane Shear (from [3.7])

Strenx 900

General Product Description

Strenx 900 is a general structural steel that, depending on thickness, guarantees a minimum yield strength of up to 900 MPa. Strenx 900 meets the requirements of EN 10 025-6 for the S 890 grade and thicknesses. Typical applications are demanding load-bearing structures.

Available dimensions

Strenx 900E is available in plate thicknesses of 4 – 100 mm and Strenx 900F is available in the thickness range up to 80 mm. Both grades are available in widths up to 3350 mm and lengths up to 14630 mm depending on thickness. More detailed information on dimensions is provided in the dimension program at www.ssab.com.

Mechanical Properties

Thickness mm	Yield strength [1] $R_{p0.2}$, Min MPa	Tensile strength [1] R_m Min MPa	Elongation A_5 Min %
4 - 53	900	940 - 1100	12
(53) - 100	830	880 - 1100	12

[1] For transverse test pieces according to EN 10025.

Impact properties	900 E -40ºC	900 F -60ºC
Impact energy (J) for tests on transverse Charpy V 10x10 mm tests specimens [2]	27 J	27 J
Meet the requirements for	S 890 QL	S 890 QL1

[2] Unless otherwise agreed, transverse impact testing according to EN 10 025-6 option 30 will apply. For thicknesses between 6 - 11.9 mm, sub-size Charpy V-specimens are used. The specifi ed minimum value is then proportional to the cross-sectional area of the specimen compared to a full-size specimen (10 x 10 mm).

Chemical Composition (ladle analysis)

C *) Max %	Si *) Max %	Mn *) Max %	P Max %	S Max %	Cr *) Max %	Cu Max %	Ni *) Max %	Mo *) Max %	B *) Max %
0.20	0.50	1.60	0.020	0.010	0.80	0.30	2.0	0.70	0.005

The steel is grain refined. *) Intentional alloying elements.

Maximum carbon equivalent CET (CEV)

Thickness mm	4 - 80	(80) - 100
Strenx 900 : CET (CEV)	0.39 (0.58)	0.41 (0.63)

$$CET = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40}$$

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$$

www.ssab.com

SSAB

Figure 3.2: WELDOX Datasheet

HOLTEC CALCULATION

Title: ___________________ HI-TRAC CS Lift Yoke Stress Analysis_________________

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**4**

CALCULATION SUMMARY INFORMATION

Scope: This supplement presents the structural qualification of the lift yoke for lifting loaded HI-TRAC CS with its two upper trunnions.

Method: Strength of materials formulations is used for the analysis.

FSAR LOCATIONS

Text (Chapter): Subsection 5.4.6

Tables: 5.4.6

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	YC 03/24/2017	VM 03/24/2017
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2		

The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

This Calculation is archived in the above-referenced Calculation Package as a labeled supplement. This document may be shared as an autonomous piece of work with external organizations and revised, if necessary, to secure their concurrence to the proposed change.

Note 1: All analyses performed to respond to a query or to initiate a design change are archived in a new Calculation Package or added to an existing Calculation Package as a Supplement and the revision number of the Calculation Package is advanced. A supplement to a Calculation Package may consist of one analysis or several discrete analyses (each containing this cover sheet) supporting several ECOs.

SUPPLEMENT 4: HI-TRAC CS LIFT YOKE STRESS ANALYSIS

4.1 INTRODUCTION

The purpose of this supplement is to demonstrate that the load bearing parts of the Lift Yoke (LY) for HI-TRAC CS meet all requirements for the in-plant handling of heavy loads.

4.2 METHODOLOGY, ACCEPTANCE CRITERIA AND ASSUMPTIONS

The analyses are carried out using strength of materials formulations for statically determinant components.

For design without redundant load paths, the maximum stress in any load bearing component, per [4.1] and [4.2], shall not exceed the minimum of one-tenth of the material ultimate tensile strength and one-sixth of the material yield strength.

60% of the tensile allowable is used as the shear allowable. There is no limit set on local bearing stress in [4.1] and [4.2] and also it is a secondary stress; the limit on bearing stress is set at yield strength to ensure that there is no change in hole shape during load testing of 3 times the lifted load without dynamic load factor.

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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4.3 REFERENCES

[4.1] U.S. NRC NUREG-0612, Control of Heavy Loads at Nuclear Power Plants, 1980.
[4.2] ANSI N14.6, Special Lifting Devices for Shipping Containers Weighing 10000 Pounds (4500 kg) or More, 1993.
[4.3] HI-STORM FW FSAR, Holtec Report HI-2114830, Revision 4.
[4.4] Holtec Licensing Drawing 10900, Lift Yoke for HI-TRAC CS, Revision 1.
[4.5] Holtec Licensing Drawing 10868, HI-TRAC CS, Revision 0.
[4.6] CMAA Specification #70, Crane Manufacturers of America, 1988.
[4.7] ASME BTH-1-2011, Design of Below-the-Hook Lifting Devices, January 2012.
[4.8] A514/A514M-14, Standard Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding, ASTM International Standard Specification, 2014.
[4.9] ASME Boiler and Pressure Vessel Code, Section II, Part D, Properties, 2010.
[4.10] ASME Boiler and Pressure Vessel Code, Section II, Part A, Materials, 2010.

4.4 INPUT DATA

4.4.1 Lifted Weight

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4.4.2 Material Properties

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4.4.3 Dimensions

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4.5 CALCULATIONS

4.5.1 Allowable Stresses

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4.5.2 Strongback Plates

4.5.2.1 Tension in Strongback Plates

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4.5.2.2 Tearout in Strongback Main Pin hole

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4.5.2.3 Bearing stress in Strongback Main Pin hole

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4.5.2.4 Single plane fracture in Strongback Main Pin hole

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4.5.2.5 Strongback bending at Main Pin hole cross-section

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4.5.3 Lift Arm Plates

4.5.3.1 Tension in Lift Arm Plates

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4.5.3.2 Bearing Stress at Lift Arm Trunnion Holes

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4.5.3.3 Single Plane Fracture at Lift Arm Trunnion Holes

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4.5.3.4 Tearout at Lift Arm Trunnion Holes

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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4.5.3.5 Shear in Lift Arm Tabs

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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4.5.4 <u>Actuator Plates</u>

4.5.4.1 Tension in Actuator Plates

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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4.5.4.2 Bearing Stress in Lift Arm Tab hole

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4.5.4.3 Tearout in Lift Arm Tab hole

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4.5.4.4 Tearout in Actuator Pin hole

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4.5.4.5 Single Plane Fracture at the Actuator Pin hole

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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4.5.5 Main Pin

The Main Pins allow the lift yoke to be lifted by a crane hook. The pin is subjected to bending moments and shear forces. The bending stresses are evaluated by conservatively considering the pin as a simply-supported beam with the load acting as a point load at the center of the beam.

4.5.5.1 Main Pin bending stress

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4.5.5.1 Main Pin shear stress

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4.5.6 <u>Actuator Pins</u>

The two Actuator Pins connect the two sets of Actuator Plates to the Strongback and allow the Lift Yoke to support the load. These pins are subjected to bending moments and shear forces. The load is assumed to act as a point load at the center of each Actuator Plate on each pin. The pin is assumed to be simply-supported at the center of the Strongbacks.

4.5.6.1 Actuator Pin bending stress

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4.5.6.2 Actuator Pin shear stress

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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4.6 COMPUTER CODES AND COMPUTER FILES

MathCad 15.0 is used to prepare this supplement. The computer files associated with this analysis are stored in Holtec's network at the following location:

G:\Projects\5025\REPORTS\Structural Reports\HI-2177585 (HI-STORE CISF Calc Package)\REV 0\Supplement 4

4.7 FIGURES

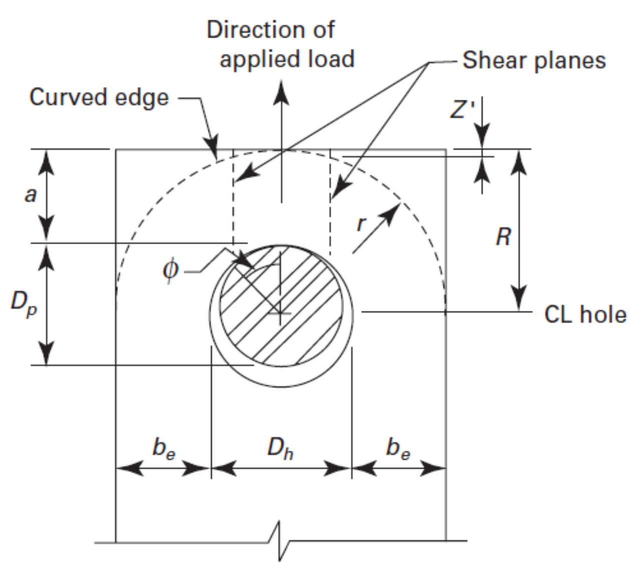

Figure 4.1: Inputs Used for Single Plane Fracture and Double Plane Shear (from [4.7])

Strenx 900

General Product Description

Strenx 900 is a general structural steel that, depending on thickness, guarantees a minimum yield strength of up to 900 MPa. Strenx 900 meets the requirements of EN 10 025-6 for the S 890 grade and thicknesses. Typical applications are demanding load-bearing structures.

Available dimensions

Strenx 900E is available in plate thicknesses of 4 – 100 mm and Strenx 900F is available in the thickness range up to 80 mm. Both grades are available in widths up to 3350 mm and lengths up to 14630 mm depending on thickness. More detailed information on dimensions is provided in the dimension program at www.ssab.com.

Mechanical Properties

Thickness mm	Yield strength [1] $R_{p0.2}$, Min MPa	Tensile strength [1] R_m Min MPa	Elongation A_5 Min %
4 - 53	900	940 - 1100	12
(53) - 100	830	880 - 1100	12

[1] For transverse test pieces according to EN 10025.

Impact properties	900 E -40°C	900 F -60°C
Impact energy (J) for tests on transverse Charpy V 10x10 mm tests specimens [2]	27 J	27 J
Meet the requirements for	S 890 QL	S 890 QL1

[2] Unless otherwise agreed, transverse impact testing according to EN 10 025-6 option 30 will apply. For thicknesses between 6 - 11.9 mm, sub-size Charpy V-specimens are used. The specifi ed minimum value is then proportional to the cross-sectional area of the specimen compared to a full-size specimen (10 x 10 mm).

Chemical Composition (ladle analysis)

C * Max %	Si * Max %	Mn * Max %	P Max %	S Max %	Cr * Max %	Cu Max %	Ni * Max %	Mo * Max %	B * Max %
0.20	0.50	1.60	0.020	0.010	0.80	0.30	2.0	0.70	0.005

The steel is grain refined. *Intentional alloying elements.

