[redacted]

MAGNASTOR®

(Modular Advanced Generation
Nuclear All-purpose STORage)

FINAL SAFETY ANALYSIS REPORT

MSO Amendment
RAI Responses

NON-PROPRIETARY VERSION

NAC INTERNATIONAL

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Enclosure 1

NAC INTERNATIONAL

RESPONSES TO THE

**UNITED STATES
NUCLEAR REGULATORY COMMISSION
REQUEST FOR ADDITIONAL INFORMATION #1**

for

MAGNASTOR® FSAR
RAI Responses for Amendment 10
Revision 21A

(Docket No 72-1031)

NAC International

February 2021

NAC INTERNATIONAL

NON-PROPRIETARY RESPONSE TO THE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REQUEST FOR ADDITIONAL INFORMATION #1

October 2020

FOR REVIEW OF THE MAGNASTOR

(CoC NO. 1031, DOCKET NO. 72-1031)

February 2021

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NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

Structural Evaluation

3-1. Clarify how the effects of material nonlinearities (e.g., strain rate and triaxiality) are accounted for in the structural integrity evaluation of the MSO pedestal assembly and transportable storage container (TSC) when subjected to a 24-inch drop accident.

Based on the LS-DYNA finite element models provided with the SAR and the evaluation of the 24-inch drop presented in Calculation Package No. 30082-2604, "Evaluation of the MAGNASTOR® Metal Storage Overpack for a 24-inch Drop," it is not clear to the staff if these material nonlinearities have been accounted for in the plastic analysis of the MSO pedestal assembly or the finite element models supporting the plastic analysis. In the finite element models of the 24-inch drop provided to the staff, it appears that strain rate effects and triaxiality of failing components have not been incorporated into the analysis. For the piecewise linear plasticity material model used for the pedestal components, the option to account for strain rate effects by scaling the yield stress was chosen. However, the curve for the scaling factor does not appear to have been defined. The staff is concerned that higher g-loads could be experienced by the TSC and the structural integrity of the pedestal could be diminished when incorporating these material properties. Since the structural evaluation of the TSC in the drop is based on a comparison of the g-loads to the design TSC g-loads, the staff's concern is related to confinement. And since the deformations in the pedestal affect the geometry of the MSO air inlets, the staff's concern also relates to the thermal performance of the cask. The staff requests clarification of how these material nonlinearities are addressed and that the simulations, calculations, and the SAR be updated as necessary.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(l).

NAC International Response to Structural Evaluation RAI 3-1:

The effects of strain rate are accounted for by defining stress versus plastic strain curve for different strain rates. The solutions for the different cases were regenerated using the strain rate sensitive properties. From the revised solutions, a Triaxiality factor was determined using ASME Section VIII Division 2 Part 5 for protection against local failure. The factors of safety were recomputed using the Triaxiality factor.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

Structural Evaluation

3-2. Clarify the geometry of the MSO pedestal and the g-loads experienced by the TSC as a result of the 24-inch drop scenario.

LS-DYNA simulations of the 24-inch drop scenario show the TSC striking the MSO pedestal. The simulations show the part labeled "SHORT support rail," which is green in Figure 3-1 below and apparently unlabeled in the drawings but shown in detail AA-AA on sheet 4 of Drawing No. 71160-565, "MSO Body, Lid, and Details," rotating and engaging the inner liner (shown in red). The clearance between the inner "SHORT support rail" and the inner liner according to the drawings is

(proprietary information removed)

The staff is concerned that this extra clearance allows the pedestal to absorb more of the impact energy in the model than it would in the real drop. The "SHORT support rail" should "lock up" with the inner liner earlier in the simulation, this would increase the stiffness and allow for an "anvil and hammer" effect, which would increase the g-loads on the TSC. The staff also notes that several parts of the top portion of the MSO (e.g., the trunnions) are "ghosting through" (i.e., unrealistically passing through with no resistance) outer portions of the MSO. Though as this behavior occurs at the top of the model, the staff accepts that it may not impact the area of concern at the bottom of the model. The staff requests clarification of the MSO pedestal geometry, clarification of the g-loads experienced by the TSC in the drop scenario, and that the LS-DYNA models that simulate drop events, the calculations, and the FSAR be updated as necessary.

(Proprietary figure removed)

Figure 3-1, "SHORT Support Rail in LS-DYNA Heavy Drop Model"

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(l).

<u>NAC International Response to Structural Evaluation RAI 3-2:</u>

NAC International Response to Structural Evaluation RAI 3-2 can be found in the proprietary section of this enclosure.

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Structural Evaluation

3-3. Justify the assumption that the MSO will behave as a cantilever beam when determining the natural frequency of the MSO in Appendix A to Calculation Package No. 30082-2605, "Tip-Over Analysis for the MAGNASTOR Metal Storage Overpack (MSO)."

The stress analysis for the non-mechanistic tip-over provided on page 30 of the calculation package considers the MSO to be a simply supported beam with a triangular loading applied when striking the pad. However, this calculation applies a dynamic load factor that is derived from the natural frequency of the MSO calculated in Appendix A, which assumes a cantilever beam behavior. The staff notes that the LS-DYNA model that simulates tip-over produces the largest accelerations when the bottom lip of the MSO and tip of the MSO are in contact with the pad, resembling more closely a simply supported beam. Looking at Figure 6.1.5-1 of Calculation Package 30082-2605, the staff believes that the dynamic load factor determined from assuming a cantilever beam behavior may be non-conservative when a simply supported beam assumption appears to be more appropriate for the boundary conditions of the MSO when striking the pad. The staff requests justification of the assumption of cantilever beam behavior in the tip-over stress analysis and that the calculations and FSAR be updated with the appropriate dynamics load factor as necessary.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(l).

<u>NAC International Response to Structural Evaluation RAI 3-3:</u>

The calculation of the fundamental mode of the MSO has been updated using a pinned-free boundary condition, which is considered to be more appropriate than a cantilevered assumption. Also, the resulting fundamental frequency of pinned-free beam is higher than both a cantilevered and simply supported beam, and this results in a higher filtering frequency to be applied to the accelerations time histories, which is conservative. In addition, the methodology for calculating the MSO frequency has been modified by treating the MSO as a single composite beam comprised of the inner and outer liners. Both bending and shear effects are considered, and the calculated fundamental frequency of the MSO is 189 Hz. A filter frequency of 200 Hz is applied to the nodal accelerations from the solution results. Using the revised acceleration and pulse duration, the DLF has been updated.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

Thermal Evaluation

4-1. If the casks will be situated outside on a concrete pad, demonstrate that low-speed wind does not adversely impact the fuel peak clad temperature or other components important to safety such that the components exceed their allowable temperature limits described in the SAR.

In the response to request for supplemental information "Submission of a Responses to the NRCs Request for Supplemental Information for the NAC International MAGNASTOR® Cask System Amendment No. 10" (ADAMS Accession No. ML20143A102), the applicant states that it does not expect any negative thermal performance effects due to low wind speed even though this new cask design has traditional inlets and nontraditional outlet vents. These non-traditional outlet vents are circular and encompass the entire perimeter of the upper cask. However, the staff notes that because of a larger number of outlet vents that encompass the entire circumference, air exiting the outlet vents could encounter a larger resistance to the air flow compared to the traditional discrete design. Any justification that this outlet design does not impact the cask thermal performance needs to be supported by adequate analysis. The staff needs this information to have assurance predicted temperatures remain below the allowable limits described in the SAR, during long term storage. 10 CFR Part 72 regulations require that the spent fuel cladding must be protected during storage against degradation that leads to gross ruptures or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. The above is accomplished by keeping the cladding temperature below 400°C for the entire duration of the licensed storage period. Currently the SAR shows that for normal conditions of storage, predicted peak cladding temperature (PCT) is about 15°C below the allowable limit. Based on the information provided in the SAR regarding the unique design of the MSO outlet vent, the staff can't determine whether the increase in PCT (due to a potential reduction in air flow because of low speed wind) can be accommodated by the margin shown in the SAR. Therefore, the staff does not have reasonable assurance the spent fuel cladding would be protected from degradation during the entire licensed period for normal storage.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(b) and 72.236(f).

<u>NAC International Response to Thermal Evaluation RAI 4-1:</u>

As previously submitted to the RSI response cycle the MSO is expected to be used within a building protecting the cask from low speed impact. Technical Specification requirement for the use of a building is added to the MSO definition and Section 4.3.1 as item (j). The thermal basis building requirements are discussed in the response to RAI 4-2.

NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR ADDITIONAL INFORMATION

Thermal Evaluation

4-2. If the casks will be situated outside on a concrete pad, demonstrate that low-speed wind does not adversely impact the fuel peak clad temperature or other components important to safety such that the components exceed their allowable temperature limits described in the SAR.

In the response to request for supplemental information "Submission of a Responses to the NRCs Request for Supplemental Information for the NAC International MAGNASTOR® Cask System Amendment No. 10" (ADAMS Accession No. ML20143A102), the applicant states that it does not expect any negative thermal performance effects due to low wind speed even though this new cask design has traditional inlets and nontraditional outlet vents. These non-traditional outlet vents are circular and encompass the entire perimeter of the upper cask. However, the staff notes that because of a larger number of outlet vents that encompass the entire circumference, air exiting the outlet vents could encounter a larger resistance to the air flow compared to the traditional discrete design. Any justification that this outlet design does not impact the cask thermal performance needs to be supported by adequate analysis. The staff needs this information to have assurance predicted temperatures remain below the allowable limits described in the SAR, during long term storage. 10 CFR Part 72 regulations require that the spent fuel cladding must be protected during storage against degradation that leads to gross ruptures or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage. The above is accomplished by keeping the cladding temperature below 400°C for the entire duration of the licensed storage period. Currently the SAR shows that for normal conditions of storage, predicted peak cladding temperature (PCT) is about 15°C below the allowable limit. Based on the information provided in the SAR regarding the unique design of the MSO outlet vent, the staff can't determine whether the increase in PCT (due to a potential reduction in air flow because of low speed wind) can be accommodated by the margin shown in the SAR. Therefore, the staff does not have reasonable assurance the spent fuel cladding would be protected from degradation during the entire licensed period for normal storage.

This information is needed to determine compliance with the regulatory requirements in 10 CFR 72.236(b) and 72.236(f).

NAC International Response to Thermal Evaluation RAI 4-2:

As discussed in RAI 4-1 the use of the MSO is limited to building assuring protection from low speed wind. This building design will depend on site specific conditions, including but no limited to type of building material used, number of casks to be stored, heat load of casks to be stored, and environment conditions outside the building. 10 CFR 72.212 (6) requires an evaluation of site parameters to see if they are bounded. In this case the buildings influence on cask performance must be evaluated. Per 10 CFR 72.212 (7) a 72.48(c) based evaluation for any changes must be performed which limits the evaluation to FSAR MOE or equivalent methods.

NAC is also proposing Technical Specification condition 5.4(d) explicitly requiring this evaluation to be performed in the context of thermal limits.

NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR ADDITIONAL INFORMATION

Shielding Evaluation

5-1. See proprietary section of this enclosure. The entire question contains proprietary information.

5-2 See proprietary section of this enclosure. The entire question contains proprietary information.

NAC International Response to Shielding Evaluation RAI 5-1 and 5-2 can be found in the proprietary section of this enclosure.

NAC INTERNATIONAL RESPONSE
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Materials Evaluation

8-1. Clarify the fracture toughness testing requirements and acceptance criteria for the procured structural steels for the MSO and provide a technical basis for any criteria that deviates from the design code.

SAR Tables 1.3-5 and 2.1-1 state that all steel materials shall meet applicable requirements in the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code, and that the design code of the MSO is ASME B&PV Code, Section III, Division 1, Subsection NF. ASME B&PV NF-2300 includes testing requirements and acceptance criteria for procured steels to verify that the steels were produced with adequate toughness. However, the staff notes that some of the fracture toughness testing requirements and acceptance criteria for the MSO structural steels do not appear to be defined in the SAR, while other test requirements appear to be inconsistent with the ASME B&PV code.

