May 2016

Revision 16A

MAGNATRAN

(Modular Advanced Generation Nuclear All-purpose TRANsport)

MAGNATRAN RAI Response Package Submittal

Book 1 of 1

NON-PROPRIETARY VERSION

Docket No. 71-9356

NAC INTERNATIONAL

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Enclosures

Enclosure 1

RAI Responses

No. 71-9356 for the MAGNATRAN Cask

MAGNATRAN SAR, Revision 16A

Enclosure 1 Contents

Enclosure 1A, Proprietary Request for Additional Information #3
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NAC INTERNATIONAL

RESPONSE TO THE

UNITED STATES NUCLEAR REGULATORY COMMISSION

PROPRIETARY REQUEST FOR ADDITIONAL INFORMATION #3

February 2016

FOR REVIEW OF THE CERTIFICATE OF COMPLIANCE NO. 9356, REVISION NO. 0

(CoC NO. 9356, DOCKET NO. 71-9356)

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[redacted]

NAC INTERNATIONAL

RESPONSE TO THE

UNITED STATES
NUCLEAR REGULATORY COMMISSION

NON-PROPRIETARY
REQUEST FOR ADDITIONAL INFORMATION #3

February 2016

FOR REVIEW OF THE CERTIFICATE OF COMPLIANCE NO. 9356, REVISION NO. 0

(CoC NO. 9356, DOCKET NO. 71-9356)

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NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR ADDITIONAL INFORMATION

GENERAL INFORMATION EVALUATION

1-1. Modify Table 1.3-16 of the application to remove the heading for neutron source assemblies (NSA) from the column for guide tube plug devices (GTPD).

Table 1.3-16 currently has two columns showing additional cooling time for loading neutron source assemblies, NSAs. The shielding analysis supports the last, or right-most, column values. To avoid confusion, the column heading 'GTPD/NSA' should be changed to read just 'GTPD'.

This information is needed to confirm compliance with Title 10 of the Code of Federal Regulations (10 CFR) 71.33 and 71.47.

NAC International Response to General Information Evaluation RAI 1-1:

The heading "GTPD/NSA" is revised to "GTPD" in Table 1.3-16.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

THERMAL EVALUATION

3-1. Provide a thermal analysis for the hypothetical accident condition fire transient that models the thermal inertia associated with the transportable storage canister (TSC) and spent fuel contents.

The previously supplied analyses did not consider the thermal inertia effect or adequately show that the analyses were bounding. In addition, recognizing that the extent of aluminum fin degradation after reaching their melting point is uncertain, explain and clarify that the approach used to model the aluminum fins is bounding during the transient.

This information is needed to determine compliance 10 CFR 71.73.

NAC International Response to Thermal Evaluation RAI 3-1:

A thermal transient analysis is performed for the hypothetical fire accident condition for the PWR configuration using a three-dimensional model that includes the transport cask and the loaded canister, including basket and the fuel. The model is based on the three-dimensional models presented in SAR Section 3.4.1.1.1 for the evaluation of normal conditions of transport. The top half of the cask is modeled to maximize the heat input during the fire accident as the cask top half is approximately 30% longer than the bottom half. The model details and analysis results are presented in Appendix F of calculation 71160-3015, Revision 5. The transient analysis results show that the maximum temperature is 747°F for the fuel and 722°F for the basket, which are significantly (146°F) lower than the temperatures reported in SAR Table 3.5-1. Therefore, the maximum temperatures of the basket and fuel as determined using the 'ΔT method' (discussed in SAR Section 3.5.1.1) are conservative and bounding. The time history of the maximum temperatures for the fuel and basket are presented in Figure F-3 of Calculation 71160-3015, Appendix F. Note that, due the significant thermal mass of the system, the maximum temperatures of the fuel and basket (at the center of the basket) did not respond to the heat input from the suddenly applied fire at the cask surface until approximately 4 hours after the fire started.

Since the fire temperature of 1475°F is significantly higher than the melting point of the aluminum, the aluminum fins are considered to be totally destroyed as soon as the fire starts and, therefore, are not included in the thermal model for the fire transient analysis. The total energy produced by aluminum oxidization due to the fire is insignificant compared with the energy from the fire and fuel (see more discussion in Appendix M of Calculation 71160-3015, Revision 5). After the 30-minute fire, the NS4FR is modeled using air properties.

Therefore, the only means to reject heat is through the copper fins and not the NS4FR and the aluminum fins. This provides bounding conditions to minimize the heat rejection after the fire.