Maximum carbon equivalent CET (CEV)

Thickness mm	4 - 80	(80) - 100
Strenx 900 : CET (CEV)	0.39 (0.58)	0.41 (0.63)

$$CET = C + \frac{Mn + Mo}{10} + \frac{Cr + Cu}{20} + \frac{Ni}{40}$$

$$CEV = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Cu + Ni}{15}$$

www.ssab.com

SSAB

Figure 4.2: WELDOX Datasheet

HOLTEC CALCULATION

Title: ______ HI-TRAC CS Stack-up Analyses at CTF and UMAX_______

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**5**

CALCULATION SUMMARY INFORMATION

Scope: This supplement presents the Stack-up analyses of the HI-TRAC CS at HI-STORE Canister Transfer Facility (CTF) and UMAX ISFSI pad in the event of a design basis earthquake. In addition to evaluating the stability of the stack, structural evaluations of all components in the load path are also performed.

Method: The seismic analysis is performed using LS-DYNA. ANSYS and strength of materials formulations are used to perform structural evaluations of the HI-TRAC CS components in the load path.

FSAR LOCATIONS

Text (Chapter): Subsection 5.4.2

Tables: Table 5.4.1

Figures: Figure 5.4.1

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	DS 03/24/2017	AB 03/24/2017
1		
2		

The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

This Calculation is archived in the above-referenced Calculation Package as a labeled supplement. This document may be shared as an autonomous piece of work with external organizations and revised, if necessary, to secure their concurrence to the proposed change.

Note 1: All analyses performed to respond to a query or to initiate a design change are archived in a new Calculation Package or added to an existing Calculation Package as a Supplement and the revision number of the Calculation Package is advanced. A supplement to a Calculation Package may consist of one analysis or several discrete analyses (each containing this cover sheet) supporting several ECOs.

SUPPLEMENT 5: HI-TRAC CS STACK-UP ANALYSIS AT CTF AND UMAX

REVISION LOG

Revision 0 – Initial issue

1.0 INTRODUCTION AND SCOPE

This supplement presents the seismic analysis of the HI-TRAC CS (HT) [1] at the Canister Transfer Facility (CTF) [2] and on the HI-STORM UMAX at the ISFSI pad location [3]. The HI-STAR 190 (without the lid) [12] is positioned in the CTF cavity with the Adapter Plate [2] centered on top. The HI-TRAC CS is placed on top of the Adapter Plate and bolted down using the Anchor Rods [2] to the Cask Transfer Building (CTB) slab [4]. The fuel transfer operation is performed by lifting the sealed MPC, which contains spent fuel assemblies, into the empty HI-TRAC CS. The loaded HI-TRAC CS is subsequently transferred to the ISFSI pad. The HI-STORM UMAX (without the lid), which is an in-ground Vertically Ventilated Module (VVM), sits with its top just above the ISFSI top grade level. To carry out the MPC transfer operation, the HT transfer cask is mounted atop the recipient HI-STORM UMAX. The fuel transfer operation is performed by lowering the sealed MPC into the empty HI-STORM UMAX storage module. The seismic analyses are performed for the bounding case of MPC in the HI-TRAC CS at both locations.

This calculation package also presents the structural qualification of the HT Shield Gate weldment, the connections between HT and CTB slab, and between the HT and HI-STORM UMAX Cavity Enclosure Container (CEC) under the design basis earthquakes.

The following are the objectives of the current supplement:

1. Perform a time history analysis to evaluate the stability of the HI-STORM UMAX/HI-TRAC stack using the applicable modified real recorded time history set in three

orthogonal directions (east-west, north-south, and vertical). A single time history analysis is appropriate as the system is linear with bolted HI-TRAC CS.

2. Determine the maximum loadings at the bolted connections under seismic conditions for the stack. Subsequently, perform a structural evaluation of the HT Shield Gate weldment, and the bolted connections to demonstrate their structural adequacy and establish the corresponding margins of safety.

3. Determine the maximum bearing load imposed on the CTB slab and ISFSI pad by the stack during seismic activity. Subsequently, perform a structural evaluation of the CTB slab and ISFSI pad to demonstrate adequate concrete bearing capacity.

2.0 METHODOLOGY AND ANALYSIS

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3.0 ASSUMPTIONS

The following assumptions are made in the stack-up analysis:

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4.0 RESULTS

The maximum displacements recorded at the top of the HI-TRAC CS in the X and Y directions (refer to Figure 1 for model orientation) are negligible (i.e. less than 0.1 inches). Hence, there is no potential for impact between the HT and VCT or other adjacent structures during stack-up. Also, as the HI-TAC CS is bolted to the CEC/CTB slab and all connections are structurally qualified, there is no concern of the stack tipping over during a design basis earthquake.

The bolted connections between the HI-TRAC CS and CEC/CTB slab anchor blocks are evaluated in Appendix B. The peak tensile are shear loads from the DECE analysis are conservatively evaluated against Level B allowables to show that all safety factors are greater than 1.0.

The structural evaluation of the Shield Gate weldment is performed in Appendix C. Since the Shield Gate supporting plate structure is modeled in sufficient detail in LS-DYNA, all plate stresses are directly exported from the LS-DYNA results and compared with the stress allowable. The Shield Gate itself is analyzed in ANSYS [11] using a bounding load from the LS-DYNA analysis. Other components and welds that are not explicitly modeled are evaluated using bounding loads obtained from the analysis results. All components are shown to have safety factors greater than 1.0.

Finally, the bearing load imposed by the HI-TRAC CS on the ISFSI pad through the CEC top cover plate is evaluated in Appendix D. The peak load between the HI-TRAC CS and the CEC top cover plate is used to calculate the safety factor for bearing on the ISFSI pad concrete and is shown to be greater than 1.0. This envelopes the bearing stresses in the CTB slab as the contact area is greater on the CTB slab and concrete properties are identical.

5.0 CONCLUSIONS

The following conclusions are deduced from the detailed results presented in this calculation package:

1. The kinematic stability of the stack is satisfied under seismic conditions.

2. The HT to CEC/CTB slab interface bolted connections are structurally adequate to withstand the loads from the analysis.

3. The load bearing components and welds in the HT Shield Gate weldment are structurally adequate to withstand the loads from the analysis.

4. The ISFSI pad and the CTB slab concrete has adequate bearing capacity to withstand the loads from the analysis.

5. The stack along with its internals (MPC, fuel basket and fuel assemblies, as applicable) will remain intact during and after a seismic event.

6.0 REFERENCES

[1] Holtec Drawing 10868, “HI-TRAC CS”, Revision 0.

[2] Holtec Drawing 10895, “Canister Transfer Facility (CTF)”, Revision 0.

[3] Holtec Drawing 10875, “HI-STORE UMAX Vertical Ventilated Module Version C”, Revision 0.

[4] Holtec Drawing 10912, “Cask Transfer Building Floor Slab”, Revision 0.

[5] Holtec Report HI-2167374, “Licensing Report on the HI-STORE CIS Facility”, Revision 0.

[6] Holtec Report HI-2146083, “Regulatory Guide 1.60 Time Histories Using EZ-FRISK”, Revision 2.

[7] NUREG 0800, Standard Review Plan 3.7.1, Revision 3, March 2007.

[8] Holtec Report HI-2115090, "HI-STORM UMAX FSAR", Revision 3.

[9] LS-DYNA Version 971, Livermore Software Technology, 2012.

[10] Holtec Generic Report HI-2135676, "NRC-Concurred Seismic Analysis Methodology for the HI-STORM/HI-TRAC Stack using LS-DYNA", Revision 1.

[11] ANSYS Version 17.1, SAS IP, Inc., 2016.

[12] Holtec Drawing 9841, "HI-STAR 190 Cask Assembly", Revision 0.

[13] ASME Boiler and Pressure Vessel Code, Section III, Subsection NF, 2010.

[14] ASME Boiler and Pressure Vessel Code, Section III, Appendices, 2010.

[15] ASME Boiler and Pressure Vessel Code, Section II, Part D, Properties, 2010.

[16] Building Code Requirements for Structural Concrete (ACI 318-05) and commentary (ACI 318R-05), American Concrete Institute, 2005.

[17] U.S. Nuclear Regulatory Commission, Regulatory Guide 1.61, "Damping values for Seismic Design of Nuclear Power Plants", Revision 1, March 2007.

[18] AISC Steel Construction Manual, 13th Edition.

[19] Machinery's Handbook, 27th Edition, 2004, Industrial Press, Inc.

[20] Holtec Report HI-2146279, "Seismic Analysis of Stack-up and HI-STORM's Egress and Structural Qualification of Floor and Mating Device for Clinton Power Station", Revision 4.

[21] Holtec Report HI-2114830, "HI-STORM FW FSAR", Revision 4.

[22] Holtec Approved Computer Program List, Revision 342.

[23] Shigley's Mechanical engineering Design, 8th Edition.

[24] Holtec Position Paper DS-307, "Construction of True Stress-Strain Curve for LS-DYNA Simulations", Revision 2.

[25] Holtec Report HI-2094353, "Analysis of the Non-Mechanistic Tipover Event of the Loaded HI-STORM FW Storage Cask", Revision 12.

7.0 FIGURES

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Figure 1: LS-DYNA Model of Stack-up

8.0 COMPUTER CODES AND FILES

This safety analysis summary is prepared in Microsoft Office Word. The appendices of this calculation package are prepared in Mathcad. Finite Element analyses are performed using LS-DYNA [9] and ANSYS [11]. Computers 1416 and 1417 are used for running LS-DYNA, and computer 1189 is used for running ANSYS. These computers are verified for the computer codes in question per [22].