SAR Section 8.1.1, "Fracture Toughness," does not include a description of the toughness testing and acceptance criteria for many of the MSO components, such as the bottom weldment and inner and outer liners. In addition, the basis provided for not requiring fracture toughness testing of the MSO trunnion steels (the MSO handling is limited to temperatures of 0°F and above) does not appear to be consistent with ASME Code. The staff notes that ASME B&PV Code, Section III, Division 1, Subsection NF-2300 includes materials that do not require testing; however, it is not clear how the trunnion steels meet the ASME B&PV Code exception criteria.

In order to complete its review, the staff requires information on the fracture toughness testing and acceptance criteria for the procured MSO steels and a technical basis for any criteria that deviates from the design code.

This information is needed to determine compliance with the regulatory requirements in 72.146(a), 72.234(a), and 72.236(b).

<u>NAC International Response to Materials Evaluation RAI 8-1:</u>

The Metal Storage Overpack (MSO) is evaluated for the same design events as the Concrete Cask (CC) and qualified to meet the stress design factors of ASME Section III, Division 1, Subsection NF, in accordance with Article NF-3000 "Design". The MSO is not considered an ASME NF component and need not be fabricated in accordance with ASME Section III, Division 1, Subsection NF requirements. As noted in the revised 71160-565 license drawing, the MSO structural materials shall meet ASTM requirements and all welding procedures and qualifications are to be in accordance with AWS D1.1 or

NAC International Response to Materials Evaluation RAI 8-1 Continued:

ASME Section IX. The interfacing lift points (i.e., trunnions) are qualified to meet ANSI N14.6 stress requirements for non-critical lift conditions and the cask is evaluated for drop conditions in accordance with NUREG-0612. The identified MSO design basis for storage conditions does not require impact testing of the materials used unless dictated by the ASTM material standard. As noted, consistent with the Concrete Cask, for lift conditions the interfacing lift points of the MSO have been qualified to ANSI N14.6 requirements for lifting devices. Similarly, the impact testing requirements of ANSI N14.6 are applied to the lift anchors of the Concrete Cask and lift trunnions of the MSO. Descriptions in Chapter 8 provide justification for why the Concrete Cask lift anchors are exempt from impact testing by stating the material type, thickness and service temperature that is consistent with the ASME Section III, Division 1, Subsection NF exemptions in Article NF-2300. The exemptions provided in Article NF-2300 do not address the ASTM A696 material used for the MSO trunnions. Therefore, consistent with the imposed requirements of the Concrete Cask, impact testing is to be required for the MSO trunnion material to support a lift service temperature of 0°F. The impact testing requirements detailed in Article NF-2300 are used as the basis for qualifying the MSO trunnion material using Charpy V-Notch testing. SAR pages are revised to clarify the fabrication requirements including applicable impact testing as follows:

- Table 1.3-5 is revised to clarify the fabrication specification summary for the MSO.
- Section 1.8 is revised to reflect the updated revision number for the 71160-565 license drawing.
- Chapter 8 is revised for the clarification of the steel components for the MSO
    - Sections 8.1, 8.2, & 8.10.2.2 are updated to reflect ASTM materials for the MSO consistent with the revised 71160-565 license drawing.
    - Section 8.1.1 is revised to clarify the impact testing requirements for the MSO trunnion material consistent with the above discussion.
    - Section 8.4 is revised to clarify the requirement for weld design and specification.
- Section 10.1.1 is revised to provide visual inspection and nondestructive examination requirement description of MSO steel components consistent with the changes made to Table 1.3-5, the 71160-565 license drawing, and Section 8.4.

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Materials Evaluation

8-2. Provide a copy of the NS-3 shielding material fabrication specification per SAR licensing Drawing No. 71160-565, Revision 0P and describe the qualification activities for the installation (mixing/pouring) process that demonstrates that it will prevent or sufficiently minimize gaps and voids to ensure shielding performance, with no requirement for testing of the MSO for shielding effectiveness.

SAR Section 8.7.2 stated that the NS-3 shielding material is installed by pouring the material into the annulus formed by the MSO inner and outer shells and the cavity of the MSO lid and that the installation of the material utilizes a process that minimizes gaps and voids in the installed material. Consequently, no shop or field testing of the MSO for gamma or neutron shielding effectiveness is required or performed.

The staff requests additional information on the details of the fabrication specification and the qualification activities that were performed to demonstrate that the specification will minimize or ensure the absence of voids and gaps, without the need for subsequent shielding performance tests. Such qualification details may include, but are not necessarily limited to, shielding effectiveness tests that were performed on NS-3 material fabricated over the ranges of processing variables allowed under the specification.

This information is required to ensure compliance with 10 CFR 72.146(a) and 72.236(d).

<u>NAC International Response to Materials Evaluation RAI 8-2:</u>

The NS-3 material is cementitious, mixed in a typical mortar mixer, and will be placed in the MSO shielding cavity in a similar manner to the way concrete is placed in NAC concrete overpacks. No specific void/gap testing is required for concrete placement and no such testing is expected for the NS-3 placement. 10 CFR 72.104/106 requirements are placed on controlled boundary performance and significant voiding, not expected of the cementitious product placed into the open cask cavity, would be required to impact controlled area boundary dose. Technical Specification 3.3.1 will ensure that the bulk shield of the MSO meets controlled area boundary requirements.

NS-3 has been used in NAC concrete cask shield plugs and a NUHOMS transfer cask design. Installation procedures that assure a uniform mix were prepared for each of the installations and are included with the RAI response (Attachments 1 and 2 in the proprietary section of this enclosure). The procedures are consistent with NS3 samples that were tested and are designed to eliminate significant gaps or voids. Gaps and shrinkage are minimized by covering the material during curing avoiding excess moisture loss. NAC records related to the shield plugs do not indicate any significant shrinkage or voids.

NAC International Response to Materials Evaluation RAI 8-2 Continued:

Material properties resulting from the testing/qualification are included in the updated FSAR (as a response to Chapter 5 RAIs). The testing included radiation and thermal impacts of the material. Material mixed and placed in accordance with installation procedures will serve its intended function similar to the requirements of a concrete radiation shield.

Fabrication Specification

A placeholder fabrication specification number was placed on the NAC license drawing. Fabrication specifications are not written and approved until a CoC is granted and the licensed component has been purchased by an NAC customer. As the specification has not been required at this time the number has since been removed in Revision 1 of the drawing.

Prequalification of each NS-3 Lot for Hydrogen Content

A test kit for each lot of NS-3 material will be mixed and sent to a laboratory for hydrogen content testing. The minimum hydrogen requirement will be limited by what is analyzed in the NAC shielding calculation (4.85wt%). As demonstrated in Chapter 5 total dose rates are relatively sensitive to the hydrogen levels in the material. The minimum hydrogen requirement was therefore added to the licensing drawing.

Placement of NS-3 in an MSO

The NS-3 material will be mixed in a typical mortar mixer and pumped into the shielding cavity. In its liquid state, NS-3 flows readily. It contains no aggregate and there is no rebar in the cavity impeding its flow as is the case with concrete. The wet density of the NS-3 will be measured prior to placement into the metal overpack as is similarly done for concrete installations into NAC concrete overpacks. Similar to the concrete requirement, the MSO licensing drawing has been updated to include the minimum required material density (i.e., that evaluated in Chapter 5) of 1.70 g/cm^3.

Minimum hydrogen content and density, in conjunction with an appropriate installation procedure, will assure that the cask will perform its intended safety function.

Material Observations:

8-1 The description for item 6, shielding material, in the bill of materials on licensing Drawing No. 71160-565 sheet 1 of 9 refers to note 13, however note 13 does not describe the shielding material. Note 12 describes shielding material.

The staff observed that all descriptions that refer to drawing notes are incorrect for the following items: 22, 26, 28, 33 and 49.

NAC International Response to Materials Observation Evaluation RAI 8-1:

Corrections have been made to Licensing Drawing No. 71160-565, Revision 1P of the drawing to address the noted inconsistencies.

8-2 SAR Licensing Drawing No. 71160-565, sheet 2 of 9, Detail D-D. The weld symbol for welding item 5 gussets to item 7 bottom weldment shows a 0.5-inch weld. However, the staff does not recognize whether this weld symbol is a groove (square) or fillet weld.

NAC International Response to Materials Observation Evaluation RAI 8-2:

Specification of the welds for the assembly weldment are revised in Licensing Drawing No. 71160-565, Revision 1P of the drawing for clarity and consistency with the structural evaluation. As detailed in the revised drawing, ½ inch fillet welds on both sides are used to attach each of the eight Gussets (Item 5) to the Bottom Weldment (Item 7) and the Inner Liner (Item 1).

8-3 SAR licensing Drawing No. 71160-565, sheet 4 of 9, View U-U. The weld symbol for welding item 12 stand to item 14 base plate shows a ¼-inch weld, every 4 inches. However, the staff does not recognize whether this weld symbol is a groove (square) or fillet weld.

NAC International Response to Materials Observation Evaluation RAI 8-3:

The weld symbol is revised in Licensing Drawing No. 71160-565, Revision 1P of the drawing to clarify a fillet weld geometry. The Short Support Rails (Item 10), Long Support Rails (Item 11) and Support Rail Gussets (Item 13) are welded to form a cross-beam structure for the bottom weldment which supports the Base Plate (Item 14) and is supported by the Inlet Tops (Item 9). The weld in question attaches the Base Plate (Item 14) to the welded cross-beam structure of Items 10, 11 and 13. Delta Note 27 specifies that the weld starts at the radius of the Stand (Item 12) and extends outwards for the specified length of 4 inches.

NAC INTERNATIONAL

PROPRIETARY RESPONSE TO THE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
REQUEST FOR ADDITIONAL INFORMATION #1

October 2020

FOR REVIEW OF THE MAGNASTOR

(CoC NO. 1031, DOCKET NO. 72-1031)

February 2021

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TO
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Structural Evaluation

3-1. See the non-proprietary section of this enclosure. The entire question contains non-proprietary information.

NAC International Response to Structural Evaluation RAI 3-1 can be found in the non-proprietary section of this enclosure.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

Structural Evaluation

3-2. [redacted]

[redacted]

NAC INTERNATIONAL RESPONSE
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Structural Evaluation

3-3. See the non-proprietary section of this enclosure. The entire question contains non-proprietary information.

NAC International Response to Structural Evaluation RAI 3-3 can be found in the non-proprietary section of this enclosure.

NAC INTERNATIONAL RESPONSE
TO
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Thermal Evaluation

4-1. See the non-proprietary section of this enclosure. The entire question contains non-proprietary information.

4-2 See the non-proprietary section of this enclosure. The entire question contains non-proprietary information.

NAC International Response to Thermal Evaluation RAI 4-1 and 4-2 can be found in the non-proprietary section of this enclosure.

NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR ADDITIONAL INFORMATION

Shielding Evaluation

5-1. [redacted]

NAC INTERNATIONAL RESPONSE
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Shielding Evaluation

5-2. [redacted]

NAC INTERNATIONAL RESPONSE
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Materials Evaluation

8-1. See the non-proprietary section of this enclosure. The entire question contains non-proprietary information.

8-2 See the non-proprietary section of this enclosure. The entire question contains non-proprietary information.

NAC International Response to Materials Evaluation RAI 8-1 and 8-2 can be found in the non-proprietary section of this enclosure.

Materials Observation

8-1. See the non-proprietary section of this enclosure. The entire question contains non-proprietary information.

8-2 See the non-proprietary section of this enclosure. The entire question contains non-proprietary information.

8-3 See the non-proprietary section of this enclosure. The entire question contains non-proprietary information.

NAC International Response to Materials Observation RAI 8-1, 8-2 and 8-3 can be found in the non-proprietary section of this enclosure.

Attachment 1

NAC Proprietary

NS-3 Installation Procedure

BISCO Procedure No. NS-3-02 Rev. 5

PROCEDURE IS PROPRIETARY AND WITHHELD IN ITS ENTIRETY PER 10 CFR 2.390

Attachment 2

NAC Proprietary

NS-3 Installation Procedure

IONICS, Inc. Procedure No. MI-1142 Rev. 1

PROCEDURE IS PROPRIETARY AND WITHHELD IN ITS ENTIRETY PER 10 CFR 2.390

Enclosure 2

List of Changes

for

MAGNASTOR® FSAR
RAI Responses for Amendment 10
Revision 21A

(Docket No 72-1031)

NAC International

February 2021

List of Changes for the MAGNASTOR® FSAR, Revision 21A

Note: The List of Effective Pages and the Chapter Table of Contents, List of Figures, and List of Tables have been revised accordingly to reflect the list of changes detailed below.