NAC INTERNATIONAL RESPONSE
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SHIELDING EVALUATION

5-1. Provide tolerances on the technical drawings for items relied on in the shielding analysis.

As stated in the NRC RAI dated June 2, 2015 (see ADAMS Accession No. ML15181A013), it is not clear that the drawings include the tolerances for items important to shielding:

- Packaging (i.e., overpack) lead shielding radial (thickness) and axial dimensions,
- Packaging inner and outer steel shell thicknesses,
- Packaging neutron shield assembly component tolerances (radial/thickness and axial and width),
- Packaging lid thickness,
- Cask cavity spacer axial length,
- Packaging bottom forging thickness,
- TSC lid thickness,
- TSC wall thickness,
- TSC base thickness,
- TSC basket tube thickness, and
- Absorber plate tolerances.

Thus, it is not clear that the dimensions in the shielding analysis are consistent with the package's tolerances. The drawings should include tolerances on appropriate dimensions of the items relied on for shielding, which are listed in this question.

This information is needed to confirm compliance with 10 CFR 71.33 and 71.47.

<u>NAC International Response to Shielding Evaluation RAI 5-1:</u>

The license drawings provide sufficient information to demonstrate the adequacy of the MAGNATRAN transport package design. The majority of the plate material used in the fabrication of the package has an under allowance of 0.01 inches with an over tolerance of 0.03 inches. Even with the variations in the plate manufacturing process it is not expected that the package will have less than the nominal shield mass. The design has shown there is sufficient margin to allow the minor variations created by these tolerances in the plate material and don't have an appreciable effect on the dose rates. A discussion addressing the tolerance of the basket and TSC is added to Section 5.5.1.1.

NAC INTERNATIONAL RESPONSE
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SHIELDING EVALUATION

5-2. Modify the package shielding analysis to include the effects of dimensional tolerances of the TSC and its components.

Based on the information provided in the application to date, the applicant's shielding analysis appears to only include tolerances for the overpack (Sections 6.3.3.5 and 4.3 of the calculation package (Calculation Number 71160-5508)). Thus, it is not clear whether and how the analyses includes the tolerances for the TSC components (including the basket) listed in item 1, immediately above. If these tolerances are included, the applicant should clearly demonstrate how they are included in the analyses and models. If they aren't included, then the applicant should modify the analyses to address these tolerances. Another option for evaluating these tolerances, particularly if the tolerances are quite small, would be for the applicant to clarify or describe the (estimated) impact the TSC components' tolerances would have on dose rates and how other conservatisms compensate for the TSC components' tolerances.

This information is needed to confirm compliance with 10 CFR 71.47.

<u>NAC International Response to Shielding Evaluation RAI 5-2:</u>

The tolerances associated with the TSC and basket components were not considered in the previously provided response. Previous request was for tolerance discussion for those items significant to shielding. NAC did not consider the TSC tolerances to be significant to the shielding analysis, in particular as significant basket mass on the basket periphery was not included in the models, and therefore had not included a discussion on these components.

The basket contains a significant quantity of peripheral structural support that is not included in the model to offset any of the minor negative tolerances that are typically encountered on steel plate material. Plate used in the construction of the basket tubes, TSC shell and bottom plate has a small under allowance, 0.01 inch, with a significantly larger over tolerance (e.g., tubes and shell have a 0.03 inch over tolerance). As plate material allows significant thickness increase within the tolerance band, and only a minor decrease, there is no expectation that the overall model of the TSC/basket has less than the nominal shield mass even without considering the corner and side weldment components not included in the model. The TSC lid is the exception to the standard plate definition as it is defined as a plate/forging with a over/under tolerance of 0.03 inch permitted (bounding for single

piece/dual piece lid options). A 0.03 inch reduction in material will not impact the axial dose rates significantly. Top axial dose rates are significantly below limits. Impact limiter models are axially truncated and provide additional margin in material quantity modeled in the axial direction. A discussion addressing the tolerance of the basket and TSC is added to Section 5.5.1.1.

**NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR ADDITIONAL INFORMATION**

SHIELDING EVALUATION

5-3. Clarify how the specific activity analyzed for the greater than class C (GTCC) waste should be applied in the package operations, modifying either the contents specification in Section 1.3.2 or the package operations in Chapter 7 of the application as appropriate.