All relevant computer files associated with this revision of the calculation package are archived on the Holtec Server under:

Revision 0: G:\ Projects\5025\REPORTS\Structural Reports\HI-2177585 (HI-STORE CISF Calc Package)\REV 0\Supplement 5

9.0 APPENDICES

Appendix A – Inputs used in the LS-DYNA Stack-up Model

Appendix B – Stack-up Bolting and Anchor Block Evaluation

Appendix C – Shield Gate Weldment Structural Evaluation

Appendix D – ISFSI Pad Concrete Bearing Evaluation

Appendix A: Inputs used in the LS-DYNA Stack-up Model

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Figure A.1: Loaded HI-TRAC CS CG and Mass Properties from Solidworks

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Appendix B: Stack-up Bolting and Anchor Block Evaluation

Introduction

The finite element analysis of the HI-STORM UMAX/HI-TRAC stack provides the maximum loads realized by the HI-TRAC-to-HI-STORM UMAX CEC/CTB slab bolts during design extended conditions earthquake (DECE) and safe shutdown earthquake (SSE). Using the bounding loads at these bolted connections, output from LS-DYNA, the following sections evaluate the bolts, anchor blocks, and supporting connections. Conservatively, the DECE results are compared with Level B allowables. Hence, the SSE results do not need to be evaluated separately. The following points are noted:

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Appendix C - Shield Gate Weldment Structural Evaluation

C.1 - Shield Gate Weld Evaluation Under DECE

Introduction

The structural evaluation of the HT Shield Gate weldment [1] subjected to loads from the Stack-up during a design extended conditions earthquake (DECE) is presented in this section. The weld groups between the Spacer Supports (items 10, 11, 12) and Top/Bottom Flanges (items 9, 13), between the Mounting Hole Support Gussets (item 14) and the Top/Bottom Flanges (items 9, 13), and between the Mounting Hole Support Gussets (item 14) and the Spacer Supports (item 11) are evaluated here. The following points are noted:

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C.2 - Shield Gate Weld Evaluation Under SSE

Introduction

The structural evaluation of the HT Shield Gate weldment [1] subjected to loads from the Stack-up during a safe shutdown earthquake (SSE) is presented in this section. The weld groups between the Spacer Supports and Top/Bottom Flanges, between the Mounting Hole Support Gussets and the Top/Bottom Flanges, and between the Mounting Hole Support Gussets and the Spacer Supports are evaluated here. The following points are noted:

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C.3 - Shield Gate Plate Structure Evaluation

Introduction

In this section, the HT Shield Gate supporting plate structure is evaluated using LS-DYNA (except for the Shield Gate itself - see Section C.4). The primary components of the Shield Gate weldment in the load path are made of SA 516 Gr 70 and SA 36 [1]. Instead of qualifying each plate individually, the combined stress plots for the entire Shield Gate supporting structure are plotted and compared with the minimum stress allowable calculated below.

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Figure C.1: Maximum Shear Stress Plot from LS-DYNA Analysis

C.4 - Shield Gate Evaluation

Introduction

In this section, the HT Shield Gate is evaluated using ANSYS by applying a bounding vertical load on the Shield Gate (360 kips) due to the MPC from the LS-DYNA DECE analysis. The primary load bearing component of the Shield Gate is the 3" thick bottom plate that is made of SA 516 Gr 70 [1]. The top three plates are conservatively ignored in the structural evaluations. The stress intensity in the Shield Gate is compared with the minimum stress allowable calculated below.

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Figure C.2: Stress Intensity Plot from ANSYS Analysis

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Figure C.3: Linearized Stress Intensity Plot from ANSYS Analysis

C.5 - Shield Gate Locking Pin Assembly Evaluation

Introduction

The Shield Gate is locked in the closed position using a Locking Pin (item 22) that passes through the Shield Gate Top Flange (item 9) and through the Shield Gate Bar (item 23). During Stack-up, the lateral loads from the MPC sliding on the Shield Gate are taken by this assembly to prevent the Shield Gate from opening.

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Appendix D: ISFSI Pad Concrete Bearing Evaluation

Introduction

During stack-up, the HT Shield Gate Bottom Flange [1] sits on top of the UMAX CEC inlet plenum cover plate [3]. The outer edges of the cover plate are directly supported by the ISFSI pad concrete that surrounds the CEC. Hence, the impact load from the HT on the CEC cover plate is conservatively evaluated against the bearing capacity of the ISFSI pad concrete that directly supports the cover plate. The bearing area for the HT on CTB slab at CTF location is greater that that at UMAX location. Therefore, the calculation is not repeated for the CTB slab. The following points are noted:

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HOLTEC CALCULATION

Title: ______VCT, HI-TRAC CS and HI-STAR 190 Seismic Stability Evaluations_______

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**6**

CALCULATION SUMMARY INFORMATION

Scope: This supplement presents the dynamic stability (tipping and sliding) evaluation of a representative Vertical Cask Transporter (VCT) (empty and with empty/loaded HI-TRAC CS) when staged and during movement on Cask Transfer Building (CTB) slab, haul path and UMAX ISFSI pad at HI-STORE CIS facility in the event of a design basis earthquake. The supplement also presents the dynamic stability evaluations of freestanding HI-TRAC CS (empty and loaded) and HI-STAR 190 (empty and loaded) when staged on CTB slab and Canister Transfer Facility (CTF) foundation slabs, respectively, in the event of design basis earthquake.

Method: VCT, HI-TRAC CS and HI-STAR 190 are assumed to be rigid bodies which are first analyzed for the possibility of incipient tipping and sliding, where simple dynamic equations are formulated based on moment and force equilibrium. For any cases that do not pass the initial incipient tipping and sliding checks, the methodology per Appendix A.0 of ASCE 43-05 is used to estimate the maximum rocking angle and the maximum sliding distance.

FSAR LOCATIONS

Text (Chapter): Subsections 5.4.2 and 5.5.2

Tables: 5.4.7 and 5.5.2

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	AB 03/21/2017	YC 03/24/2017
1		
2		

The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

This Calculation is archived in the above-referenced Calculation Package as a labeled supplement. This document may be shared as an autonomous piece of work with external organizations and revised, if necessary, to secure their concurrence to the proposed change.

Note 1: All analyses performed to respond to a query or to initiate a design change are archived in a new Calculation Package or added to an existing Calculation Package as a Supplement and the revision number of the Calculation Package is advanced. A supplement to a Calculation Package may consist of one analysis or several discrete analyses (each containing this cover sheet) supporting several ECOs.

Supplement 6: VCT, HI-TRAC CS and HI-STAR 190 Seismic Stability Evaluations

TABLE OF CONTENTS

1.0 INTRODUCTION

This supplement presents the dynamic stability (tipping and sliding) evaluation of a representative Vertical Cask Transporter (hereafter referred to as VCT) [6.4C], unloaded and carrying empty or loaded HI-TRAC CS [6.4A], when staged and during movement on Cask Transfer Building (CTB) slab [6.4B], haul path and UMAX ISFSI pad at HI-STORE CIS facility. The supplement also presents the dynamic stability evaluation of empty and loaded HI-TRAC CS (freestanding) and empty and loaded HI-STAR 190 (freestanding) [6.4D] when staged on CTB slab and Canister Transfer Facility (CTF) foundation slab [6.4B], respectively. The driving loads for this evaluation are the applicable seismic response spectra and the 3-D time history motion at HI-STORE CIS facility (see Section 5.0). The results of the analyses in this supplement demonstrate that the VCT (unloaded/empty and carrying empty/loaded HI-TRAC CS), the HI-TRAC CS (empty and loaded) and the HI-STAR 190 (empty and loaded) remain stable and do not lift (or tip) under the applicable site-specific earthquake. The maximum sliding distance of the VCT anywhere on CTB slab, haul path and ISFSI pad is also computed. It is also demonstrated that the HI-TRAC CS (empty and loaded) and HI-STAR 190 (empty and loaded) will not slide on the CTB slab and the CTF foundation slab, respectively, in the event of a SSE.

2.0 OBJECTIVE

This supplement presents the analysis performed to ensure that:

a. the VCT (without or with empty/loaded HI-TRAC CS) does not tip-over or slide excessively to impact adjacent safety related structures under the bounding site-specific earthquake when staged on or during movement on CTB slab, haul path and UMAX ISFSI pad.

b. the HI-TRAC CS (empty and loaded) does not tip-over or slide excessively to impact adjacent safety related structures under the site-specific earthquake when staged on CTB slab.

c. the HI-STAR 190 (empty and loaded) does not tip-over or slide excessively to impact adjacent safety related structures under the site-specific earthquake when staged on CTF foundation slab.

3.0 METHODOLOGY AND ACCEPTANCE CRITERIA

3.1 Methodology

[

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]

3.2 Acceptance Criteria

During and after the design basis seismic event, the VCT (empty and with empty/loaded HI-TRAC CS), the HI-TRAC CS (empty and loaded) and the HI-STAR 190 (empty and loaded) must remain dynamically stable and not tip-over or slide off the supporting structure. The criteria for sliding is to ensure that the outside edge of VCT tracks and the outside edge of base of HI-TRAC CS and HI-STAR 190 remain supported by the structure underneath. Also, it is required to ensure that VCT, HI-TRAC CS and HI-STAR 190 do not impact any adjacent safety related structures. The guidance and the acceptance criteria from Appendices A and B of [6.5] are followed.

4.0 ASSUMPTIONS

[

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]

5.0 DESIGN INPUT

5.1 Weights

The weights of HI-TRAC CS, HI-STAR 190, MPC and VCT are listed below.

[

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]

5.2 Dimensions and C.G.'s

The dimensions of HI-TRAC CS and HI-STAR 190 are listed below. The dimensions of the assumed VCT design are obtained from [6.4C]. The C.G. of the VCT with loaded HI-TRAC CS is calculated in Appendix 6A.

[

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Note: For the purpose of this analysis, a nominal HI-TRAC CS lift height of 12 inches, when carried by a VCT, is specified. This value of lift height must be controlled procedurally at the site. Any greater lift heights will either require further evaluation or technical justification.

5.3 Seismic Loading

The site-specific response spectra for SSE (or DBE) and DECE are defined in Table 4.3.3 of [6.3C] and are obtained from Appendix B of [6.3B]. SSE is used for stability evaluations of HI-TRAC CS (empty and loaded) on CTB slab and HI-STAR 190 (empty and loaded) on CTF foundation slab. Conservatively, DECE is used for stability evaluation of VCT (unloaded and carrying empty/loaded HI-TRAC CS) to account for any amplification on SSE input at the top of ISFSI pad due to Soil-Structure Interaction (SSI) effects with loaded canisters in the UMAX ISFSI. It is noted that Operating Basis Earthquake (OBE) is bounded by SSE and DECE [6.3C].

Horizontal SSE ZPA E-W direction (top of CTB slab)	0.15 g
Horizontal SSE ZPA N-S direction (top of CTB slab)	0.15 g
Vertical SSE ZPA (top of CTB slab)	0.15 g
Horizontal DECE ZPA E-W direction (top of ISFSI pad)	0.25 g
Horizontal DECE ZPA N-S direction (top of ISFSI pad)	0.25 g
Vertical DECE ZPA (top of ISFSI pad)	0.25 g

[

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The response spectra curves for 10% damping are required per [6.5] to calculate maximum sliding displacement, and are generated using SHAKE 2000 [6.2] from the Regulatory Guide 1.60 earthquake time histories scaled to applicable ZPA levels [6.3B].