Chapter 1

- Page 1.3-23, modified Table 1.3-5 where indicated.
- Page 1.7-2, inserted new Reference 25, and renumbered and modified Reference 26 where indicated.
- Page 1.8-1, modified the list of License Drawings where indicated. (Proprietary version only.)
- Page 1.8-2, text flow changes (editorial). (Proprietary version only.)

Chapter 2

- No changes

Chapter 3

- Pages 3.11.4-15 thru 3.11.4-16, modified text throughout Section 3.11.4.5 where indicated.
- Page 3.11.4-17, modified text in the last paragraph of Section 3.11.4.6, including the embedded table, where indicated.
- Page 3.11.4-18, text flow changes.
- Pages 3.11.4-19 thru 3.11.4-20, replaced Figures 3.11.4-2 and 3.11.4-3 where indicated.
- Page 3.11.4-21, text flow changes.
- Page 3.11.4-22, replaced Figure 3.11.4-5 where indicated.
- Page 3.11.4-23, text flow changes.

Chapter 4

- No changes

Chapter 5

- Pages 5.12.4-2 thru 5.12.4-4, modified text throughout Sections 5.12.4.2 and 5.12.4.3 where indicated.
- Pages 5.12.4-5 thru 5.12.4-6, text flow changes.
- Pages 5.12.4-7 thru 5.12.4-12, added new Figures 5.12.4-3 thru 5.12.4-8 where indicated.
- Page 5.12.4-13, modified column heading in Table 5.12.4-2 where indicated.

Chapter 6

- No changes

Chapter 7

- No changes

Chapter 8

- Page 8.1-2, modified text near the middle of the page, where indicated.
- Pages 8.1-3 thru 8.1-4, modified text in the fourth paragraph in Section 8.1.1 where indicated.
- Page 8.2-1, modified text in the fourth and fifth paragraphs of Section 8.2, where indicated.
- Page 8.4-1, modified text in the third paragraph in Section 8.4 where indicated.
- Page 8.10-4, modified text at the top of the page in the last paragraph of Section 8.10.2.2 where indicated.

Chapter 9

- No changes

Chapter 10

- Page 10.1-1, modified text in Section 10.1.1, step "e"; deleted first sentence of the second paragraph where indicated.
- Pages 10.1-2, modified text in Section 10.1.1, step "j"; deleted last two sentences of the step where indicated.
- Page 10.1-3, text flow changes.

Chapter 11

- No changes

Chapter 12

- No changes

Chapter 13

- No changes

Chapter 14

- No changes

Chapter 15

- No changes

Enclosure 3

List of Drawing Changes

for

MAGNASTOR® FSAR
RAI Responses for Amendment 10
Revision 21A

(Docket No 72-1031)

NAC International

February 2021

Drawing 71160-565, Body, Lid and Details, Metal Storage Overpack (MSO), MAGNASTOR, Revision 3P

[redacted]

Drawing 71160-565, Body, Lid and Details, Metal Storage Overpack (MSO), MAGNASTOR, Revision 2P

[redacted]

DRAWINGS UPDATED IN THIS SUBMITTAL ARE PROPRIETARY AND WITHHELD IN THEIR ENTIRETY PER 10 CFR 2.390

Enclosure 4

Proposed Changes

for

MAGNASTOR® Technical Specifications
RAI Responses to Amendment 10
Revision 21A

(Docket No 72-1031)

NAC International

February 2021

MSO (Metal Storage Overpack)	The MSO is the vertical storage module that receives, holds and protects the sealed TSC for storage at the ISFSI. The MSO passively provides the radiation shielding, structural protection, and heat dissipation capabilities for the safe storage of spent fuel in a TSC. The ISFSI pad (storage pad) for the MSO must be located within a building structure.
NONFUEL HARDWARE	NONFUEL HARDWARE is defined as reactor control components (RCCs), burnable poison absorber assemblies (BPAAs), guide tube plug devices (GTPDs), neutron sources/ neutron source assemblies (NSAs), hafnium absorber assemblies (HFRAs), instrument tube tie components, guide tube anchors or other similar devices, in-core instrument thimbles, steel rod inserts (used to displace water from lower section of guide tube), and components of these devices such as individual rods. All nonfuel hardware, with the exception of instrument tube tie components, guide tube anchors or other similar devices, and steel rod inserts, may be activated during in-core operations. RCCs are commonly referred to as rod cluster control assemblies (RCCAs), control rod assemblies (CRAs), or control element assemblies (CEAs). RCCs are primarily designed to provide reactor shutdown reactivity control, are inserted into the guide tubes of the assembly, and are typically employed for a significant number of operating cycles. Burnup poison absorber assemblies (BPAAs) are commonly referred to as burnup poison rod assemblies (BPRAs), but may have vendor specific nomenclature such as BPRA, Pyrex BPRA or WABA (wet annular burnable absorber). BPAAs are used to control reactivity of fresh fuel or high reactivity fuels and are commonly used for a single cycle, but may be used for multiple cycles. GTPDs are designed to block guide tube openings when no BPAA is employed and are commonly referred to as thimble plugs (TPs), thimble plug devices (TPDs), flow mixers (FMs), water displacement guide tube plugs, or vibration suppressor inserts. GTPDs may be employed for multiple cycles. NSAs are primary and secondary neutron sources used during reactor startup and may be used for multiple cycles. Integral fuel burnable absorbers, either integral to a fuel rod or as a substitution for a fuel rod, and fuel replacement rods (fueled, stainless steel, or zirconium alloy) are considered components of spent nuclear fuel (SNF) assemblies and are not considered to be nonfuel hardware.

(continued)

OPERABLE	A system, component, or device is OPERABLE when it is capable of performing its specified safety functions.
SPENT NUCLEAR FUEL (SNF)	Irradiated fuel assemblies consisting of end-fittings, grids, fuel rods and integral hardware. Integral hardware for PWR assemblies primarily consists of guide/instrument tubes, but may contain integral fuel burnable absorbers, either integral to a fuel rod or as a fuel rod substitution, and fuel replacement rods (another fuel rod, stainless steel rod, or zirconium alloy rod). For BWR fuel, integral hardware may consist of water rods in various shapes, inert rods, fuel rod cluster dividers, and/or fuel assembly channels (optional). PWR SNF may contain NONFUEL HARDWARE.
STORAGE CASK	A STORAGE CASK is either a CONCRETE CASK or an MSO.
STORAGE OPERATIONS	STORAGE OPERATIONS include all licensed activities that are performed at the ISFSI following placement of a CONCRETE CASK or MSO containing a loaded TSC at its designated storage location on the storage pad.
TRANSFER CASK	TRANSFER CASK is a shielded lifting device designed to hold the TSC during LOADING OPERATIONS, TRANSFER OPERATIONS, and UNLOADING OPERATIONS. Either a MAGNASTOR TRANSFER CASK (MTC) or Passive MAGNASTOR TRANSFER CASK (PMTC) may be used.
TRANSFER OPERATIONS	TRANSFER OPERATIONS include all licensed activities involved in using a MAGNASTOR TRANSFER CASK (MTC) or Passive MAGNASTOR TRANSFER CASK (PMTC) to move a loaded and sealed TSC from a; CONCRETE CASK to another CONCRETE CASK or from an MSO to another MSO.
TRANSPORT OPERATIONS	TRANSPORT OPERATIONS include all licensed activities performed on a loaded MAGNASTOR CONCRETE CASK or MSO when it is being moved to and from its designated location on the ISFSI. TRANSPORT OPERATIONS begin when the loaded CONCRETE CASK or MSO is placed on or lifted by a transporter and end when the CONCRETE CASK or MSO is set down in its storage position on the ISFSI pad.

(continued)

TRANSPORTABLE STORAGE CANISTER (TSC)	The TRANSPORTABLE STORAGE CANISTER (TSC) is the welded container consisting of a basket in a weldment composed of a cylindrical shell welded to a baseplate. The TSC includes a closure lid, a shield plate (optional), a closure ring, and redundant port covers at the vent and the drain ports. The closure lid is welded to the TSC shell and the closure ring is welded to the closure lid and the TSC shell. The port covers are welded to the closure lid. The TSC provides the confinement boundary for the radioactive material contained in the TSC cavity.
TSC TRANSFER FACILITY	The TSC TRANSFER FACILITY includes: 1) a transfer location for the lifting and transfer of a TRANSFER CASK and placement of a TSC into or out of a CONCRETE CASK or MSO; and 2) either a stationary lift device or a mobile lifting device used to lift the TRANSFER CASK and TSC, but not licensed as part of the 10 CFR 50 facility.
UNDAMAGED FUEL	SNF that can meet all fuel specific and system-related functions. UNDAMAGED FUEL is SNF that is not DAMAGED FUEL, as defined herein, and does not contain assembly structural defects that adversely affect radiological and/or criticality safety. As such, UNDAMAGED FUEL may contain: a) BREACHED SPENT FUEL RODS (i.e, rods with minor defects up to hairline cracks or pinholes) but cannot contain grossly breached fuel rods; b) Grid, grid strap, and/or grid spring damage provided that the unsupported length of the fuel rod does not exceed 60 inches.
UNLOADING OPERATIONS	UNLOADING OPERATIONS include the activities required to remove the fuel assemblies from a sealed TSC. UNLOADING OPERATIONS begin with the movement of the TSC from a CONCRETE CASK or MSO into a TRANSFER CASK in an unloading facility and end when the last fuel assembly has been removed from the TSC.

minimum radiation shield equivalent to 2 inches of carbon steel or stainless steel and 3.2 inches of lead gamma shielding and 2.25 inches of NS-4-FR (with 0.6 wt % B_4C and 6.0 wt % H) neutron shielding. Material and dimensions of the individual shield layers may vary provided maximum calculated radial dose rates of 1100 mrem/hr (PWR system) and 1600 mrem/hr (BWR system) are maintained on the vertical surface (not including doors or vent shielding).

4.1.4 TSC Confinement Integrity

The TSC shell, bottom plate, all confinement welds, and the COMPOSITE CLOSURE LID shall be fabrication helium leak-tested in accordance with ANSI N14.5 to leaktight criterion.

The closure lid shall be helium leak-tested during fabrication (in accordance with ANSI N14.5 to leaktight criterion) if it is constructed with a lid thickness less than 9 inches (nominal).

4 2 Codes and Standards

The American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), 2001 Edition with Addenda through 2003, Section III, Subsection NB, is the governing Code for the design, material procurement, fabrication, and testing of the TSC.

The ASME Code, 2001 Edition with Addenda through 2003, Section III, Subsection NG, is the governing Code for the design, material procurement, fabrication and testing of the spent fuel baskets.

The American Concrete Institute Specifications ACI-349 and ACI-318 govern the design and construction of the vertically reinforced concrete structure of the CONCRETE CASK, respectively and not the CONCRETE CASK lid or upper segment, if equipped.

The American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), 2001 Edition with Addenda through 2003, Section III, Subsection NF, is the governing Code for the design of the MSO. The applicable standards of the American Society for Testing and Materials (ASTM) govern material procurement and the American Welding Society (AWS) D1.1 or ASME Code Section VIII govern fabrication of the MSO.

The American National Standards Institute ANSI N14.6 (1993) and NUREG-0612 govern the TRANSFER CASK design, operation, fabrication, testing, inspection, and maintenance.

4.2.1 Alternatives to Codes, Standards, and Criteria

Table 2.1-2 of the FSAR lists approved alternatives to the ASME Code for the design, procurement, fabrication, inspection and testing of MAGNASTOR SYSTEM TSCs and spent fuel baskets.