The analysis assumes a specific activity for the GTCC waste that is uniform over the entire contents. In reality, GTCC waste that is loaded into a package can have varying specific activities. This variation may be from component (or object) to component. Also, large components may have significant variation in specific activity from one area of the component to the other. Furthermore, loose contamination may be present that can collect in one area of the TSC cavity. It is not clear how or whether, the application treats these kinds of variation in the contents' specific activity. The specific activity of a particular package's GTCC waste contents may, when averaged over the entire contents, meet the proposed specific activity limit; however, dose rates may be significantly higher than those calculated in the application due to the variations described in this RAI. Therefore, the application should specify the method for a package user to demonstrate compliance with the proposed specific activity limit for a package containing GTCC waste contents and should demonstrate that variations in the contents' specific activity that would be acceptable with that method will not result in dose rates that exceed the regulatory limits. The method should apply the specific activity limit to sufficiently small volumes of waste and sufficiently small volumes of items/components that make up the waste. Loose contamination should also be addressed in applying the limit properly.

This information is needed to confirm compliance with 10 CFR 71.33 and 71.47.

<u>NAC International Response to Shielding Evaluation RAI 5-3:</u>

NAC's response is divided into two sections; one dealing with the concern on loose contamination and one the assumption of uniform source distribution of larger section GTCC material. The SAR is revised to the address the RAI in the context of the baseline analysis applying a constant 2.7 Ci Co-60 / lb. This analysis resulted in a normal condition 2-m radial dose rate of 1.3 mrem/hr which is less than 15% of transport limits (10 mrem/hr regulatory limit or 9.5 mrem/hr as applied in the fuel analysis to account for analysis uncertainties). Normal condition surface as well as 2-meter axial dose rates have significantly larger percentage margins. Accident dose rates are less than 1% of limits.

Loose Contamination:

NAC acknowledges that surface contamination will be present on the GTCC components expected to be loaded. The dose contribution of surface contamination is expected to be negligible versus the metal activation. To demonstrate that the fraction is negligible see the following example calculation:

The surface contamination (crud) for fuel in transport cask containment evaluations is 140 $\mu Ci/cm^2$ (PWR) and 1254 $\mu Ci/cm^2$ (BWR) at discharge (NUREG/CR-6487). A 1 inch thick plate has approximately 45 cm^2 of surface area per lb (using 7.9 g/cm^3 as the density and assuming equivalent contamination on both sides), yielding about 0.05 Ci/lb at the higher BWR surface contamination value of 1254 $\mu Ci/cm^2$. While an argument could be made that contamination on GTCC components may be higher the calculation shown assumes no decay from the baseline value. The GTCC application applied an activation level of 2.7 Ci/lb Co-60. The ratio of contamination to metal activation demonstrates that contamination will not be significant to system shielding performance.

In the context of loose contamination there is no expectation of significant loose contamination in the system. GTCC material to be loaded is the result of structural material activation within the pressure boundary of the reactor. Significant loose contamination adhering to the GTCC material and yet loose enough to migrate in the system will not exist given the flow rates in the core which would remove "loose material". Any "loose contaminant" in the canister is expected to be removed when the GTCC canister is pumped down and vacuum dried prior to loading. Suspended contamination in the water would be removed from the system using this approach. Contamination (crud) that adhered to the GTCC material can be postulated to release during dry storage or transport operation but as indicated the expected contamination levels are low compared to activation levels. A release fraction (15%) of crud is applied during normal conditions for fuel containment analysis. Applying a similar condition to the GTCC material would further reduce the contamination dose rate effects. While a 100% release during accident condition would magnify the contamination relocation dose rates the dose rates for accident conditions are less than 1% of allowable making GTCC contamination, even if reconfigured, a negligible concern versus allowable transport limits. Reconfiguration of contamination is overall not considered by NAC to be a concern to cask shielding.

GTCC activity distribution

As indicated by the staff review the GTCC material was evaluated at an activity level of 2.7 (2.68) Co-60 Ci/lb. It is understood that variations in activation are expected (e.g., axial and radial core power profiles). To address the NRC concern on distribution Section 1.3.2 and 5.8.11 of the SAR is revised to address the 2.7 Ci Co-60 as an average over the TSC with localized activation allowed as high as 6 times that level (16.1 Ci / lb Co-60). Conservatively

assuming all material is at the maximum level allows simple ratios to generate revised dose rates. A simple increase of all contents to 16.1 Ci/lb would result in radial 2-m dose rate of 7.8 mrem/hr which is still significantly below regulatory limits and allowing substantial margins to address any additional uncertainty concerns on the GTCC shielding analysis. Using a ratio approach provides a substantial conservatism as the 2-meter dose rate is limiting any peaking associated with high activity material. Section 5.8.11 of the SAR is revised to include the potentially higher dose rates from higher Co-60 content material.