[

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]

Figure 5.1: CG Height of Loaded HI-STAR 190 (obtained from CAD model)

6.0 REFERENCES

[6.1] Mathcad 15.0, Parametric Technology Corporation, 2011.

[6.2] SHAKE2000, Version 7.7.0.

[6.3] Holtec Reports:

A: HI-STORM FW FSAR, HI-2114830, Revision 4.

B: Regulatory Guide 1.60 Time Histories Using EZ-FRISK, HI-2146083, Revision 2.

C: Licensing Report on the HI-STORE CIS Facility, HI-2167374, Revision 0.

[6.4] Drawings:

A: 10868, Licensing Drawing for HI-TRAC CS, Revision 0.

B: 10912, Licensing Drawing for Cask Transfer Building Floor Slab, Revision 0.

C: VCT415W081, General Arrangement Drawing for Vertical Cask Transporter, Revision 0 (used for illustrative purposes).

D: 9841, Licensing Drawing for HI-STAR 190 Cask Assembly, Revision 0.

E: 10895, Licensing Drawing for Canister Transfer Facility (CTF), Revision 0.

[6.5] ASCE/SEI 43-05, Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities, ASCE, 2005.

[6.6] Holtec Approved Computer Program List, Revision 342.

7.0 COMPUTER CODES AND FILES

Computer files associated with this supplement are stored on the HOLTEC network at: G:\Projects\5025\REPORTS\Structural Reports\HI-2177585 (HI-STORE CISF Calc Package)\REV 0\Supplement 6.

The main section of this supplement is written using Microsoft Word. All the calculations (Appendices 6A through 6C) are performed using Mathcad 15.0 [6.1]. The response spectra curves at 10% damping are generated using SHAKE 2000 [6.2] on Computer No. 1372 which is on the Holtec Approved Computer Program List [6.6].

8.0 RESULTS

Stability analyses are performed for a representative VCT (empty and with empty/loaded HI-TRAC CS), the HI-TRAC CS (empty and loaded) and the HI-STAR 190 (empty and loaded) at the HI-STORE CIS facility.

The analyses performed in Appendix 6A confirm that the VCT (empty and with empty/loaded HI-TRAC CS) will remain stable and will not lift under site's DECE when staged or during transport on CTB slab, haul path and UMAX ISFSI pad. [

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The analyses performed in Appendices 6B and 6C confirm that the HI-TRAC CS (empty and loaded) and HI-STAR 190 (empty and loaded) will remain stable and will not lift under site's SSE when staged on CTB slab and CTF foundation slab, respectively. The HI-TRAC CS (empty and loaded) and the HI-STAR 190 (empty and loaded) will not begin to slide under site's SSE when staged on CTB slab and CTF foundation slab, respectively.

9.0 SUMMARY AND CONCLUSIONS

In this supplement, seismic stability analyses of a representative VCT (empty and with empty/loaded HI-TRAC CS), the HI-TRAC CS (empty and loaded) and the HI-STAR 190 (empty and loaded) at the HI-STORE CIS facility are performed. The results of the analyses demonstrate that the VCT, the HI-TRAC CS and the HI-STAR 190 will remain stable. [PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390] The HI-TRAC CS and the HI-STAR 190 will not slide under site-specific SSE.

10.0 APPENDICES

Appendix 6A – VCT Tipping and Sliding Calculations

Appendix 6B – HI-TRAC CS Tipping and Sliding Calculations

Appendix 6C – HI-STAR 190 Tipping and Sliding Calculations

Appendix 6A - VCT Tipping and Sliding Calculations

This appendix evaluates tipping and sliding of the VCT with empty/loaded HI-TRAC CS on CTB slab, haul path and UMAX ISFSI pad. Conservatively bounding seismic input and grade/slope are used for all locations.

6A.1: Input Parameters

[

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6A.2: Tipping Calculations

[

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[

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]

6A.3: Sliding Calculations

During seismic event, the VCT may slide. The following section evaluates the potential sliding of VCT. Two cases are considered, i.e., empty VCT and VCT with loaded HI-TRAC CS. The conservative grade affects the sliding of VCT.

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

6A.4: Conclusions

The analysis performed in this appendix confirms that the empty VCT and the VCT with the empty/ loaded HI-TRAC CS will remain stable and will not lift under bounding design basis seismic event when staged or traveling on CTB slab, haul path and UMAX ISFSI pad. [

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Appendix 6B - HI-TRAC CS Tipping and Sliding Calculations

This appendix evaluates tipping and sliding of the HI-TRAC CS [6.4A] freestanding on CTB slab [6.4B].

6B.1: Input Parameters

[

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6B.2: Tipping Calculations

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

This indicates that the loaded HI-TRAC CS will remain stable and will not start to slide under the design basis seismic event. This conclusion is also applicable to empty HI-TRAC CS as the evaluation is independent of weight and CG.

6B.4: Conclusions

The analysis performed in this appendix confirms that the HI-TRAC CS (empty and loaded) remains stable and will not lift in the event of a design basis earthquake when staged freestanding on CTB slab.

The analysis also confirms that the HI-TRAC CS (empty and loaded) will not start to slide in the event of a design basis earthquake when staged freestanding on CTB slab.

Appendix 6C - HI-STAR 190 Tipping and Sliding Calculations

This appendix evaluates tipping and sliding of the HI-STAR 190 [6.4D] freestanding in CTF [6.4E] on CTF foundation slab [6.4B].

6C.1: Input Parameters

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6C.2: Tipping Calculations

[

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6C.3: Sliding Calculations

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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This indicates that the loaded HI-STAR 190 will remain stable and will not start to slide under the design basis seismic event. This conclusion is also applicable to empty HI-STAR 190 as the evaluation is independent of weight and CG.

6C.4: Conclusions

The analysis performed in this appendix confirms that the HI-STAR 190 (empty and loaded) remains stable and will not lift in the event of a design basis earthquake when staged freestanding on CTF foundation slab.

The analysis also confirms that the HI-STAR 190 (empty and loaded) will not start to slide in the event of a design basis earthquake when staged freestanding on CTF foundation slab.

HOLTEC CALCULATION

Title: ______ MPC Lift Attachment Stress Analysis _______

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**7**

CALCULATION SUMMARY INFORMATION

Scope: This supplement presents the structural evaluation of the MPC Lift Attachment under normal lifting of a loaded MPC at the HI-STORE CIS facility. To account for lifting dynamics, a 15% increase in the load is considered.

Method: Strength of materials formulations are used to evaluate the Lift attachment.

FSAR LOCATIONS

Text (Chapter): Subsection 5.4.5

Tables: Table 5.4.5

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	AR 03/22/2017	PN 03/22/2017
1		
2		

The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

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SUPPLEMENT - 7
STRUCTURAL EVALUATION OF THE MPC LIFT ATTACHMENT FOR HI-STORE

7.1 INTRODUCTION

The purpose of this appendix is to demonstrate that the load bearing parts of the HI-STORE MPC Lift Attachment device meet all requirements for in-plant handling of heavy loads.

7.2 METHODOLOGY, ACCEPTANCE CRITERIA AND ASSUMPTIONS

The analyses are carried out using strength of materials formulations for statically determinant components.

For a design without redundant load paths, the maximum stress in any load bearing component, per Refs. [7.1] and [7.2], is limited to the minimum of either one-tenth of the material ultimate tensile strength or one-sixth of the material yield strength.

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

7.3 REFERENCES

[7.1] USNRC NUREG-0612, 1980.
[7.2] ANSI N14.6, 1993.
[7.3] HI-STORM FW FSAR, Holtec Report HI-2114830, Revision 2.
[7.4] Holtec Drawing 10889, Revision 1 "MPC Lifting Device Extension".
[7.5] Holtec Drawing 10891, Revision 1 "MPC Lift attachment".
[7.6] CMAA Specification #70 (1988), Crane Manufacturers of America.
[7.7] AISC Steel Construction Manual, Ninth Edition.
[7.8] ASME BTH-1-2008, Design of Below-the-Hook Lifting Devices, January 2009.
[7.9] Machinery's Handbook, 27th Edition, 2004..
[7.10] ASME Sec II, Part D, 2010.

7.4 INPUT DATA

7.4.1 Lifted Weight

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

7.4.2 Material Properties

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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7.4.3 Dimensions

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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$t_{lug} := 3in$ Thickness of lifting Lug

$t_{chmf} := 0.5 \cdot in$ Thickness of chamfer in lifting Lug

$t_{lach} := t_{lug} - 2 \cdot t_{chmf} = 2 \cdot in$ Top chamfer thickness along thickness direction

$l_{LAch} := 2in$ Top chamfer length along height direction:

$w_{lug\_max} := 24in$ Width of lifting lug

$t_{fl} := 4.25in$ Thickness of the base (flange)

$w_{base} := 19 \cdot in$ Maximum lateral width of the base

$w_{flg} := 10 \cdot in$ flange width extended part for bolt connection

$Nb := 8$ Number of bolts

$d_{bolt} := \left(1 + \frac{3}{4}\right)in$ Bolt 1-3/4 5UNC major diameter:

$d_{bolt} = 1.75\,in$

$n := 5\frac{1}{in}$ Bolt threads/inch

$p := \frac{1}{n} = 0.2\,in$ Thread pitch

$L_e := 3in$ Available length of thread engagement

Below bolt dimension input are taken from [7.9, unless specified]

$E_{nmax} := 1.6317in$ Maximum Pitch diameter of internal thread

$K_{nmax} := 1.568in$ Maximum minor diameter of internal thread

$E_{smin} := 1.6085in$ Minimum Pitch diameter of external thread

$D_{smin} := 1.7268in$ Minimum major diameter of external thread

8.5 ALLOWABLES STRESS

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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8.6 CALCULATIONS

8.6.1 Calculation for bolt thread

[

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[

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7.6.2) Prying force calculation for Bolt (per AISC prying calculation method) [7.7]:

[

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Figure 7.1: Lift Attachment Input dimensions

[

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[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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7.6.3) Tensile Stress in Lifting lug plate

[

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[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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7.6.4) <u>Tearout at holes location in lifting Lug</u>

Tearout could occur in the two vertical planes at Lifting Pin holes location in the Lifting lug Plates. The tearout stress and safety factor of the Lift arm Plate can be computed as (see Fig. 7.2):

Using the terminology and equation [3.51] from [7.8] (see Fig. 7.2),

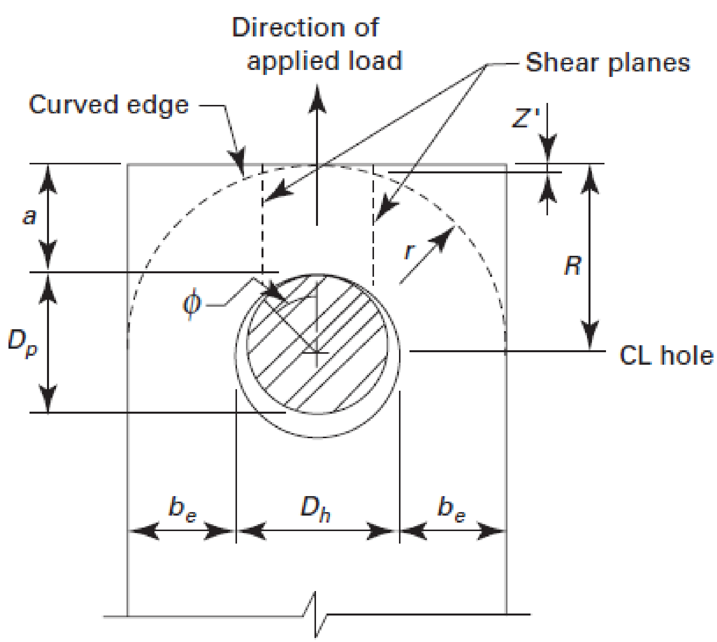

Figure 7.2: Terminology as per [7.8]

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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7.6.5) Single plane fracture at pin hole location

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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7.6.5 Shear stress in flange

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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7.6.6 Bearing Stress at pin hole location in lifting lug

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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7.7 RESULTS

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]

7.8 CONCLUSION

All safety factors are above the minimum of 1.0. Therefore, the MPC Lift Attachment is structurally adequate for its design purpose.