(continued)

e. In cases where engineered features (i.e., berms, shield walls) are used to ensure that requirements of 10 CFR 72.104(a) are met, such features are to be considered important to safety and must be evaluated to determine the applicable Quality Assurance Category on a site-specific basis.

f. The TRANSFER CASK shall not be operated and used when surrounding air temperature is < 0°F. This limit is NOT applicable to the stainless steel MTC or PMTC.

g. The CONCRETE CASK or MSO shall not be lifted by the lifting lugs with surrounding air temperatures < 0°F.

h. Loaded CONCRETE CASK or MSO lifting height limit ≤24 inches.

i. The maximum design basis earthquake acceleration of 0.37g in the horizontal direction (without cask sliding) and 0.25g in the vertical direction at the ISFSI pad top surface do not result in cask tip-over.

   For design basis earthquake accelerations up to and greater than 0.37g in the horizontal direction and 0.25g in the vertical direction at the ISFSI pad top surface, site-specific cask sliding is permitted with validation by the cask user that the cask does not slide off the pad and that the g-load resulting from the collision of two sliding casks remains bounded by the cask tip-over accident condition analysis presented in Chapter 3 of the FSAR.

   An alternative to crediting site-specific cask sliding for design basis earthquake accelerations up to and greater than 0.37g in the horizontal direction and 0.25g in the vertical direction at the ISFSI pad top surface, the use of the MAGNASTOR system is permitted provided the ISFSI pad has bollards and the cask user validates that the cask does not overturn, g-loads resulting from the cask contacting the bollard is bounded by the cask tip-over accident condition presented in Chapter 3 of the FSAR, and the ISFSI pad and bollards are designed, fabricated and installed such that they are capable of handling the combined loading of the design basis earthquake and any contact between the bollard and cask during the design basis earthquake.

j. The storage pad for the MSO must be located within a building structure. The building shall provide cooling to the storage pad array via natural convection and no credit shall be taken for any mechanical cooling of the building.

4.4 TSC Handling and Transfer Facility

The TSC provides a leaktight confinement boundary and is evaluated for normal and off-normal handling loads. A handling and transfer facility is not required for TSC and TRANSFER CASK handling and transfer operations within a 10 CFR 50 licensed facility or for utilizing an external crane structure integral to a 10 CFR 50 licensed facility.

f. Verify that the time to complete the transfer of the TSC from the TRANSFER CASK to the CONCRETE CASK or MSO and from a CONCRETE CASK to another CONCRETE CASK, and from an MSO to another MSO assures that the fuel cladding temperature limit of 400°C is not exceeded.

g. The surface dose rates of the CONCRETE CASK or MSO are adequate to allow proper storage and to assure consistency with the offsite dose analysis.

h. The equipment used to move the loaded CONCRETE CASK or MSO onto or from the ISFSI site contains no more than 50 gallons of fuel.

This program will control limits, surveillances, compensatory measures and appropriate completion times to assure the integrity of the fuel cladding at all times in preparation for and during LOADING OPERATIONS, UNLOADING OPERATIONS, TRANSPORT OPERATIONS, TRANSFER OPERATIONS and STORAGE OPERATIONS, as applicable.

5.3 Transport Evaluation Program

A program that provides a means for evaluating transport route conditions shall be developed to ensure that the design basis impact g-load drop limits are met. For lifting of the loaded TRANSFER CASK, CONCRETE CASK, or MSO using devices that are integral to a structure governed by 10 CFR 50 regulations, 10 CFR 50 requirements apply. This program evaluates the site-specific transport route conditions and controls, including the transport route road surface conditions; road and route hazards; security during transport; ambient temperature; and equipment operability and lift heights. The program shall also consider drop event impact g-loading and route subsurface conditions, as necessary.

5.4 ISFSI Operations Program

A program shall be established to implement FSAR requirements for ISFSI operations.

At a minimum, the program shall include the following criteria to be verified and controlled:

a. Minimum CONCRETE CASK or MSO center-to-center spacing.

b. ISFSI pad parameters (i.e., thickness, concrete strength, soil modulus, reinforcement, etc.) are consistent with the FSAR analyses.

c. Maximum CONCRETE CASK or MSO lift heights ensure that the g-load limits analyzed in the FSAR are not exceeded.

d. For storage operations using the MSO, thermal evaluations must be performed on the cask array within the building to assure that system maximum component temperatures, in particular fuel clad temperature, remain within allowable limits. In addition, the building shall be evaluated under 10 CFR 72.212 requirements to ensure storage within the building structure does not create a new credible accident not presented in the FSAR.

5.5 Radiation Protection Program

5.5.1 Each cask user shall ensure that the 10 CFR 50 radiation protection program appropriately addresses dry storage cask loading and unloading, and ISFSI operations, including transport of the loaded CONCRETE CASK or MSO outside of facilities governed by 10 CFR 50 as applicable. The radiation protection program shall include appropriate controls and monitoring for direct radiation and surface contamination, ensuring compliance with applicable regulations, and implementing actions to maintain personnel occupational exposures ALARA. The actions and criteria to be included in the program are provided as follows.

5.5.2 Each user shall perform a written evaluation of the TRANSFER CASK and associated operations, 30 days prior to first use, to verify that it meets public, occupational, and ALARA requirements (including shielding design and dose characteristics) in 10 CFR Part 20, and that it is consistent with the program elements of each user's radiation protection program. The evaluation should consider both normal operations and unanticipated occurrences, such as handling equipment malfunctions, during use of the transfer cask.

5.5.3 As part of the evaluation pursuant to 10 CFR 72.212(b)(5)(iii), the licensee shall perform an analysis to confirm that the dose limits of 10 CFR 72.104(a) will be satisfied under actual site conditions and ISFSI configuration, considering the number of casks to be deployed and the cask contents.

5.5.4 Each user shall establish limits on the surface contamination of the CONCRETE CASK, MSO, TSC and TRANSFER CASK, and procedures for the verification of meeting the established limits prior to removal of the components from the 10 CFR 50 structure. Surface contamination limits for the TSC prior to placement in STORAGE OPERATIONS shall meet the limits established in LCO 3.3.2.

5.6 Deleted

(continued)

Enclosure 5

Supporting Calculations

for

MAGNASTOR® FSAR
RAI Responses to Amendment 10
Revision 21A

(Docket No 72-1031)

NAC International

February 2021

List of Calculations:

30082-2604 Revision 2
30082-2605 Revision 1

CALCULATIONS ARE PROPRIETARY AND WITHHELD
IN THEIR ENTIRETY PER 10 CFR 2.390

Enclosure 6

FSAR Changed Pages and LOEP

for

MAGNASTOR® FSAR
RAI Responses to Amendment 10
Revision 21A

(Docket No 72-1031)

NAC International

February 2021

[redacted]

MAGNASTOR®

(Modular Advanced Generation
Nuclear All-purpose STORage)

FINAL SAFETY ANALYSIS REPORT

NON-PROPRIETARY VERSION

NAC INTERNATIONAL

Atlanta Corporate Headquarters 3930 East Jones Bridge Road, Norcross, Georgia 30092 USA
Phone 770-447-1144, Fax 770-447-1797, www nacintl com

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Table 1.3-5 MSO Fabrication Specification Summary

Materials

- All steel materials shall be of the material as specified in the referenced drawings .
- NS-3 non-structural biological shielding material shall be governed by the referenced drawings.

Welding

- Welds shall be in accordance with the referenced drawings.
- Filler metals shall be appropriate ASME Code materials.
- Welders and welding operators shall be qualified in accordance with ASME Code Section IX [12] or ANSI/AWS D1.1 [25].
- Welding procedures shall be written and qualified in accordance with ASME Code Section IX or ANSI/AWS D1.1.
- Personnel performing weld examinations shall be qualified in accordance with the NAC International Quality Assurance Program and SNT-TC-1A [13].
- Weld inspection and examination requirements and acceptance criteria are specified in Chapter 10.

Fabrication

- Cutting, welding, and forming shall be in accordance with ASME Code, Section VIII [26] or ANSI/AWS D1.1.
- Surfaces shall be cleaned to a surface cleanness classification D, or better, as defined in ANSI N45.2.1 [14].
- Fabrication tolerances shall meet the requirements of the referenced drawings after fabrication.

Packaging

- Packaging and shipping shall be in accordance with ANSI N45.2.2 [15].

Quality Assurance

- The MSO shall be fabricated under a quality assurance program that meets 10 CFR 72, Subpart G, and 10 CFR 71, Subpart H.

1.7 References

1. 10 CFR 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste and Reactor-Related Greater Than Class C Waste," Code of Federal Regulations, US Nuclear Regulatory Commission, Washington, DC.
2. NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," US Nuclear Regulatory Commission, Washington, DC, January 1997.
3. 10 CFR 71, "Packaging and Transportation of Radioactive Materials," Code of Federal Regulations, US Nuclear Regulatory Commission, Washington, DC.
4. Regulatory Guide 3.61, "Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Concrete Cask," US Nuclear Regulatory Commission, Washington, DC, February 1989.
5. ISG-15, "Materials Evaluation," US Nuclear Regulatory Commission, Washington, DC, Revision 0, January 10, 2001.
6. ANSI/ANS 57.9-1992, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)," American Nuclear Society, La Grange Park, IL, May 1992.
7. ACI 318-95, "Building Code Requirements for Structural Concrete," American Concrete Institute, Farmington Hills, MI.
8. ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, "Class I Components," American Society of Mechanical Engineers, New York, NY, 2001 Edition with 2003 Addenda.
9. ASME Boiler and Pressure Vessel Code, Section III, Subsection NG, "Core Support Structures," American Society of Mechanical Engineers, New York, NY, 2001 Edition with 2003 Addenda.
10. ISG-11, "Cladding Considerations for the Transport and Storage of Spent Fuel," US Nuclear Regulatory Commission, Washington, DC, Revision 3, November 17, 2003.
11. ANSI N14.6-1993, "American National Standard for Radioactive Materials – Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More," American National Standards Institute, Inc., Washington, DC, June 1993.
12. ASME Boiler and Pressure Vessel Code, Section IX, "Qualification Standards for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators," American Society of Mechanical Engineers, New York, NY, 2001 Edition with 2003 Addenda.
13. Recommended Practice No. SNT-TC-1A, "Personnel Qualification and Certification in Nondestructive Testing," The American Society for Nondestructive Testing, Inc., Columbus OH, edition as invoked by the applicable ASME Code.

14. ANSI N45.2.1-1973, "Cleaning of Fluid Systems and Associated Components During Construction Phase of Nuclear Power Plants," American National Standards Institute, Inc., Washington, DC.
15. ANSI N45.2.2-1978, "Packaging, Shipping, Receiving, Storage, and Handling of Items for Nuclear Power Plants," American National Standards Institute, Inc., Washington, DC.
16. ASTM C94[a], "Standard Specification for Ready-Mixed Concrete," American Society for Testing and Materials, West Conshohocken, PA.
17. ASTM C150[a], "Standard Specification for Portland Cement," American Society for Testing and Materials, West Conshohocken, PA.
18. ASTM C33[a], "Standard Specification for Concrete Aggregates," American Society for Testing and Materials, West Conshohocken, PA.
19. ASTM C637[a], "Specification for Aggregates for Radiation-Shielding Concrete," American Society for Testing and Materials, West Conshohocken, PA.
20. ASTM C494[a], "Standard Specification for Chemical Admixtures for Concrete," American Society for Testing and Materials, West Conshohocken, PA.
21. ASTM C618[a], "Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete," American Society for Testing and Materials, West Conshohocken, PA.
22. ASTM C172[a], "Standard Practice for Sampling Freshly Mixed Concrete," American Society for Testing and Materials, West Conshohocken, PA.
23. ASTM C31[a], "Method of Making and Curing Concrete Test Specimens in the Field," American Society for Testing and Materials, West Conshohocken, PA.
24. ASTM C39[a], "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens," American Society for Testing and Materials, West Conshohocken, PA.
25. ANSI/AWS D1.1, "Structural Welding Code – Steel," American National Standards Institute, Inc., Washington, DC, 1998.
26. ASME Boiler and Pressure Vessel Code, Section VIII, "Rules for Construction of Pressure Vessels", American Society of Mechanical Engineers, New York, NY, 2001 Edition with 2003 Addenda.

[a] Current edition of testing standards at time of fabrication/construction is to be used.

1.8 License Drawings

This section presents the list of License Drawings for MAGNASTOR.