Section 1.3.2 (Contents) is revised to limit GTCC Co-60 content to the following.

"The specific Curie content source of the GTCC shall be limited to:

a.) a maximum of 2.7 Ci ^{60}Co/lb averaged over GTCC contents
b.) a localized peak of 16.1 Ci ^{60}Co/lb
c.) a total ^{60}Co activity of 85,760 Ci at transport."

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SHIELDING EVALUATION

5-4. Provide the updated drawings (both the proprietary and non-proprietary versions of Drawing No. 71160-502) described in the response to NRC RAI letter dated June 2, 2015, question 1-1f.

The applicant responded to the specified question by stating that the requested neutron shield specifications were added to the drawings in the RAI. However, the applicant did not include these updated drawings with the response. The updated drawings are needed since they will be referenced in the certificate of compliance.

This information is needed to confirm compliance with 10 CFR 71.33 and 71.47.

NAC International Response to Shielding Evaluation RAI 5-4:

Both the proprietary and non-proprietary versions of Drawing No. 71160-502 were inadvertently left out of the previous RAI. Proprietary and non-proprietary versions of Drawing No. 71160-502 are provided in this response package.

NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR ADDITIONAL INFORMATION

SHIELDING EVALUATION

5-5. Confirm and, as applicable, provide information to support the following:

a. The proposed cooling time for Westinghouse (WE) 15x15 fuel assemblies with 60 GWd/MTU burnup and a minimum enrichment of 3.1% and the added cooling time for damaged fuel of this fuel type, burnup and enrichment (in Tables 5.8-16 and 5.8-49 of the application). The revision of the calculation package submitted during the review (with MAGNATRAN Safety Analysis Report (SAR) Version 14A which was submitted with supplement dated December 1, 2014) does not support loading of this fuel type at this burnup, enrichment and decay time nor the added cooling time for damaged fuel with these specifications. If a later version of the calculation package does support this, it should be provided.

b. The added cooling time for WE 14x14 fuel assemblies with 55 GWd/MTU burnup and a minimum enrichment of 3.1% in Table 5.8-49 of the application. It is not clear that the added cooling time is correct; it seems the added time should be at least as long as or longer than the added time for enrichments at 3.3%.

c. The staff's understanding that the added cool time in Table 5.8-49 applies to all fuel in the basket. That would mean that the table should be read as: 'For TSCs that include damaged fuel, the added cooling time shown in the table for a specific fuel type, burnup and enrichment applies to all the fuel in the TSC, the damaged and the undamaged fuel. Since high burnup fuel is always treated as damaged fuel, the added cooling times shown for damaged high burnup fuel always apply to TSCs containing high burnup fuel.'

This information is needed to confirm compliance with 10 CFR 71.33, 71.47 and 71.51(a).

<u>NAC International Response to Shielding Evaluation RAI 5-5:</u>

a. Review staff is correct in the observation that the data point was not included in the calculation provided. The calculation included in the 14A submittal was 71160-5508 Revision 0. Revision 1 contains the required data and is provided as an attachment to this RAI response set.

b. The numbers in Table 5.8-49 are correct based on the calculation approach applied. The additional cool times to load damaged fuel are based on the need to offset dose increase associated with the DFC. Therefore, the values reflect uncertainties in the dose rate calculations that vary slightly between enrichments. Furthermore, values applied are rounded to 0.1 year intervals. The two enrichments, therefore, do not necessarily start with

the same margin to the next 0.1 year interval. The larger additional cool time for the slightly higher initial enrichment in select cases is due to the combination of rounding the numbers to the indicated precision, uncertainties associated with the dose rate calculations, and interpolation of dose rate tables. It should be noted that the same trend occurs at 60 GWd/MTU between 3.3 and 3.5 wt% ^{235}U.

c. The staff's conclusion is correct. Chapter 1 already contains the statement "High burnup fuel is treated as damaged fuel and must apply the damaged fuel delta cool time as applicable." Therefore, NAC did not consider it necessary to restate the "high burnup being damaged fuel limitation". To assure that the SAR is clear in this context the NRC statement from the RAI is added as a note to Table 5.8-49.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

CRITICALITY EVALUATION

6-1. Revise the application to provide isotopic depletion (SCALE/TRITON) and criticality (MCNP) input and output files for the calculations performed to support the response to NRC RAI 6-3 (RAI letter dated June 2, 2015), contained in the NAC letter dated October 15, 2015.