HOLTEC CALCULATION

Title: ______ MPC Lifting Device Extension Stress Analysis _______

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**8**

CALCULATION SUMMARY INFORMATION

Scope: This supplement presents the structural evaluation of the MPC Lifting Device Extension under the normal lifting of a loaded MPC at the HI-STORE CIS facility. To account for lifting dynamics, a 15% increase in the load is considered.

Method: Strength of materials formulations are used to evaluate the MPC lifting device extension.

FSAR LOCATIONS

Text (Chapter) : Subsection 5.4.6

Tables: Table 5.4.6

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	AR 03/22/2017	PN 03/22/2017
1		
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SUPPLEMENT - 8
STRUCTURAL EVALUATION OF THE MPC LIFTING DEVICE EXTENSION

8.1 INTRODUCTION

The purpose of this appendix is to demonstrate that the load bearing parts of the MPC Lifting extension device meet all requirements for in-plant handling of heavy loads.

8.2 METHODOLOGY, ACCEPTANCE CRITERIA AND ASSUMPTIONS

The analyses are carried out using strength of materials formulations for statically determinant components.

For a design without redundant load paths, the maximum stress in any load bearing component, per Refs. [8.1] and [8.2], is limited to the minimum of either one-tenth of the material ultimate tensile strength or one-sixth of the material yield strength.

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

8.3 REFERENCES

[8.1] USNRC NUREG-0612, 1980.
[8.2] ANSI N14.6, 1993.
[8.3] HI-STORM FW FSAR, Holtec Report HI-2114830, Revision 4.
[8.4] Holtec Drawing 10889, Revision 1 "MPC Lifting Device Extension".
[8.5] Holtec Drawing 10891, Revision 1 "MPC Lift attachment".
[8.6] CMAA Specification #70 (1988), Crane Manufacturers of America.
[8.7] AISC Steel Construction Manual, Ninth Edition.
[8.8] ASME BTH-1-2008, Design of Below-the-Hook Lifting Devices, January 2009.
[8.9] ASME Sec II, Part D, 2010.
[8.10] A514/A514M-05, ASTM International Standard Specification.

8.4 INPUT DATA

8.4.1 Lifted Weight

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

8.4.2 Material Properties

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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8.4.3 Dimensions

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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[

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8.5 ALLOWABLES STRESS

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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8.6 CALCULATIONS

8.6.1 Tensile Stress in Lift arm

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[

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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8.6.2 Tearout at upper hole location in lift arm

Tearout could occur in the two vertical planes above the Lifting Pin hole\ location in the Lift arms.

The tearout stress and safety factor of the lift arm can be computed as (see Fig. 8.1):

Using the terminology and equation [3.51] from [8.8] (see Fig. 8.1),

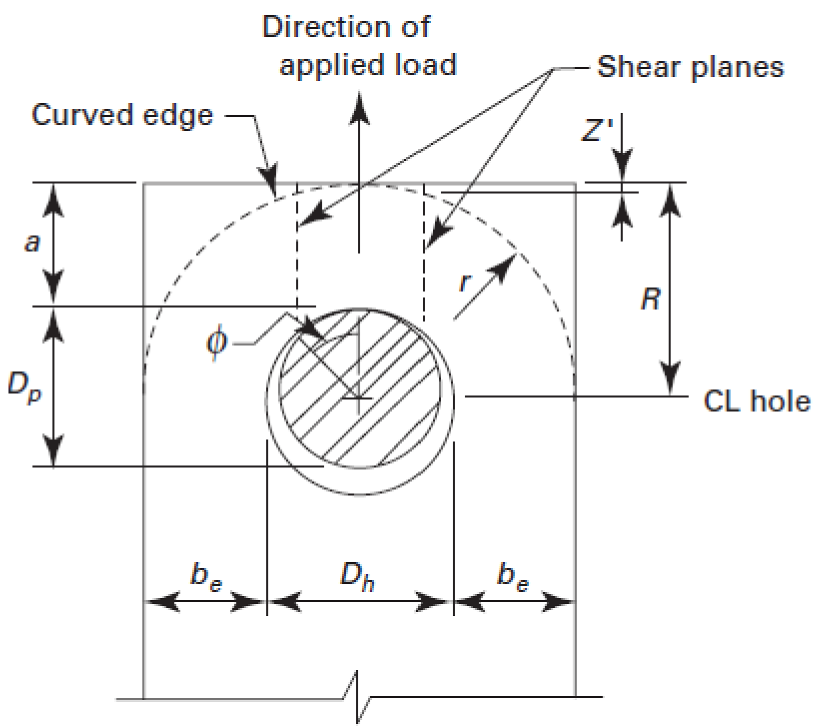

Figure 8.1: Terminology as per [8.8]

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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8.6.3 Single plane fracture at upper pin hole location

[

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[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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8.6.4 Bearing Stress at top pin hole location in lift arm

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

8.6.5 Tearout at bottom pin holes location in lift arm plate

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

8.6.6 Single Plane Fracture at bottom pin hole location

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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8.6.7) Bearing Stress at bottom pin hole

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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8.6.8) Lifting pin (upper pin) bending and shear

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

]

8.6) Lift arm pin (bottom pin) bending and shear

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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7.7 RESULTS

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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7.8 CONCLUSION

All safety factors are above the minimum of 1.0. Therefore, the MPC Lifting Device Extension [8.4] is structurally adequate for its design purpose.

HOLTEC CALCULATION

Title: HI-STAR 190 HORIZONTAL LIFT BEAM STRESS ANALYSIS

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**9**

CALCULATION SUMMARY INFORMATION

Scope: The Horizontal Lift Beam, used to lift the HI-STAR 190 cask in the horizontal orientation, is evaluated against NUREG 0612 and ANSI N14.6 acceptance criteria.

Method: Strength of materials formulations and an ANSYS FEA model are used to evaluate the lifting ancillary.

FSAR LOCATIONS

Text (Chapter): Subsection 5.4.6

Tables: Table 5.4.6

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	PN 03/24/2017	DS 03/24/2017
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The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

This Calculation is archived in the above-referenced Calculation Package as a labeled supplement. This document may be shared as an autonomous piece of work with external organizations and revised, if necessary, to secure their concurrence to the proposed change.

Note 1: All analyses performed to respond to a query or to initiate a design change are archived in a new Calculation Package or added to an existing Calculation Package as a Supplement and the revision number of the Calculation Package is advanced. A supplement to a Calculation Package may consist of one analysis or several discrete analyses (each containing this cover sheet) supporting several ECOs.

SUPPLEMENT 9: HI-STAR 190 HORIZONTAL LIFT BEAM STRESS ANALYSIS

9.1 INTRODUCTION

The purpose of this supplement is to demonstrate that the load bearing parts of the Horizontal Lift Beam meets all requirements for the in-plant handling of heavy loads.

9.2 METHODOLOGY, ACCEPTANCE CRITERIA AND ASSUMPTIONS

The analyses are carried out using a finite element model in ANSYS 17.1 [9.3] and strength of materials formulations for statically determinant components.

For a design without redundant load paths, the following acceptance criteria are used per per [9.1] and [9.2]:

Primary stress on any load bearing component	$\min\left(\frac{Sy}{6}, \frac{Su}{10}\right)$
Shear stress on any load bearing component (conservative)	$\frac{1}{\sqrt{3}} \cdot \min\left(\frac{Sy}{6}, \frac{Su}{10}\right)$
Shear stress on effective weld throat	$\frac{Su}{10}$

The device is load tested to 300% of the design load. To prevent yielding during the load test an additional criteria is also used:

Effective (Von-Mises) stress on any component	$\frac{Sy}{3}$
Bearing stress	$0.9 \cdot \frac{Sy}{3}$

Note that these criteria are to be compared against the lift beam when it is loaded under the actual design load.

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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9.3 REFERENCES

[9.1] USNRC NUREG-0612, 1980.
[9.2] ANSI N14.6, 1993.
[9.3] ANSYS Mechanical, Release 17.1, 2016 SAS IP, .Inc.
[9.4] Holtec Drawing 10894, "Transport Cask Horizontal Lift Beam", Revision 0.
[9.5] ASME Boiler and Pressure Vessel Code, Section II, Part D, Properties, 2010.
[9.6] CMAA Specification #70, Crane Manufacturers of America, 1988.
[9.7] ASME BTH-1-2008, Design of Below-the-Hook Lifting Devices, January 2009.
[9.8] A514/A514M-05, ASTM International Standard Specification.
[9.9] HI-2114830, HI-STORM FW FSAR, Revision 4.
[9.10] Holtec Drawing 9841, “HI-STAR 190 Cask Assembly", Revision 0.
[9.11] Holtec Drawing 9848, “HI-STAR 190 Impact Limiter", Revision 0.
[9.12] A500/A500M-07, ASTM International Standard Specification.
[9.13] A53/A53M-07, ASTM International Standard Specification.
[9.14] HI-2115090, HI-STORM UMAX System FSAR, Revision 3.
[9.15] I&ISling, http://www.iandisling.com/twin_path_extra_covermax.htm, Accessed 2017.
[9.16] AISC Steel Construction Manual, 13th edition.