Drawing Number	Title	Revision No.
71160-551	Fuel Tube Assembly, MAGNASTOR – 37 PWR	10NP*
71160-556	Assembly, MAGNASTOR Transfer Cask (MTC), Stainless Steel	4
71160-560	Assembly, Standard Transfer Cask, MAGNASTOR	2
71160-561	Structure, Weldment, Concrete Cask, MAGNASTOR	9
71160-562	Reinforcing Bar and Concrete Placement, Concrete Cask, MAGNASTOR	9
71160-565	Body, Lid and Details, Metal Storage Overpack (MSO), MAGNASTOR	0NP*
71160-567	Loaded MSO Metal Storage Overpack (MSO), MAGNASTOR	0NP*
71160-571	Details, Neutron Absorber, Retainer, MAGNASTOR – 37 PWR	8
71160-572	Details, Neutron Absorber, Retainer, MAGNASTOR – 87 BWR	8NP*
71160-574	Basket Support Weldments, MAGNASTOR – 37 PWR	6
71160-575	Basket Assembly, MAGNASTOR – 37 PWR	11NP*
71160-581	Shell Weldment, TSC, MAGNASTOR	5
71160-584	Details, TSC, MAGNASTOR	9
71160-585	TSC Assembly, MAGNASTOR	12
71160-590	Loaded Concrete Cask, MAGNASTOR	8
71160-591	Fuel Tube Assembly, MAGNASTOR – 87 BWR	8NP*
71160-598	Basket Support Weldments, MAGNASTOR – 87 BWR	7NP*
71160-599	Basket Assembly, MAGNASTOR – 87 BWR	8NP*
71160-600	Basket Assembly, MAGNASTOR – 82 BWR	5NP*
71160-601	Damaged Fuel Can (DFC), Assembly, MAGNASTOR	0
71160-602	Damaged Fuel Can (DFC), Details, MAGNASTOR	1
71160-656	Cask Body Weldment, Passive Transfer Cask, MAGNASTOR	1NP*
71160-657	Passive Transfer Cask, Assembly, MAGNASTOR	1NP*
71160-671	Details, Neutron Absorber, Retainer, For DF Corner Weldment, MAGNASTOR – 37 PWR	0
71160-673	Damaged Fuel Can (DFC), Spacer, MAGNASTOR	0
71160-674	DF Corner Weldment, MAGNASTOR	3NP*
71160-675	DF Basket Assembly, 37 Assembly PWR, MAGNASTOR	3NP*
71160-681	DF, Shell Weldment, TSC, MAGNASTOR	1

Drawing Number	Title	Revision No.
71160-684	Details, DF Closure Lid, MAGNASTOR	2
71160-685	DF, TSC Assembly, MAGNASTOR	6

* Proprietary drawing replaced by nonproprietary version.

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OD_{inner} = 92.1 in
ID_{inner} = 79.5 in

Pedestal Crush Evaluation

Upon a bottom-end impact of the MSO, the TSC produces a force on the pedestal (base weldment) located near the bottom of the cask. The ring above the air inlets is expected to yield. To determine the resulting acceleration of the TSC and deformation of the pedestal, a half-symmetry model of the MSO, including the base weldment, is used to perform an impact analysis using the LS-DYNA program. The model is shown in Figure 3.11.4-1.

The model is constructed of 4-node shell elements and 8-node brick elements. Symmetry conditions are applied along the planes of symmetry. 8-node solid elements located in the canister bottom plate represent the loaded canister. The inner and outer shells along with the neutron shield are connected to the top of the inlet top plate using LSDYNA tied contact definitions. The TSC is modeled as an inelastic plate with the loaded TSC weight uniformly distributed at the surface of the plate. The impact plane is represented as a rigid plane

To ensure that maximum deformations and accelerations are determined, two 24-in drop analyses are performed. The first analysis uses the upper-bound TSC weight of 105 kips and envelops the maximum deformation of the pedestal. The second analysis employs the lower-bound TSC weight of 60 kips to account for maximum acceleration.

The maximum accelerations of the TSC during the 24-inch bottom-end impact are calculated to be 16.6g and 24.5g for the upper-bound TSC weight and lower-bound TSC weight, respectively. The acceleration time histories of the TSC, which are filtered at a frequency of 200 Hz, are shown in Figure 3.11.4-2 for the analysis using the upper-bound weight model and Figure 3.11.4-3 for the lower-bound weight model. The dynamic load factor (DLF) for the TSC is determined to be less than 1.0 (1.0 is used) for the upper-bound TSC weight and 1.15 for the lower-bound TSC weight, based on the response of one-degree systems subjected to a triangular load pulse [22]. Therefore, the accelerations for the upper-bound TSC weight and lower-bound TSC weight are 16.6g and 28.2g, respectively. These accelerations are significantly less than the 60g design basis acceleration used in the TSC evaluation in Section 3.7.1.2.1.

Elements in the pedestal components in the model with the highest calculated plastic strain are selected for the Triaxiality Factor based strain limit evaluation for protection against local failure per ASME B&PV Code, Section VIII, Division 2, Part 5, Sub-section 5.3.3 [33] ASME Boiler and Pressure Vessel Code, Section VIII Division 2 Rules for Construction of Pressure Vessels. 2010 Edition]. The local failure criterion limits the plastic strain as defined in paragraph 5.3.3.1(c). The minimum factor of safety is 2.97, where the factor of safety is defined as the

ratio of the limiting triaxial strain to the calculated effective plastic strain from the analysis. This occurs for the 24-in drop case with the upper-bound canister weight.

The maximum vertical displacement of the air inlet is calculated to be 0.62-inch for the upper-bound and lower-bound TSC. The original opening is 4.4 inches and, therefore, the minimum air inlet opening is 3.78 inches (4.4–0.62), which is approximately 86% of the original air inlet opening. This condition is bounded by the consequences of the loss of one-half of the air inlets off-normal event.

Two additional drop cases are performed to evaluate that the plastic instability load limit per ASME B&PV Code, Section III, Division 1, Appendix F, Sub-section F-1341(d) [8]. In these analyses, the maximum canister weight of 105 kips is used and drop heights of 34.3-in and 40-in are selected (the applied loading at a 24-in drop height is 0.7 of the loading at a 34.3-in drop height per Sub-section F-1341.4, and 0.6 of the loading at a drop height of 40-in.). The maximum vertical deflections of the pedestal at these applied loads show no unbounded plastic deformation without an increase in load. Accordingly, the design-based drop height of 24-in is below 70% loading of the structural instability load and in compliance with Sub-section F-1341.4.

3.11.4.6 MSO Tip-Over

Tip-over of the MSO is a nonmechanistic, hypothetical accident condition that presents a bounding case for evaluation. Existing postulated design basis accidents do not result in the tip-over of the MSO. Functionally, the MSO does not suffer significant adverse consequences due to this event. The MSO, TSC, and basket maintain design basis shielding, geometry control of contents, and contents confinement performance requirements.

For a tip-over event to occur, the center of gravity of the MSO and loaded TSC must be displaced beyond its outer radius, i.e., the point of rotation. When the center of gravity passes beyond the point of rotation, the potential energy of the cask and TSC is converted to kinetic energy as the cask and TSC rotate toward a horizontal orientation on the ISFSI pad. The subsequent motion of the cask is governed by the structural characteristics of the cask, the ISFSI pad and the underlying soil.

The MSO tip-over analysis is performed using LS-DYNA. As shown in Figure 3.11.4-4, a half symmetry finite element model is used for the MSO, the ISFSI concrete pad and the soil. The ISFSI concrete pad in the model is 15 feet × 60 feet × 3 feet. The soil below the concrete pad is 17.5 feet wide × 70 feet long and 18 feet deep. Not all components within the MSO are modeled and equivalent densities are assigned to ensure that all component weights are accounted for. The inner layer of elements within the MSO represent the steel liner. The loaded canister, MSO

lid and pedestal are conservatively treated as rigid bodies in the analysis. The material properties used to model the MSO, the concrete pad, and the soil are identical to those used for the model for concrete cask tip-over analysis in Section 3.10.4.4.

The acceleration time histories for the MSO tip-over for locations at the top of the basket and at the top of the TSC lid are shown in Figure 3.11.4-5. A cut-off frequency of 200 Hz is applied to filter the analysis results. Two peaks for each acceleration curve are shown in the figure. The first and second peak accelerations are 34.8g and 30.0g for the top of the basket. The dynamic load factors (DLF) for the top of the basket are calculated to be 0.71 and 1.1 for the first and second peaks, respectively, and are based on the response of one-degree systems subjected to a triangular load pulse [22]. The maximum accelerations for the top of the basket at the two peaks are then 24.7g and 33.0g. The first and second peak accelerations from the figure for the top of the TSC lid are 36.2g and 31.2g, respectively. The DLF for the TSC lid is 1.0. A summary of the maximum accelerations is shown in the following table. The maximum accelerations of the basket and TSC are 33.0g and 36.2g, respectively. These are below the design basis values of 35g for the basket in Section 3.7.1.3 and 40g for the TSC in Section 3.10.1.3.3.

Location	Position from Base of MSO (in)	Peak	Peak Acceleration (g)	DLF	Maximum Acceleration (g)
Top of basket	188.8	1st	34.8	0.71	24.7
		2nd	30.0	1.1	33.0
Top of TSC closure lid	197.8	1st	36.2	1.0	36.2
		2nd	31.2	1.0	31.2

Figure 3.11.4-1 Half-Symmetry Finite Element Model for MSO 24-inch Drop Analysis

[redacted]

Figure 3.11.4-2 Acceleration Time History of the Upper-Bound TSC Weight – 24-Inch Drop

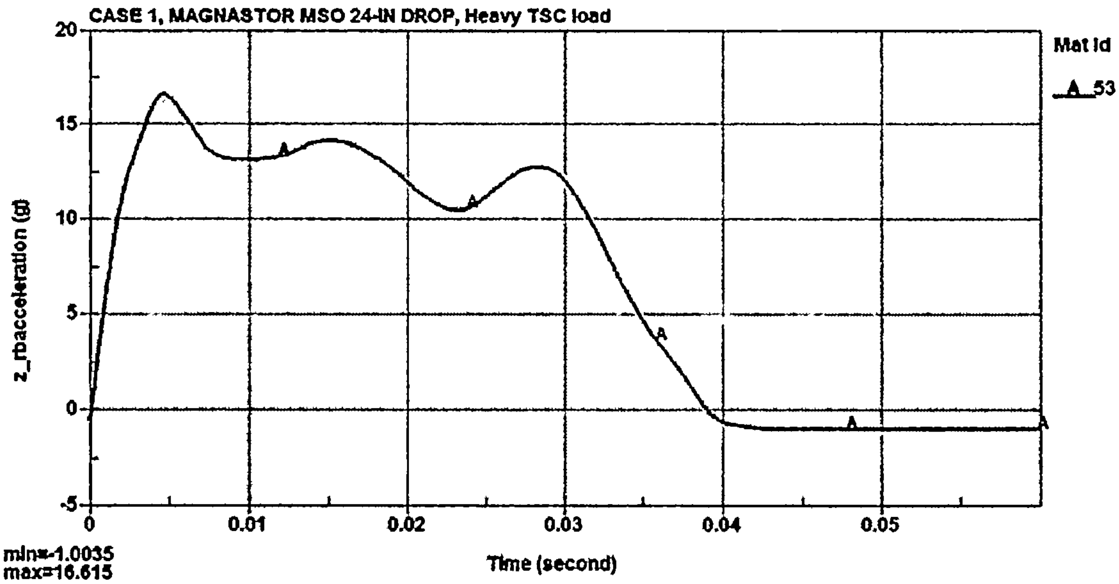

Figure 3.11.4-3 Acceleration Time History of the Lower-Bound TSC Weight – 24-Inch Drop