The applicant updated the SAR for the Model No. MAGNATRAN package in response to NRC RAI 6-3, which asked for additional information regarding the depletion calculation methodology used for the PWR burnup credit criticality analysis. Staff requests that the applicant provide the SCALE/TRITON depletion and MCNP criticality code input and output files supporting this update, specifically the files that support the calculations summarized in Tables 6.10.1-43 and 6.10.1-44 of the SAR.

This information is required in order for the staff to ensure that the package will meet the criticality safety requirements of §71.55 and §71.59 when loaded with the contents described in the application.

NAC International Response to Criticality Evaluation RAI 6-1:

The TRITON depletion and MCNP criticality code input and output files that support the calculations summarized in Tables 6.10.1-43 and 6.10.1-44 are provided on CD.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

OPERATING PROCEDURES EVALUATION

7-1. Modify the following in Chapter 7 of the application:

a. Section 7.1.2 Step 9 to address loading of TSCs into the MAGNATRAN overpack that have not been previously in storage. This applies to both spent fuel TSCs and GTCC waste TSCs (note that while GTCC may have been in storage in TSCs prior to transport, that storage was not done under the MAGNASTOR CoC).
b. Section 7.2.1 Step 11, which appears that it should refer to Steps 8 thru 10. The current reference in Section 7.2.1 appears to be incomplete or out of synch with the current numbering of operations.

This information is needed to confirm compliance with 10 CFR 71.87.

<u>NAC International Response to the General Observation 7-1:</u>

a. Section 7.1.2 was revised to clarify intent to cover both loading the MAGNATRAN directly from storage operations or immediately following loading with spent fuel TSCs and GTCC waste TSCs
b. The reviewer is correct and Section 7.2.1 has been revised to correct editorial error.

NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR ADDITIONAL INFORMATION

ACCEPTANCE AND MAINTENANCE TESTS EVALUATION

8-1 Modify the shielding acceptance test in Section 8.1.6.3 and the maintenance test in Section 8.2.3 of the application to:

a. Clarify that the acceptance criteria (estimated/calculated dose rates) for the maintenance test are not the same as the acceptance criteria for the acceptance test. In other words, it should be clear that the dose rates that are used for acceptance criteria for the respective test are unique to the loaded contents for which dose rates are measured for the respective test. The loaded contents for the maintenance test will not be the same as the loaded contents for the acceptance test; so, the dose rates that are the acceptance criteria for the one test will not be the same as the dose rates for the other test.
b. Clarify that the characteristics of the contents, such as assembly type, MTU/assembly, and enrichment(s), (and not just burnup and cool time) are used in the calculations to estimate the radiation source terms for the dose rate estimates/calculations for both tests.
c. Clarify that the package configuration in the analyses for estimating/calculating dose rates is the configuration that represents the minimum shielding effectiveness of the package shielding (including material and geometric tolerances) specified in the package drawings.
d. Clarify the intended meaning of the language 'will be' in the new text in Sections 8.1.6.3 and 8.2.3, as compared to the rest of the test description text. This language is not consistent with the rest of the language in these sections that specific actions 'are' done.

This information is needed to confirm compliance with 10 CFR 71.85 and to ensure the package maintenance activities are performed in a way that assures continued compliance with the requirements in 10 CFR Part 71, Subparts E and F during its service life.

<u>NAC International Response to the General Observation 8-1:</u>

a. The revision made to address item b. clarifies that the dose rate calculations are to apply the properties of the fuel at the time of measurement.

b. The following statement is added in Section 8.1.6.3 and 8.2.3 to address the NRC staff concern.

"Neutron and gamma source terms applied in these dose rate calculations are to be based on the fuel type, MTU, burnup, and initial enrichment of the fuel loaded in the cask at the time dose rate measurements are taken."

c. The text in both Section 8.1.6.3 and 8.2.3 is revised to include the requirement of minimum shielding (including material and geometric tolerances). Rather than a blanket drawing statement, a reference to the minimum shielding configuration as discussed in Chapter 5 is added.

   "The package configuration (including materials and geometry) to be applied in the dose rate calculation must represent the minimum shielding effectiveness configuration discussed in Chapter 5."

d. The intent of "will be" is the same as "are" in the context used. "Will be" represents a requirement that an action will be taken at the designated point in time (acceptance/maintenance). There are in excess of 80 occurrences of "will be" in the Chapter 8 when discussing tests to be done on the package. As the new text in question seems to have caused confusion the "will be" is replaced by "are" in Section 8.1.6.3 and in the 15A revised Section of 8.2.3.