9.4 INPUT DATA

9.4.1 Lifted Weight

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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9.4.2 Material Properties

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9.4.3 Dimensions

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9.5 CALCULATIONS

9.5.1 Maximum lifted load on each corner of the horizontal lift beam

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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9.5.2 Lift Arm Trunnion Plate (item 9)

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9.5.3 Lift Arm Pin Plate (item 10)

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9.5.4 Connecting Pin (item 11)

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9.5.5 Main Pipe, Spreader Beams, Gussets, and all Support Plates (Analyzed with an ANSYS FEA model; items 1 to 8, and 12)

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9.5.6 Adjusting pin (item 12)

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9.5.7 Weld Evaluations

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9.6 COMPUTER FILES

The analyses described in this calculation are performed with ANSYS 17.1 [9.3], in Computer ID# 1271. This code and computer are both validated under Holtec International's QA program per the Holtec ACPL, Revision 342, dated March 6, 2017. All relevant ANSYS files are stored in:

G:\Projects\5025\REPORTS\Structural Reports\HI-2177585 (HI-STORE CISF Calc Package)\REV 0\Supplement 9\ANSYS

9.7 RESULTS

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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9.8 CONCLUSION

A structural evaluation of the Horizontal Lift Beam was performed with a combination of strength of materials formulations and a finite element analysis in ANSYS Mechanical [9.3]. All safety factors with respect to the acceptance criteria are above the minimum of 1.0. Therefore, the horizontal lift beam is qualified as a special lifting device per NUREG 0612 [9.1] and ANSI N14.6 [9.2] for loads up to:

$$\frac{W_{tot}}{DLF} = 418 \cdot kip$$

HOLTEC CALCULATION

Title: FATIGUE EVALUATION OF THE HI-TRAC CS AND LIFTING ANCILLARIES

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**10**

CALCULATION SUMMARY INFORMATION

Scope: The fatigue life of the HI-TRAC and lifting ancillaries due to repeated lifting and handling loads is evaluated. Thermal cycling related fatigue is also considered.

Method: Allowable stress limits for the HI-TRAC are conservatively used to calculate the maximum number of loading cycles with S-N curves from Appendix I of ASME BPVC, Section III.

FSAR LOCATIONS

Text (Chapter): Subsection 5.4.2 and 5.4.6

Tables: Tables 5.4.8 & 5.4.9

REVISION LOG

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0	PN 03/24/2017	VM 03/24/2017
1		
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The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

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Note 1: All analyses performed to respond to a query or to initiate a design change are archived in a new Calculation Package or added to an existing Calculation Package as a Supplement and the revision number of the Calculation Package is advanced. A supplement to a Calculation Package may consist of one analysis or several discrete analyses (each containing this cover sheet) supporting several ECOs.

SUPPLEMENT 10: FATIGUE EVALUATION OF HI-TRAC CS AND LIFTING ANCILLARIES

10.1 INTRODUCTION

This supplement evaluates the fatigue life of the HI-TRAC CS and under lifting/handling operations. Fatigue evaluations of the various HI-STORE lifting ancillaries are also presented.

10.2 METHODOLOGY

The fatigue life of the HI-TRAC CS and the lifting ancillaries is calculated by comparing a bounding stress value with the cycle life curves defined in Appendix I of ASME BPVC Section III [10.3]. The maximum stress is conservatively taken as the bounding allowable stress in the load bearing components during a lifting/handling operation.

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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10.3 REFERENCES

[10.1] USNRC NUREG-0612, 1980.
[10.2] ANSI N14.6, 1993.
[10.3] ASME BPVC, Section III, Appendix I, 2010.
[10.4] HI-2167374, HI-STORE FSAR, Revision 0.
[10.5] ASME BPVC, Section II, Part A to D, 2010.
[10.6] Holtec Drawing 10894, "Transport Cask Horizontal Lift Beam", Revision 0.
[10.7] Holtec Drawing 10868, "HI-TRAC CS", Revision 0.
[10.8] A514/A514M-05, ASTM International Standard Specification.
[10.9] A336/A336M-09, ASTM International Standard Specification.
[10.10] A572/A572M-07, ASTM International Standard Specification.
[10.11] A36/A36M-08, ASTM International Standard Specification.
[10.12] A500/A500M-07, ASTM International Standard Specification.
[10.13] A53/A53M-07, ASTM International Standard Specification.
[10.14] HI-2115090, HI-STORM UMAX System FSAR, Revision 3.
[10.15] ASME BPVC, Section III, Subsection NF, 2010.
[10.16] Holtec Drawing 10900, "Lift Yoke for HI-TRAC CS", Revision 1.
[10.17] Holtec Drawing 10902, "Lift Yoke for HI-STAR 190", Revision 1.
[10.18] Holtec Drawing 10899, "Tilt Frame and Saddle", Revision 0.
[10.19] Holtec Drawing 10901, "Lift Link for HI-TRAC CS", Revision 0.
[10.20] Holtec Drawing 10891, "MPC Lift Attachment", Revision 0.
[10.21] Holtec Drawing 10889, "MPC Lifting Device Extension", Revision 0.
[10.22] HI-2002444, HI-STORM 100 FSAR, Revision 13.

10.4 ASSUMPTIONS

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10.4 INPUTS

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10.5 ANALYSIS

10.5.1 HI-TRAC CS [10.7] Lifting Related Fatigue Life

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10.5.2 Fatigue Life of the Horizontal Lift Beam [10.6]

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10.5.3 Fatigue Life of the HI-TRAC CS Lift Yoke [10.16]

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10.5.4 Fatigue Life of the HI-STAR 190 Lift Yoke [10.17]

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10.5.5 Fatigue Life of the MPC Lifting Device Extension [10.21]

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10.5.6 Fatigue Life of the HI-TRAC CS Lift links [10.19]

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10.5.7 Fatigue Life of the MPC Lift Attachment [10.20]

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10.5.8 Fatigue Life of the HI-STAR 190 Tilt Frame & Saddle [10.18]

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10.5.9 Fatigue due to Thermal Cycling of the HI-TRAC CS and Lifting Ancillaries

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10.6 RESULTS

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<table>
<tr><td colspan="4">HOLTEC CALCULATION

Title: _______ CTB Slab and CTF Foundation Slab Structural Evaluations ____________</td></tr>
<tr><td>PROJECT No. – ECO No. – REV. No.:</td><td colspan="3">__5025__ - ___N/A___ - ___N/A___</td></tr>
<tr><td>Calculation Package No.:</td><td>HI-2177585</td><td>Supplement No.:</td><td>11</td></tr>
<tr><td colspan="4">CALCULATION SUMMARY INFORMATION</td></tr>
<tr><td colspan="4"><u>Scope:</u> This supplement presents the evaluation of Cask Transfer Building (CTB) and Canister Transfer Facility foundation slab under the loads from Crane, Rail Car, VCT, loaded HI-TRAC CS and loaded HI-STAR 190.

<u>Method:</u> Beams on elastic foundations formulations are used for the analysis.</td></tr>
<tr><td colspan="4">FSAR LOCATIONS</td></tr>
<tr><td colspan="4"><u>Text (Chapter):</u> Subsections 5.3.2 and 5.3.3

<u>Tables:</u> Table 5.3.2</td></tr>
</table>

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	RJ 03/24/2017	YC/VRP 03/24/2017
1		
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The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

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SUPPLEMENT 11: CTB Slab and CTF Foundation Slab Structural Evaluations

1.0 INTRODUCTION

This supplement performs the computations for the structural analysis of the Cask Transfer Building (CTB) Floor Slab under the load combinations identified in Section 5.3.3 of HI-STORE SAR [1]. CTB floor slab is evaluated for loads from VCT, Crane, Rail Car and HI-TRAC CS. Since the CTB floor slab and Canister Transfer Facility Foundation Slab have the same design. A bounding evaluation is performed in this supplement.

2.0 METHODOLOGY

All evaluations are performed using beams on elastic foundations based relationship from Chapter 9 of [3]. Mathcad [2] is used for this evaluation.

3.0 ASSUMPTIONS

The following assumptions are made in this analysis:

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4.0 ACCEPTANCE CRITERIA

The CTB Floor slab is designed to meet the strength requirements of ACI 318-05 [4]. Per the HI-STORE SAR [1], the CTB floor slab needs to be evaluated for the following load combinations:

Load Combination #1 : 1.4D
Load Combination #2: 1.2D+1.6L
Load Combination #3: 1.2D+L+E

Where D is the dead load of the CTB slab, L is the live load acting on the CTB slab (including weight of VCT,Crane,Rail and HI-TRAC CS) and E is the Design Basis Earthquake for the site which is same as Safe Shutdown Earthquake (SSE).

5.0 INPUTS

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6.0 MOMENT AND SHEAR CAPACITY CALCULATION

The moment and shear capacity of the CTB floor slab are calculated in this section using ACI code [4].

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7.0 ANALYSIS

In this section, the loading on the slab due to its self-weight and from each of the loading cases (viz. crane, rail car, VCT and Loaded HI-TRAC CS are first individually calculated. Each of these loading cases are then combined using the load combinations identified in Section 4.0.

7.1 Loading from CTB Floor Slab

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7.2 Loading from Crane

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7.3 Loading from Rail Car

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7.4 Loading from the VCT

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7.5 Loading from the HI-TRAC CS

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8.0 BEARING AND PUNCHING SHEAR EVALUATION

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9.0 CONCLUSION

Structural analyses are performed to evaluate the structural integrity of the CTB floor slab. The results from the analysis demonstrate that the safety factors for the slab strength evaluation are greater than 1.0. Therefore, the CTB floor slab and Canister Transfer Facility foundation slab are adequate to support the crane, rail car, VCT and HI-TRAC CS/HI-STAR 190 loads.

10.0 COMPUTER FILES

All files related to this calculation are saved in Holtec network under:

G:\Projects\5025\REPORTS\Structural Reports\HI-2177585 (HI-STORE CISF Calc Package)\REV 0\Supplement 11

11.0 REFERENCES

[1] Holtec Report HI-2167374, "Licensing Report on the HI-STORE CIS Facility", Revision 0.

[2] Mathcad 15.0, Parametric Technology Corporation, 2011.

[3] Advanced Mechanics of Materials, A.P. Boresi, O.M.Sidebottom, F.B.Seely and J.O. Smith by John Wiley and Sons, Third Edition, 1978.

[4] ACI Standard Building Code Requirements for Structural Concrete and Commentary, ACI 318-05.

[5] Holtec Drawing 10912, "Cask Transfer Building Floor Slab", Revision 0.