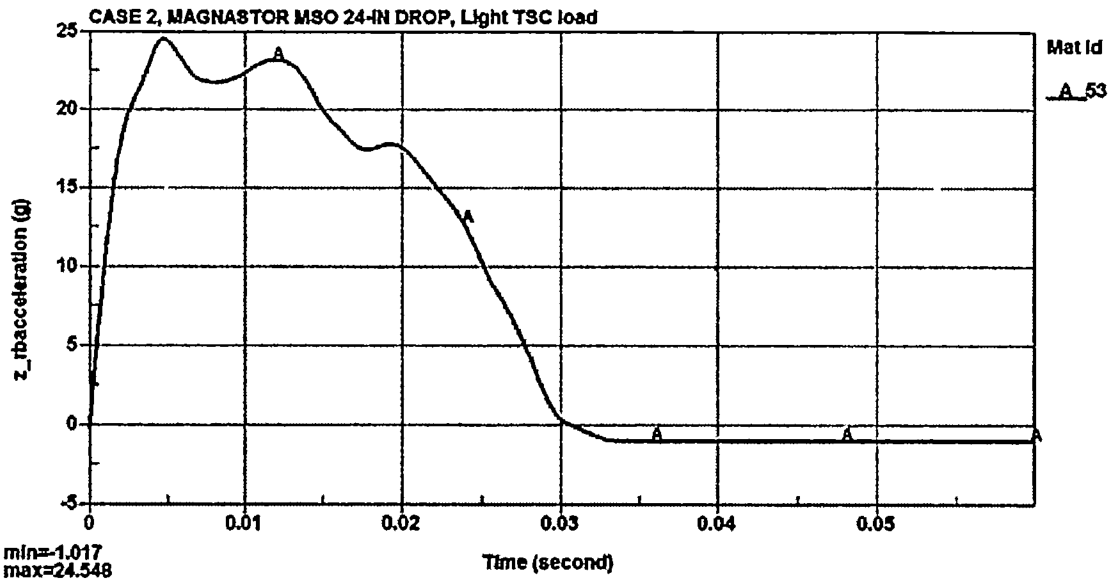

Figure 3.11.4-4 Half-Symmetry Finite Element Model for MSO Tip-Over Analysis

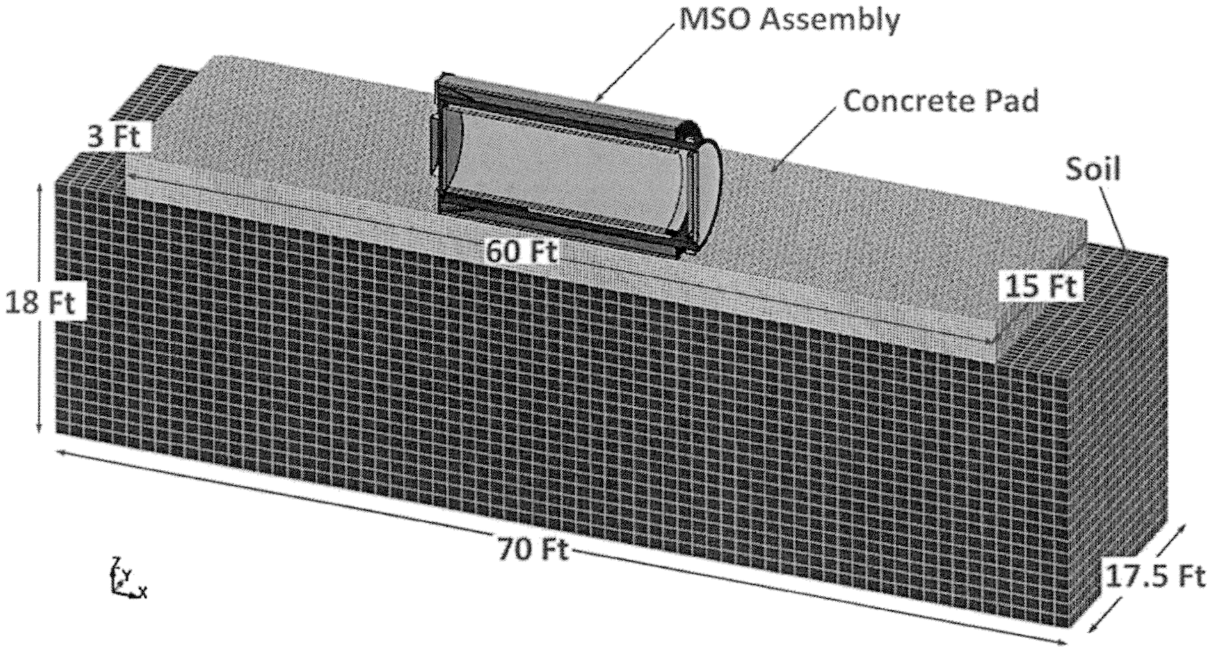

Figure 3.11.4-5 Acceleration Time Histories at Top of the Basket and TSC Lid for MSO Tip-over Event

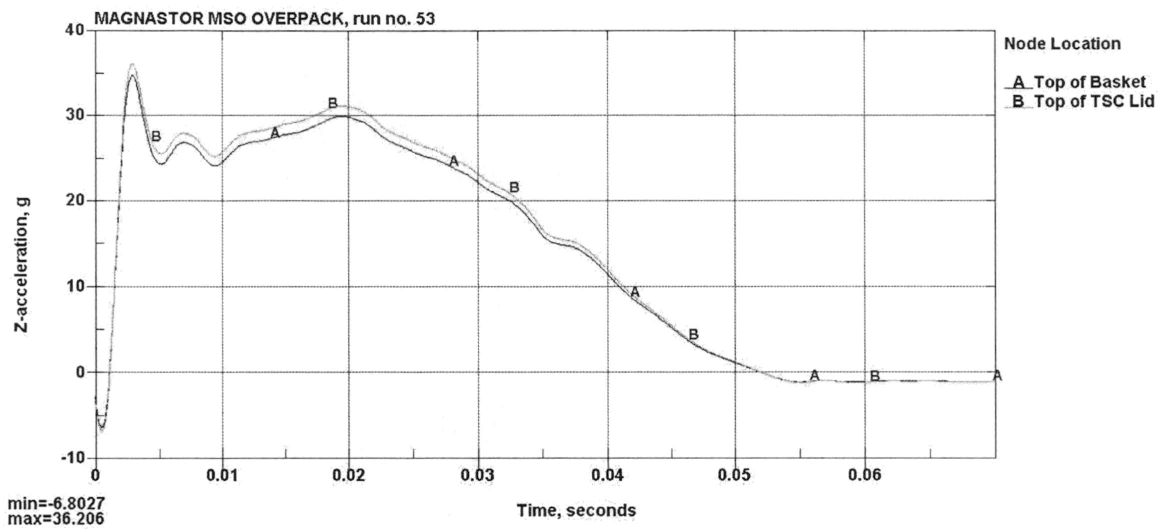

Table 3.11.4-1 Inner Liner Vertical Stress Summary – Outer Surface, psi

Combination Number	Dead	Live	NS Pressure	Wind	Handling	Seismic	Flood	Drop/ Impact	Tip-Over	Total
D1	124		6030	96						6250
D2	124		6030			769				6923
D3	124		6030				88			6242
D4	124		6030					3675		9829
D5	124		6030						5622	11,776
D6	124		6030							6154

Table 3.11.4-2 Inner Liner Vertical Stress Summary – Inner Surface, psi

Combination Number	Dead	Live	NS Pressure	Wind	Handling	Seismic	Flood	Drop/ Impact	Tip-Over	Total
D1	124		6030	83						6237
D2	124		6030			702				6856
D3	124		6030				76			6230
D4	124		6030					3675		9829
D5	124		6030						5622	11,776
D6	124		6030							6154

Table 3.11.4-3 Outer Liner Vertical Stress Summary – Outer Surface, psi

Combination Number	Dead	Live	NS Pressure	Wind	Handling	Seismic	Flood	Drop/ Impact	Tip-Over	Total
D1	124		6030	132						6286
D2	124		6030			1234				7388
D3	124		6030				118			6272
D4	124		6030					3675		9829
D5	124		6030						5622	11,776
D6	124		6030							6154

Table 3.11.4-4 Outer Liner Vertical Stress Summary – Inner Surface, psi

Combination Number	Dead	Live	NS Pressure	Wind	Handling	Seismic	Flood	Drop/ Impact	Tip-Over	Total
D1	124		6030	126						6280
D2	124		6030			1206				7360
D3	124		6030				113			6267
D4	124		6030					3675		9829
D5	124		6030						5622	11,776
D6	124		6030							6154

List of Figures (cont'd)

List of Figures (cont'd)

List of Tables (cont'd)

5.12.4 Model Specification

The MSO is evaluated using the MCNP three-dimensional Monte Carlo code. In the MCNP fuel assembly model, the fuel and hardware source regions are homogenized within a volume defined by the fuel assembly width and height. This volume is subdivided axially into active fuel, upper plenum, and upper and lower end fitting source regions. Within these axial volumes, the material masses of the fuel assembly are homogenized.

The three-dimensional shielding analysis allows detailed modeling of the shield regions, including streaming paths. In all models, the cask and TSC shield thicknesses and axial extents are explicitly represented, including streaming paths.

The geometric description of an MCNP model is based on the combinatorial geometry system embedded in the code. In this system, surfaces and bodies, such as cylinders and rectangular parallelepipeds, and their logical intersections and unions, are used to describe the extent of material zones.

The MCNP code employs an automated biasing technique for the Monte Carlo calculation based on weight window adjustments in mesh cells. Radial biasing is performed to estimate dose rates at the MSO radial surface, including air inlets and outlets. Axial biasing is used for cask top surface dose rates. Exponential transforms are used to direct particles in the area of interest.

5.12.4.1 TSC, Basket, and Fuel Assembly Model Description

The fuel assembly model described in Section 5.8.3.1.1 is retained. The 37-assembly PWR basket model described in Section 5.8.3.1.2 is retained. The TSC model described in Section 5.5.1.1 is retained. The TSC lid is modeled as stainless steel for the MSO dose rate evaluation.

5.12.4.2 Model Description

The MSO is evaluated in detail for TSC storage. The TSC and basket, except for the fuel assembly, are discretely modeled. Key MSO shield features, i.e., those associated with the radial shielding, are listed in Table 5.12.4-1. Figure 5.12.4-1 and Figure 5.12.4-2 provide a model sketch of the MSO.

[redacted]

[redacted]

[redacted]

5.12.4.3 Shield Regional Densities

[redacted]

[redacted]

Figure 5.12.4-1 MSO Model – Cask Body

[redacted]

Figure 5.12.4-2 MSO Model – Cask Lid

[redacted]

Figure 5.12.4-3 Normal/Off-Normal Side Temperature Results

[redacted]

Figure 5.12.4-4 Normal/Off-Normal Top Temperature Results

[redacted]

Figure 5.12.4-5 Accident (Extreme Heat) Side Temperature Results

[redacted]

Figure 5.12.4-6 Accident (8 Minute Fire) Side Temperature Results

[redacted]

Figure 5.12.4-7 Accident (1 Hour Fire) Side Temperature Results

[redacted]

Figure 5.12.4-8 Accident (Extreme Heat) Top Temperature Results

[redacted]

Table 5.12.4-1 Key MSO Shielding Features

[redacted]

Table 5.12.4-2 NS-3 Material Description

[redacted]

Table 5.12.4-3 NS-3 Weight Reduction

[redacted]

8.1 Material Selection

Type 304 stainless steel is used in the TSC, except for the shield plate and shield plate bolts of the composite closure lid assembly. It is selected for this use because of its high strength, ductility, resistance to corrosion and brittle fracture, and metallurgical stability for long-term storage. The steels used in the fabrication of the TSC are as follows.

Shell	ASME SA240, Type 304/304L dual-certified, stainless steel
Bottom	ASME SA240, Type 304/304L dual-certified, stainless steel
Closure Lid	ASME SA240, Type 304 stainless steel
Closure Ring	ASME SA479/SA240, Type 304/304L dual-certified, stainless steel
Port Covers	ASME SA240, Type 304/304L dual-certified, stainless steel
Shield Plate	ASTM A36 carbon steel
Shield Plate Bolts	ASME SA193, Grade B6 high alloy bolting steel
Lifting Lug – PWR/BWR	ASTM A240/A276, Type 304/304L dual-certified stainless steel
Lifting Lug – PWR Damaged Fuel	ASTM A240/276, Type 347 stainless steel

Note: SA182/SA336, Type F304/F304L and SA240, Type 304L stainless steel may be substituted for SA240, Type 304 stainless steel for the closure lid, provided that their material yield and ultimate strengths are greater than, or equal to, those of SA240, Type 304 stainless steel.