[6] Holtec Drawing 9841, "HI-STAR 190 Cask Assembly", Revision 0.

[7] Holtec Drawing 10899, "Tilt Frame and Saddle", Revision 0.

[8] Holtec Drawing 10868 "HI-TRAC CS", Revision 0.

[9] https://www.wabtec.com/uploads/outlinedrawings/Track_Components_Section.pdf

12.0 APPENDIX

APPENDIX A -Representative Design Drawings of Crane, Rail Car and VCT

APPENDIX -A

REPRESENTATIVE DESIGN DRAWINGS OF CRANE, RAIL CAR AND VCT

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HOLTEC CALCULATION

Title: ______ HI-TRAC CS Lift Links Stress Analysis_______

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**12**

CALCULATION SUMMARY INFORMATION

Scope: This supplement presents the evaluation of the HI-TRAC CS Lift Links subjected to a bounding weight of the loaded HI-TAC CS.

Method: The analysis is performed using strength of materials formulations in Mathcad.

FSAR LOCATIONS

Text (Chapter): Subsection 5.4.6

Tables: Table 5.4.6

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	SP 03/21/2017	DS 03/24/2017
1		
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The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

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SUPPLEMENT NO. 12 - HI-TRAC CS LIFT LINKS STRESS ANALYSIS

A.1 INTRODUCTION

The purpose of this appendix is to demonstrate that the load bearing parts of the HI-TRAC CS Lift Link for HI-STORE [A.6] meet all requirements of NUREG 0612 [A.1] and ANSI N14.6 [A.2].

A.2 METHODOLOGY

The analyses are carried out using strength of materials formulations for statically determinant components.

A.3 ACCEPTANCE CRITERIA

For a design without redundant load paths, the maximum stress in any load bearing component, per Refs. [A.1] and [A.2], is limited to the minimum of either one-tenth of the material ultimate tensile strength or one-sixth of the material yield strength.

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A.4 ASSUMPTIONS

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A.5 REFERENCES

[A.1] NUREG-0612, Control of Heavy Loads at Nuclear Power Plants,Section 5.1.6(3), 1993

[A.2] ANSI N14.6, American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 Kg) or More for Nuclear Materials, ANSI, 1993.

[A.3] ASME BTH-1-2008, Design of Below-the-Hook Lifting Devices, January 2009.

[A.4] ASME BPVC, Section II, Part D, 2010.

[A.5] CMAA Specification #70 (1988), Crane Manufacturers of America.

[A.6] Holtec Drawing 10901, Revision 0, "HI-TRAC CS Lift link"

[A.7] AISC Steel Construction Manual, Ninth Edition.

[A.8] Holtec Drawing 10868, Revision 0, "HI-TRAC CS".

[A.9] Holtec Report HI-2114830, Revision 4, "HI-STORM FW FSAR".

[A.10] STRENX 900E Data Sheet, SSAB, 2010.

[A.11] ASTM A514/A514M - 05, Standard Specification for High-Yield Strength, Quenched

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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A.6 INPUT DATA

A.6.1 Lifted Weight

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A.6.2 Material Properties

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A.6.3 Lift Link

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A.7.0 CALCULATIONS

A.7.1 Allowable Stresses

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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A.7.2 Tensile Stress

The load on each Lift link is one-half of the total lifted load. The maximum tensile stress occurs at the section with the minimum cross-sectional area.

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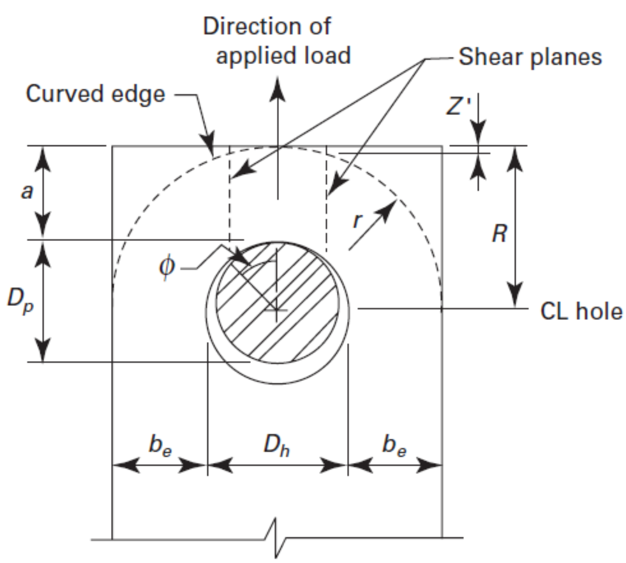

Figure 1: Inputs Used for Single Plane Fracture and Double Plane Shear (from [A.3])

A.7.3 Lift Link Bottom Hole Tearout

Tearout could occur in the two vertical planes at each lifting pin through the holes in the lift link. The load is taken as the total capacity and weight of the lift link combined. The tearout stress and safety factor of the lift link can be computed as (see Fig. 1):

[

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A.7.4 Single Plane Fracture at Bottom hole

Single plane fracture at bottom hole is bounding over top hole as diameter of bottom hole is more than top hole.

Using the terminology and equations used in [A.3], Single plane fracture for the lift link is

calculated. Figure 1 shows an illustration of the inputs for the method.

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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A.7.5 Bearing Stress at Top hole

Bearing stress on top hole is bounding over bottom hole as top hole bearing area is smaller than bottom hole.

The bearing loads at the top pin are distributed to both the lift link and from lift link to holes, each of which is subjected to one-half the load. The material with the lower bearing stress allowable governs the calculation of the bearing stress safety factor.

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A.7.6 Lift Link Top Hole Tearout

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A.8 COMPUTER FILES

The computer files associated with this analysis are stored in Holtec's network at the following location :

G:\Projects\5025\REPORTS\Structural Reports\HI-2177585 (HI-STORE CISF Calc Package)\REV 0\Supplement 12

A.9 CONCLUSION

The analysis performed in this supplement shows that the HI-TRAC CS lift link is structurally adequate as all safety factors are above 1.0.

HOLTEC CALCULATION

Title: ______ HI-STAR 190 TILT FRAME AND SADDLE STRESS ANALYSES _______

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**13**

CALCULATION SUMMARY INFORMATION

Scope: In this calculation, tilt frame assembly for HI-STORE is analyzed under normal condition.

Method: Combination of finite element code (ANSYS) and formulation of strength of materials are used for evaluation.

FSAR LOCATIONS

Text Modifications (Chapter): Subsection 5.5.1

Table Modifications : Table 5.5.1

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	VM / 03-24-2017	AIS/ 03-24-2017
1		
2		

The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

This Calculation is archived in the above-referenced Calculation Package as a labeled supplement. This document may be shared as an autonomous piece of work with external organizations and revised, if necessary, to secure their concurrence to the proposed change.

Note 1: All analyses performed to respond to a query or to initiate a design change are archived in a new Calculation Package or added to an existing Calculation Package as a Supplement and the revision number of the Calculation Package is advanced. A supplement to a Calculation Package may consist of one analysis or several discrete analyses (each containing this cover sheet) supporting several ECOs.

SUPPLEMENT 13: HI-STAR 190 Tilt Frame And Saddle Stress Analyses

13.1 Introduction

This supplement documents the structural evaluation undertaken to demonstrate that the HI-STAR 190 tilting plate and saddle assembly (hereafter referred as tilting frame assembly) [13.1] meets the applicable structural acceptance criteria. The tilting frame assembly will be used to rotate the loaded HI-STAR 190 cask [13.2] from vertical to horizontal, and from horizontal back to vertical orientation.

The loaded HI-STAR 190 cask with impact limiters arrives in the HI-STORE CIS facility on a rail cart in the horizontal orientation. The loaded cask with impact limiters is then lifted using the horizontal lift beam and staged on the tilting frame assembly. The tilting frame assembly is designed to support the loaded HI-STAR 190 cask with impact limiters along its length. The HI-STAR 190 trunnions on the saddle end engage with the lift yoke for the upending/downending operation of loaded HI-STAR 190 cask (without impact limiters). The HI-STAR 190 cask pivots about the bottom trunnions supported on the trunnion support block (item 9 of [13.1]). Once the cask is upended, it is removed from the frame and positioned over CTF.

As the above operations are expected to span within a work shift, the tilt frame assembly is seismic-exempt per [13.3]. Furthermore, if the above operations extends beyond a work-shift, the HI-STAR 190 cask will be staged on the tilt frame assembly with the impact limiters. Thus based on the above discussion, the tilt frame assembly is evaluated under the following loading cases:

1) Upending of HI-STAR 190 at 90 degrees from the ground
2) Upending of HI-STAR 190 at 45 degrees from the ground
3) HI-STAR 190 cask staged on tilt frame assembly with impact limiters

For all the above load cases, appropriate bounding loads are considered.

13.2 References

[13.1] Holtec Drawing 10899, Tilt Frame & Saddle, Revision 0.
[13.2] Holtec Drawing 9841, HI-STAR 190 Cask Assembly, Revision 0.
[13.3] Licensing report on the HI-STORE CIS Facility, HI-2167374, Revision 0.
[13.4] ANSYS, Version 17.1, ANSYS Inc., 2017.
[13.5] HI-STORM UMAX FSAR, HI-2115090, Revision 3.
[13.6] ASME Section III, Subsection NF, 2010.
[13.7] ASME Section II, Part D, 2010.
[13.8] AISC Steel Construction Manual, Thirteenth Edition.
[13.9] ASTM Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel, A572/A572M-07.
[13.10] Shigleys Mechanical Engineering Design, McGraw-Hill Publications, Eigth Edition.
[13.11] Machinery's Hand Book, 27th Edition.
[13.12] Holtec Report HI-2146286, latest revision.

13.3 Methodology

The CAD models of the tilting frame assembly [13.1] (built in Solidworks) is imported into the finite element simulation code ANSYS [13.4]. The tilting frame assembly is analyzed and qualified under the above mentioned load cases. The structural evaluations are carried out using a combination of strength of material formulations and finite element analysis. A CAD model of the tilting frame assembly is shown in Figure 13.1 below. Necessary dimensions to perform the strength of material evaluations are taken from CAD model directly. Minor deviations are noted between the final drawing [13.1] and the CAD model used in the analysis. However, these deviations have negligible affect on the safety conclusions drawing in this supplement.

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Figure 13.1 Tilting Frame Assembly

13.4 Acceptance Criteria

Per [13.3], tilting frame assembly is evaluated against ASME Section III, Subsection NF [13.6]. For the normal downending/upending condition, the applicable stress limits of Level A shall not be exceeded. In lieu of considering individual stress components, the strength limits from [13.6] are compared with the tension, bending and shear stresses.

All safety factors of the tilting frame components, defined as the ratio of the allowable stress to the actual stress, must be larger than 1.0.

13.5 Assumptions

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13.6 Analysis

13.6.1 Input Data

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13.6.2 Analysis for upending of HI-STAR 190 at 90 degrees from the ground (Load Case 1)

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13.6.3 Analysis for upending of HI-STAR 190 at 45 degrees from the ground (Load Case 2)

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13.6.4 Analysis of HI-STAR 190 cask staged on tilting frame assembly with impact limiters (Load Case 3)

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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13.7 Computer Codes and Computer Files

MathCad 15.0 is used to prepare this supplement.

ANSYS 17.1 [13.4] is used for structural evaluation of the tilt frame assembly. ANSYS 17.1 is QA validated software under Holtec's QA program. The computer number used for the evaluation is noted below along with applicable Holtec's Approved Computer Program List (ACPL) revision.

Computer Number used for ANSYS analysis 1269 Holtec ACPL Rev 341, Feb 16, 2017

All computer files associated with this supplement are stored under:
G\Projects\5025\REPORTS\Structural Reports\HI-2177585 (HI-STORE CISF Calc Package)\REV 0\Supplement 13

13.8 Conclusion

All safety factors for the tilt frame assembly for the three load cases given in Section 13.1 remains above 1.0. Thus the tilt frame assembly is structurally adequate for its intended use.

Furthermore the upending of HI-STAR 190 using tilt frame assembly is a short-term operation. Such operations span within a work shift and as listed in [13.3] are seismically exempt. However, it should be noted that the design of tilt frame assembly is expected to be capable of withstanding the site specific SSE loads, which are only 0.15g ZPA in all directions. The tilt frame assembly has been qualified to much higher loads and ASME NF Level A allowables during the upending operations.

HOLTEC CALCULATION

Title: EVALUATION OF CTB COLLAPSE ON HI-TRAC CS AND HI-STAR 190

PROJECT No. – ECO No. – REV. No.:	**__5025__ - ___N/A___ - ___N/A___**		
Calculation Package No.:	**HI-2177585**	**Supplement No.:**	**14**

CALCULATION SUMMARY INFORMATION

This supplement documents the analysis of the postulated CTB collapse accident to demonstrate that the HI-TRAC CS transfer cask and HI-STAR 190 transport cask can protect the spent fuel inside the two casks under the governing impact scenarios without any unacceptable safety impact. The analysis is performed using LS-DYNA.

FSAR LOCATIONS

Text Modifications (Chapter): Subsection 5.4.2 & Figures 5.4.3 to 5.4.6

Table Modifications : N/A

REVISION LOG

Rev. No.	Preparer Initials /Date	Reviewer Initials /Date
0	JZ 03/20/2017	VM 03/24/2017
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The Calculation presented herein provides the analytical basis to adopt the proposed change contemplated by the ECO (see Note 1). The Design Verification Checklist (DVC) documenting the technical review of this calculation is associated with the applicable ECO in the computerized ECO network database.

This Calculation is technically reviewed and QA validated in accordance with HQP 5.1.

This Calculation is archived in the above-referenced Calculation Package as a labeled supplement. This document may be shared as an autonomous piece of work with external organizations and revised, if necessary, to secure their concurrence to the proposed change.

Note 1: All analyses performed to respond to a query or to initiate a design change are archived in a new Calculation Package or added to an existing Calculation Package as a Supplement and the revision number of the Calculation Package is advanced. A supplement to a Calculation Package may consist of one analysis or several discrete analyses (each containing this cover sheet) supporting several ECOs.

1.0 INTRODUCTION

Multi-Purpose Canisters loaded with spent fuels need to be transferred from the HI-STAR 190 transport cask to the HI-TRAC CS transfer cask at the Cask Transfer Building (CTB) before they can be stored at the HI-STORE underground spent fuel storage facility in New Mexico. Potential environmental and man-made hazards at the HI-STORE site, such as earthquake, could result in the collapse of the CTB and a significant safety impact to a loaded HI-STAR 190 transport cask or a loaded HI-TRAC CS transfer cask in the CTB. The objective of this calculation is to evaluate the consequences of the postulated CTB collapse accident.

The CTB collapse accident evaluation documented in this calculation is focused on the analysis of the falling CTB roof onto a horizontally positioned HI-STAR 190 and a vertically positioned HI-TRAC CS. As shown in the CTB floor slab layout [1], the loaded HI-TRAC is expected to be placed between the Vertical Cask Transporter (VCT) supporting steel plates on the floor prior to being carried away by the VCT, and the horizontally positioned HI-STAR 190 on the cask cradle waiting for the MPC transfer operation is also aligned with the Canister Transfer Facility (CTF) and the expected HI-TRAC location. The CTB layout drawing also indicates that casks are expected to be at least 23 feet away from the CTB wall, which suggests that the impact between the falling CTB roof and the cask is a more realistic scenario.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

The finite element method is used to perform the analysis for the postulated impact between the falling CTB roof and the loaded HI-STAR 190 and HI-TRAC CS casks. LS-DYNA [2], a commercial computer code developed by the Livermore Software Technology Corporation and independently validated by Holtec International through its QA program [6], is used to perform the numerical simulation. This analysis methodology has been used to perform impact analyses for numerous USNRC licensed spent fuel wet and dry storage projects.

The acceptance criteria for the analyzed event are listed below. The ultimate goal is to demonstrate that both HI-STAR 190 and HI-TRAC CS casks can survive in the CTB collapse event without causing any significant safety impact.

1. The containment boundary of the HI-STAR 190 cask overpack shall not be breached or significantly deformed in the CTB collapse accident so that the spent fuel assemblies loaded inside the MPC will remain structurally intact and the MPC retrievability is not significantly affected.
2. The HI-TRAC CS transfer cask shall not overturn in the CTB collapse accident to provide continuous shielding function for the MPC.
3. The MPC enclosure vessel shall not be breached in the CTB collapse accident.
4. The shielding capacity of the impacted HI-STAR 190 overpack and HI-TRAC CS overpack shall not be significantly compromised due to the CTB collapse accident.

3.0 ASSUMPTIONS

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4.0 INPUT DATA

4.1 Geometric Input Data

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4.2 Weight

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4.3 Drop Height and Impact Velocity

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4.4 Material Properties

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5.0 REFERENCES

[1] "Cask Transport Building Floor Slab," Holtec Drawing No. 10912, Revision 0.

[2] LS-DYNA 971, Livermore Software Technology.

[3] "Finite Element Analyses of the HI-STAR 190 Transport Cask Package Drop Accidents," Holtec Report HI-2146321, Revision 1.

[4] "HI-TRAC CS Stack-up Analysis at CTF and UMAX," Supplement 5 to this calculation package.

[5] "HI-TRAC CS Licensing Drawing," Holtec Drawing 10868, Revision 0.

[6] Holtec Approved Computer Program List (ACPL), Revision 341.

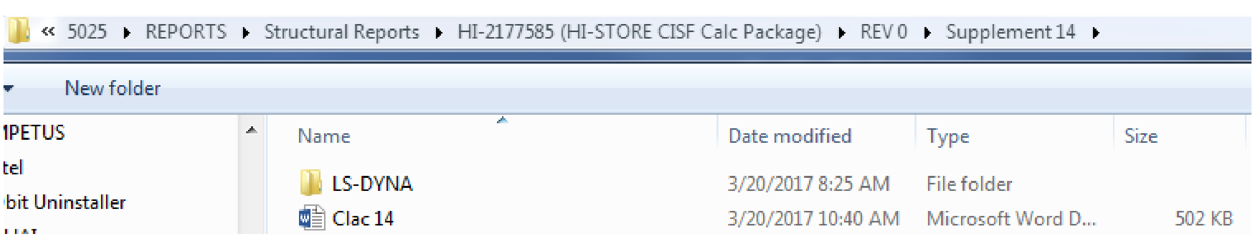
[7] "Structural Calculation Package for HI-STORM FW System," Holtec Report HI-2094418, Revision 19.

[8] HI-STAR 190 SAR, Holtec Report HI-2146214, Revision 0D.

Note: The revision status of Holtec documents cited above is subject to updates as the project progresses. This document will be revised if a revision to any of the above-referenced Holtec work products materially affects the instructions, results, conclusions or analyses contained in this document. Otherwise, a revision to this document will not be made and the latest revision of the referenced Holtec documents shall be assumed to supersede the revision numbers cited above. The Holtec Project Manager bears the undivided responsibility to ensure that there is no intra-document conflict with respect to the information contained in all Holtec generated documents on a safety significant project.

6.0 COMPUTER FILES

All computer files associated with this calculation are archived on the Holtec Server under the directories shown in following screen capture.



7.0 CALCULATIONS

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PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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8.0 RESULTS

The LS-DYNA simulation results for the analyzed CSB collapse accident are presented in Figures 8.1 through 8.7.

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9.0 CONCLUSIONS

This calculation evaluates the responses of the loaded HI-TRAC CS and HI-STAR 190 casks in the HI-STORE Cask Transfer Building due to the postulated building collapse accident. The impact event is analyzed using the LS-DYNA finite element analysis approach for the two governing impact scenarios based on conservative assumptions. The analysis results presented in this calculation package demonstrate that the both casks can protect the MPC and its contents against the building collapse event without any adverse safety consequence and without violating any of the acceptance criteria listed in Section 2.

10.0 FIGURES

Total Number of Figures = 9

[

PROPRIETARY INFORMATION WITHHELD IN ACCORDANCE WITH 10CFR2.390

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Figure 7.1, LS-DYNA Model Used to Analyze the CTB collapse Accident Involving a Loaded HI-TRAC CS Transfer Cask

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Figure 7.2, LS-DYNA Model Used to Analyze the CTB collapse Accident Involving a Loaded HI-STAR 190 Transport Cask

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Figure 8.1, Deformation of the Falling Roof I-Beam on HI-TRAC CS at the End of the CTB Collapse Accident Simulation

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Figure 8.2, Local Plastic Strain of the Impacted HI-TRAC CS Transfer Cask

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Figure 8.3, I-Beam-to-MPC Impact Force Time History

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Figure 8.4, Deformation of the Falling Roof I-Beam on HI-STAR 190 at the End of the CTB Collapse Accident Simulation

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Figure 8.5, Local Plastic Strain in the HI-STAR 190 Overpack Steel Shells and radial Ribs

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Figure 8.6, Local Plastic Strain in the MPC Enclosure Vessel

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Figure 8.7, Local Plastic Strain at the Fuel Basket Bottom Outside of the Active Fuel Region