The carbon steels used in the fuel baskets are selected based on their strength and thermal conductivity. After fabrication, the basket components are electroless nickel-coated to improve resistance to corrosion and to significantly reduce the potential for the formation of flammable gases during in-pool loading. The materials used in the fabrication of the fuel baskets are:

Basket Supports, Plates and Gussets	ASME SA537, Class 1, carbon steel
Corner Support Bars	ASME SA695, Type B, Grade 40, SA696, Grade C or SA516, Grade 70 carbon steel
Fuel Tubes	ASME SA537, Class 1, carbon steel
Pins	SA696, Grade C or ASME SA36 carbon steel (PWR only)
Mounting Bolts	ASME SA193, Grade B6 stainless steel
Neutron Absorber	Borated Metal Matrix Composite, borated aluminum alloy or Boral

The materials used in the concrete cask fabrication are:

Shell	ASTM A36 Carbon Steel
Pedestal Plate	ASTM A36 Carbon Steel
Base and Top Plates	ASTM A537, Class 2, Carbon Steel
Lift Lugs and Anchors	ASTM A537, Class 2, Carbon Steel
Lift Lug Bolts	ASME SB637, Grade NO7718 nickel alloy
Reinforcing bar	ASTM A615/A615M Carbon Steel
Concrete	ASTM C150 Type II Portland Cement

The materials used in the Metal Storage Overpack (MSO) are:

Inner Liner	ASTM SA350 LF2, Carbon Steel, Forging
Outer Liner	ASTM SA516 Gr 70
Base and Top Plates	ASTM SA516 Gr 70
Trunnions	ASTM SA696 Gr C
Standoffs	ASTM A36/A992
Shielding Material	NS-3
Lid	ASTM SA516 Gr 70

The materials used in the MTC1 transfer cask fabrication are:

Inner Shell	ASTM A588 low alloy steel
Outer Shell	ASTM A588 low alloy steel
Bottom Forging	ASTM A516, Grade 70
Top Forging	ASTM A516, Grade 70
Trunnions	ASTM A350, LF2 low alloy steel
Shield Doors and Rails	ASTM A350, LF2 low alloy steel
Retaining Block Pins	ASTM A516, Grade 70
Retaining Block	ASTM A693/A564 17-4 PH stainless steel
Gamma Shield Brick	ASTM B29 Lead-Chemical Copper Grade
Neutron Shield	NS-4-FR

The materials used in the MTC2 transfer cask fabrication are:

Inner Shell	ASTM A240, Type 304 stainless steel
Outer Shell	ASTM A240, Type 304 stainless steel
Bottom Forging	ASTM A182, Type F304 stainless steel
Top Forging	ASTM A182, Type F304 stainless steel
Trunnions	ASTM A182, Type F304 stainless steel
Shield Doors and Rails	ASTM A182, Type F304 stainless steel

Retaining Ring Bolts	ASTM A193 Grade B8 bolting steel
Retaining Ring	ASTM A240, Type 304 stainless steel
Gamma Shield Brick	ASTM B29 Lead-Chemical Copper Grade
Neutron Shield	NS-4-FR

8.1.1 Fracture Toughness

The TSC structural material is austenitic stainless steel, except for the shield plate and shield plate bolts of the composite closure lid assembly. In accordance with ASME Code, Section III, Subsection NB, Paragraph NB-2311, these materials do not require testing for fracture toughness. The carbon steel shield plate and bolts of the composite closure lid assembly do not perform a pressure-retaining function and are not in the canister support load path and, therefore, are considered a nonstructural attachment. In accordance with ASME Code, Section III, Subsection NB, Subsubarticle NB-1130, the shield plate and bolts may be classified as an internal structure with material and design requirements outside code jurisdiction. Consistent with the discussion of bolting design considerations provided in Section 5 of NUREG/CR-1815 [41], impact testing of the attachment bolts is deemed not required due to the multiple load paths and redundancy in the bolted design. Consistent with ASME Code, Section III, Subsection NF, Paragraph NF-2311, the carbon steel shield plate of the composite closure lid assembly does not require impact testing since the maximum stress does not exceed 6,000 psi tension.

The fuel basket is comprised of welded tubes and supports primarily fabricated from ASME Code SA537, Class 1, carbon steel. Fuel basket materials will meet ASME Code, Section III, Subsection NG, Subarticle NG-2300 requirements for impact tests and will be tested in accordance with paragraph NG-2320. A procurement/fabrication specification will describe fracture toughness testing of these materials for each heat of material subjected to the equivalent forming/bending process or heat-treated condition. Acceptance values shall be per ASTM A370, Section 26.1, with values meeting the requirements of Table NG-2331(a)(1) at a Lowest Service Temperature (LST) of -40°F.

The concrete cask lift lugs and anchors are fabricated from two-inch thick, ASTM A537 Class 2, carbon steel plate. Utilization of the lift lugs and anchors for handling the concrete cask is considered a noncritical lift and will be restricted for use only when the surrounding air temperature is ≥ 0°F. Therefore, impact testing of the material is not required.

The Metal Storage Overpack (MSO) trunnions are fabricated from bar stock machined to a diameter of 7.9 inches, ASME SA696 Gr C, carbon steel. Utilization of the trunnions for handling the MSO is considered a noncritical lift and will be restricted for use only when the surrounding air temperature is ≥ 0°F. MSO trunnion material will meet ASME Code, Section III, Subsection NF, Subarticle NF-2300 requirements for impact tests and will be tested in

accordance with paragraph NF-2320. Acceptance values shall be per ASTM A370, Section 26.1, with values meeting the requirements of Table NF-2331(a)-1 at a test temperature of -40°F.

The structural components of the MTC1 transfer cask are fabricated from low alloy carbon steels selected based on their low-temperature facture toughness. The nil ductility transition temperature for these steels is established as –40°F. Based on Regulatory Guide 7.11 [1], the minimum temperature for use is 40°F above the transition temperature, with no credit taken for heat produced by the contents of the transfer cask. Consequently, a minimum ambient temperature of 0°F for use of the MTC1 transfer cask is established. This condition is administratively controlled by procedure and is consistent with the analysis. Since the use of the MTC1 transfer cask is restricted to conditions when the surrounding air temperature is greater than, or equal to, 0°F, impact testing of the MTC1 transfer cask materials is not required. The structural components of the MTC2 transfer cask are fabricated from austenitic stainless steel. In accordance with ASME Code, Section III, Subsection NB, Article NB-2311, these materials do not require testing for fracture toughness.

8.2 Applicable Codes and Standards

The principal codes and standards applied to MAGNASTOR components are the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, the American Society for Testing and Materials (ASTM), and the American Concrete Institute (ACI). Materials meeting the requirements of these codes and/or standards conform to acceptable minimum thickness, chemical content and formulation specifications and are fabricated using controlled processes and procedures.

The TSC steel components, except the shield plate and shield plate attachment bolts used for the composite closure lid assembly, and associated weld filler materials are procured in accordance with the ASME Code, Section III, Subsection NB [3] requirements, except as listed in the Code Alternatives in Table 2.1-2. The materials for the shield plate and shield plate attachment bolts used for the composite closure lid assembly materials are procured in accordance with the requirements of the applicable ASTM and ASME standards, respectively. The fuel basket steel components and associated weld filler materials are procured in accordance with ASME Code, Section III, Subsection NG [4] requirements, except as stated in the Code Alternatives in Table 2.1-2.

The transfer cask steel components, associated weld filler materials and lead gamma shield materials are procured in accordance with the requirements of the applicable ASTM standards. The NS-4-FR material in the transfer cask is a commercially available product specifically designed for neutron attenuation and absorption.

The concrete cask steel components and associated weld filler materials are procured in accordance with the requirements of the applicable ASTM standards. The vertically reinforced concrete portion of the cask is procured in accordance with the requirements of ACI-318 [2], as supplemented by applicable ASTM standards. ACI-318 is not applicable to the concrete cask lid or upper segment, if equipped.

The Metal Storage Overpack (MSO) steel components and associated weld filler materials are procured in accordance with the requirements of the applicable ASTM standards. The NS-3 material in the MSO is a commercially available product specifically designed for gamma and neutron shielding.

8.4 Weld Design and Specification

The welding operations of the MAGNASTOR components are performed in accordance with the requirements of a number of codes and standards depending on the design and functional requirements of the specific component. The specific requirements met by each component are provided herein.

The TSC and fuel basket assemblies are welded using welding procedures, processes, and welders prepared and qualified in accordance with the ASME Code, Section IX [29] requirements. The specific weld designs and examination requirements for the TSC and fuel basket comply with the applicable subsection of the ASME Code, Section III, which are Subsection NB for the TSC and Subsection NG for the fuel baskets. Alternatives to the Code requirements applicable to these system components are listed in Table 2.1-2. Weld filler materials and processes used in the fabrication of the TSC are in accordance with ASME Code Section II-C requirements for SFA 5.9 and SFA 5.22. For SFA 5.9 and SFA 5.22, respectively, AWS ER 308L and AWS E308LTX-X will be specifically identified in the approved welding procedures.

The steel components of the concrete casks (i.e., liner, baseplate, etc.), Metal Storage Overpack (MSO) and the transfer cask are welded using procedures, processes, and welders prepared, qualified, and certified in accordance with either ASME Section IX or ANSI/AWS D1.1 [28]. The weld design and specification requirements for the steel components of the concrete cask are in accordance with the weld design criteria of the ASME Code, Section VIII, Division 1, Part UW [31] or ANSI/ANS D1.1. The weld design and specification requirements for the transfer cask are in accordance with the weld design criteria of the ASME Code, Section III, Subsection NF [32].

The inspection and examination requirements for all MAGNASTOR component welds, inspector qualification requirements, and the applicable acceptance criteria are specified in Chapter 10 of this SAR.

The TSC confinement boundary uses Type 304/304L dual-certified stainless steel for all components except the closure lid. The MTC2 transfer cask structural components are fabricated primarily from ASTM A240/A182 Type 304 stainless steel. No coatings are applied to the stainless steels. Type 304/304L stainless steel resists chromium-carbide precipitation at the grain boundaries during welding and assures that degradation from intergranular stress corrosion will not be a concern over the life of the TSC. Fabrication specifications control the maximum interpass temperature for austenitic steel welds to less than 350°F. The material will not be heated to a temperature above 800°F, other than by welding or thermal cutting. Minor sensitization of Type 304/304L stainless steel that may occur during welding will not affect the material performance over the design life.

8.10.2.2 Carbon Steel

Carbon steel is used to fabricate all of the structural components of the PWR and BWR baskets, and the shield plate of the TSC composite closure lid assembly. There is a small electrochemical potential difference between carbon steel and the stainless steel of the TSC shell and the stainless steel sheet used to protect the neutron absorber in the fuel tubes. However, the carbon steel basket components and the shield plate of the TSC composite closure lid assembly are coated with electroless nickel using an immersion process. The immersion process ensures that the carbon steel is appropriately coated, reducing the possibility of corrosion due to exposure to air or pool water. When in contact with stainless steel in water, the carbon steel exhibits a limited electrochemically driven corrosion. Typically, BWR pool water is demineralized, and is not sufficiently conductive to promote detectable corrosion for these metal couples. Once the TSC is loaded, the water is drained from the cavity, the air is removed, and the TSC is backfilled with helium and sealed. Removal of the water and the moisture eliminates the catalyst for galvanic corrosion between the carbon and stainless steels. In addition, the displacement of oxygen by helium effectively inhibits oxidation.

The MTC1 transfer cask structural components are fabricated primarily from ASTM A588 and A36 carbon steel. The exposed carbon steel components are coated with an epoxy enamel coating system tested and certified for use in Nuclear Service Level 1 conditions to protect the components during in-pool use and to provide a smooth surface to facilitate decontamination.

The concrete shell of the concrete cask contains an ASTM A36 carbon steel liner, as well as other carbon steel components. The exposed surfaces of the carbon steel liner and air inlets and outlets are coated to provide protection from weather-related moisture. The coating is formulated for use in continuous high- temperature environments.

The MSO contains a carbon steel ASTM SA350 inner shell and a ASTM SA516 outer shell, as well as other carbon steel components. The exposed surfaces of the carbon steel inner and outer shells, the lid, and the air inlets and outlets are coated to provide protection from weather-related moisture. The coating is formulated for use in continuous high- temperature environments.

No potential reactions associated with the shield plate of the TSC composite closure lid assembly, basket supports and fuel tubes, the transfer cask components, MSO components or concrete cask components are expected to occur.

8.10.2.3 Nonferrous Metals

Aluminum is used in the neutron absorber material. The aluminum material in electrical contact with the stainless steel cover and carbon steel fuel tube could experience corrosion driven by an electrochemically induced electromotive force when immersed in water, where the conductivity of the water is the dominant factor. Typically, BWR fuel pool water is demineralized and is not sufficiently conductive to promote detectable corrosion for these metal couples. PWR pool water, however, does provide a conductive medium.

Shortly after fabrication, aluminum produces a thin surface film of oxidation that effectively inhibits further oxidation of the surface. This oxide layer adheres tightly to the base metal and does not react readily with the materials or environments to which the fuel basket will be exposed. The volume of the aluminum oxide does not increase significantly over time. Thus, binding due to corrosion product build-up during future removal of spent fuel assemblies is not a concern. The borated water in a PWR fuel pool is an oxidizing-type acid with a pH on the order of 4.5. However, aluminum is generally passive in pH ranges down to about 4 [11]. Data provided by the Aluminum Association [12] shows that aluminum alloys are resistant to aqueous solutions (1-15%) of boric acid (at 140°F). Based on these considerations and the very short exposure of the aluminum in the fuel basket to the borated water, oxidation of the aluminum is not likely to occur beyond the formation of a thin surface film. No observable degradation of aluminum is expected as a result of exposure to BWR or PWR pool water at temperatures up to 200°F, which is higher than the normal condition permissible fuel pool water temperature.

Aluminum is high on the electromotive potential table, and it becomes anodic when in electrical contact with stainless or carbon steel in the presence of water. BWR pool water is demineralized and is not sufficiently conductive to promote detectable corrosion for these metal couples. PWR pool water is sufficiently conductive to allow galvanic activity to begin. However, exposure time of the aluminum to the PWR pool environment is short. The long-term storage environment is sufficiently dry to inhibit galvanic corrosion.

10.1 Acceptance Criteria

This section provides the workmanship and acceptance tests to be performed on the MAGNASTOR components and systems during their fabrication, as well as prior to and during loading of the system. These tests and inspections provide assurance that the components and systems have been procured, fabricated, assembled, inspected, tested, and accepted for use under the conditions and controls specified in this document and the Certificate of Compliance.

10.1.1 Visual Inspection and Nondestructive Examination

Fabrication, inspection, and testing are performed in accordance with the applicable design criteria, codes and standards specified in Chapter 2 and on the license drawings.

The following fabrication controls and inspections shall be performed to assure compliance with this document and the license drawings:

a) Materials of construction for the MAGNASTOR are identified on the license drawings and shall be procured with certification and supporting documentation as required by the ASME Code, Section II [1], when applicable; and the requirements of ASME Code, Section III, Subsection NB [2], Subsection NF [4] and Subsection NG [3], when applicable.

b) Materials and components shall be receipt inspected for visual and dimensional acceptability, material conformance to the applicable Code specification and traceability markings, as applicable. Materials for the TSC confinement boundary (e.g., TSC shell plates, base plate, closure lid, and port covers) shall also be inspected per the requirements of ASME Code, Section III, Subsection NB-2500.

c) The confinement boundary shall be fabricated and inspected in accordance with ASME Code, Section III, Subsection NB, with the code alternatives as listed in Chapter 2, Table 2.1-2. The TSC fuel basket, damaged fuel cans (DFCs) and basket supports shall be fabricated and inspected in accordance with the ASME Code, Section III, Subsection NG, with the alternatives listed in Table 2.1-2.

d) The steel components of the transfer cask shall be in accordance with ASTM specifications and fabricated in accordance with ANSI N14.6 [11]. Inspections and NDE of the transfer cask shall be in accordance with ASME Code, Section III, Subsection NF.

e) The steel components of the concrete cask and Metal Storage Overpack (MSO) shall be in accordance with ASTM specifications and fabricated in accordance with ASME Code, Section VIII [6] (or fabrication may be in accordance with ANSI/AWS D1.1). Inspections of the welded steel components of the concrete cask shall be in accordance with ASME Code, Section VIII or ANSI/AWS D1.1.

f) ASME Code welding shall be performed using welders and weld procedures qualified in accordance with ASME Code, Section IX [7] and the ASME Code, Section III subsection applicable to the component (e.g., NB, NG or NF). ANSI/AWS code welding may be

performed using welders and procedures qualified in accordance with the applicable AWS requirements or in accordance with ASME Code, Section IX.

g) Construction and inspections of the concrete component of the concrete cask shall be performed in accordance with the applicable sections and requirements of ACI-318 [8].

h) Visual examinations of the welds of the confinement boundary shall be performed in accordance with ASME Code, Section V, Articles 1 and 9 [9], with acceptance per Section III, Subsection NF, Article NF-5360. The final surface of TSC shell welds shall be dye penetrant examined (PT) in accordance with ASME Code, Section V, Articles 1, 6 and 24, with acceptance per Section III, Subsection NB, Article NB-5350. The TSC shell longitudinal and circumferential welds shall be radiographic examined (RT) in accordance with ASME Code, Section V, Articles 1 and 2, with acceptance per Section III, Subsection NB, Article NB-5320. The weld of the TSC baseplate to the TSC shell shall be ultrasonic examined (UT) in accordance with ASME Code, Section V, Articles 1 and 4, with acceptance per Section III, Subsection NB, Article NB-5330. In accordance with ISG-15 [14], the TSC closure lid to shell weld, performed following fuel loading, shall be dye penetrant (PT) examined at the root, mid-plane and final surface in accordance with ASME Code, Section V, Articles 1, 6 and 24, with acceptance per Section III, Subsection NB, Article NB-5350. The closure ring to TSC shell and the closure ring to closure lid welds shall be PT examined in accordance with the same code and acceptance criteria as the closure lid to TSC shell weld, except that only the weld final surface will be examined. The inner and outer (redundant) port covers to closure lid welds shall be PT examined at the final surface in accordance with the same code and acceptance criteria as for the closure lid to shell weld. Repairs to TSC vessel welds shall be performed in accordance with ASME Code, Section III, Subsection NB, Article NB-4450, and the welds reinspected per the original acceptance criteria applicable to the examination method.

i) Visual examinations of the welds of the fuel baskets, DFCs and basket supports shall be performed in accordance with ASME Code, Section V, Articles 1 and 9, with acceptance per Section III, Subsection NG, Article NG-5360. The fuel tube welds shall be magnetic particle examined (MT) in accordance with ASME Code, Section V, Articles 1, 7 and 25, with acceptance criteria per Section III, Subsection NG, Article NG-5340. Repairs to fuel basket welds shall be performed in accordance with ASME Code, Section III, Subsection NG, Article NG-4450, and the welds reinspected per the original acceptance criteria applicable to the examination method.

j) Visual examinations of the concrete cask and MSO structural steel weldments shall be performed in accordance with the ASME Code, Section V, Articles 1 and 9, or ANS/AWS D1.1, Section 6.9, with acceptance per Section VIII, Division 1, Part UW, Articles UW-35 and UW-36, or Table 6.1 of ANSI/AWS D1.1, respectively. Repairs to concrete cask structural weldment welds shall be performed in accordance with ANSI/AWS D1.1, and the welds reinspected per the original acceptance criteria.

k) Visual examination of the welds of the transfer cask shall be performed in accordance with ASME Code, Section V, Articles 1 and 9, or ANSI/AWS D1.1, Section 6.9, with acceptance per Section III, Subsection NF, Article NF-5360. Following structural load testing of the transfer cask, the final surface of all critical load-bearing welds shall be either dye penetrant (PT) or magnetic particle (MT) examined in accordance with ASME Code, Section V, Articles 1, 6 and 24 for PT and Articles 1, 7 and 25 for MT. The acceptance criteria for the weld examinations shall be in accordance with Section III, Subsection NF, Article NF-5350 for PT and NF-5340 for MT. Repairs to the transfer cask vertical load-bearing welds shall be performed in accordance with ASME Code, Section III, Subsection NF, Article NF-4450 or ANSI/AWS D1.1. Repaired welds shall be reinspected per the original acceptance criteria applicable to the examination method.

l) Dimensional inspections of components shall be performed in accordance with written and approved procedures to verify compliance to the license drawings and fit-up of individual components. All dimensional inspections and functional fit-up tests shall be documented.

m) All components shall be inspected for cleanliness and proper packaging for shipping in accordance with written and approved procedures. All components will be free of any foreign material, oil, grease, and solvents.

n) Inspection and nondestructive examination personnel shall be qualified in accordance with the requirements of SNT-TC-1A [10].

10.1.2 Structural and Pressure Tests

10.1.2.1 Load Testing of Transfer Casks

The transfer cask is designed, fabricated, and tested to the requirements of ANSI N14.6 [11]. The transfer cask is provided with two lifting trunnions near the top of the cask for lifting and handling. The transfer cask shield doors and supporting door rails are designed to retain and support the maximum TSC loaded weight.

Following completion of fabrication, the load-bearing components of the transfer cask, including the lifting trunnions, shield doors, and rails, are load tested to verify their structural integrity to lift and retain the applicable loads.

The lifting and handling of the transfer cask and loaded TSC are defined as critical lifting loads per NUREG-0612 [12] at a number of nuclear facilities. In accordance with ANSI N14.6, special lifting devices for critical loads shall be provided with redundant lifting paths, or be designed and tested to higher safety factors. The transfer cask lifting trunnions, shield doors, and rails are designed to higher safety factors and are load tested to 300% of the maximum service load for each type of component.

The lifting trunnion pair shall have a load equal to three times their maximum service load applied for a minimum of 10 minutes. Likewise, the transfer cask shield doors and rails shall have a load equal to three times their maximum service load applied for a minimum of 10 minutes. After release of the test loads, the accessible portions of the trunnions and the adjacent areas, and the shield doors and rails and adjacent areas shall be visually examined to verify no deformation, distortion, or cracking occurred. The critical load-bearing welds of the transfer cask shall be examined by the methods and acceptance criteria defined in Section 10.1.1, Item k).

Any evidence of deformation, distortion, or cracking of the loaded components, critical load-bearing welds or adjacent areas shall be cause for failure of the load test, and repair and/or replacement of the component. Following repair or replacement, the applicable portions of the load test shall be performed again and the components reexamined in accordance with the original procedure and acceptance criteria.

Load testing of the transfer cask shall be performed in accordance with written and approved procedures, and the test results shall be documented.

10.1.2.2 Load Testing of Concrete Cask Lifting Lugs and Anchors / Metal Storage Overpack (MSO) Trunnions

The concrete cask is designed to be lifted and transported using one of two optional pin lift configurations. The optional pin lift configurations are two lifting anchors imbedded in the reinforced concrete shell or two lifting lugs bolted to anchors that are imbedded in the reinforced concrete shell. Either configuration provides a pin connection to a lifting system. The concrete lifting anchors, lifting lugs and attachment bolting are designed, fabricated, and tested in accordance with the requirements of ANSI N14.6 for lifts not made over safety-related equipment (noncritical lifts).

The concrete cask lifting lug load test shall be performed on the lugs independently of the concrete cask. The test will consist of applying a vertical load to the individual lugs at a value that is equal to one-half of 150% of the maximum concrete cask weight. The test load shall be applied for a minimum of 10 minutes. After the release of the test load, the accessible portions of the lifting anchors shall be visually examined to verify no deformation, distortion, or cracking occurred. Critical load-bearing welds of the lifting anchors shall be magnetic particle (MT) examined in accordance with ASME Code, Section V, Articles 1, 7 and 25, or liquid penetrant (PT) examined in accordance with ASME Code, Section V, Articles 1, 6 and 24, with acceptance criteria per Section III, Subsection NF, Article NF-5340 or NF-5350.

Any evidence of deformation, distortion, or cracking of the loaded components, critical load-bearing welds or adjacent areas shall be cause for failure of the load test, and repair and/or