Enclosure 2

List of SAR Changes

No. 71-9356 for the MAGNATRAN Cask

MAGNATRAN SAR, Revision 16A

List of Changes for the MAGNATRAN® SAR, RAI Responses

Chapter/Page/ Figure/Table	Description of Change
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	
Pages 1.3-25	Modified limit item 7, creating items 7.a., 7.b., and 7.c.
Page 1.3-26 thru 1.3-32	Text flow changes.
Page 1.3-46	Modified Table 1.3-16.
Page 1.4-3 thru 1.4-4	Updated Section 1.4.3, "License Drawings," with new revision numbers.
Chapter 2	
Page 2.7.1.2-1	Modified two equations in the fourth paragraph of Section 2.7.1.2, "30-Foot Side Drop."
Page 2.7.1.7-2	Modified three equations in the top half of the page, where indicated.
Page 2.7.1.7-4	Modified three equations in the middle of the page, where indicated.
Page 2.7.8-3	Modified the title of Table 2.7.8-1, replacing "TSC" with "Canister."
Page 2.12.2-24	Replaced the regulation cited in the first paragraph of Section 2.12.2.3.17.
Chapter 3	
Page 3.5-3	Added new paragraph to the end of Section 3.5.1.1.
Pages 3.5-4 thru 3.5-5	Text flow changes.
Chapter 4	
No Changes	
Chapter 5	
Page 5-1	Modified the middle of the first paragraph of Section 5, "Shielding Evaluation."
Page 5.5-2	Added a new paragraph to the end of Section 5.5.1.1.
Pages 5.5-3 thru 5.5-14	Text flow changes.
Page 5.8.10-74	Added note following Tables 5.8-49.
Page 5.8.11-2	Modified the first and second paragraphs of Section 5.8.11.3.
Page 5.8.11-18	Added new notes following Tables 5.8-54 and 5.8-55.
Chapter 6	
No Changes	

Chapter/Page/ Figure/Table	Description of Change
Chapter 7	
Page 7.1-5	Modified the first "Note" in Section 7.1.2, "Loading of Contents," and second "Note" under Step 8.
Pages 7.1-6 thru 7.1-7	Modified Step 9, "Condition 2)" and the first two "Notes" of Step 9.
Pages 7.1-8 thru 7.1-15	Text flow changes.
Page 7.1-16	Modified the "Note" in Step 16.
Page 7.2-3	Modified Step 11 of Section 7.2.1, "Receipt of Package from Carrier."
Chapter 8	
Pages 8.1-25	Added text to the first paragraph of section 8.1.6.3, "Neutron and Gamma Shield Effectiveness Test"
Pages 8.1-26 thru 8.1-27	Text flow changes
Pages 8.2-6 thru 8.2-7	Added text to the fifth paragraph of section 8.2.3
Pages 8.2-8	Text flow changes

Enclosure 3

List of Drawing Changes

No. 71-9356 for the MAGNATRAN Cask

MAGNATRAN SAR, Revision 16A

NAC PROPRIETARY INFORMATION REMOVED

List of Drawing Changes, MAGNATRAN SAR, Revision 16A

Drawing 71160-502, Transport Cask Body, MAGNATRAN, Rev. 4P

[redacted]

Drawing 71160-502, Transport Cask Body, MAGNATRAN, Rev. 4NP

Sheet 1:

1. Cloud out Note 2 which was revised adding proprietary information

Drawing 71160-502, Transport Cask Body, MAGNATRAN, Rev. 5P

[redacted]

Drawing 71160-581, Shell Weldment, TSC, MAGNASTOR, Rev. 5

1. Revise Delta note 3 to read, "... Section V, Article 1 and 4. ...", was "... Section V, Article 1 and 5. ...".

Drawing 71160-602, Damaged Fuel Can (DFC), Details, MAGNASTOR, Rev. 1

Sheet 1,

1. Revise the description of Item 4, Wiper Plate in the BOM table.
   Is: ".004-.008 (.102-.203mm) SHEET/STRIP"; was: ".005-.008 (.127-.203mm) SHEET/STRIP"

Drawing 71160-681, DF Shell Weldment, TSC, MAGNASTOR, Rev. 1

1. Revise Delta note 2 to read, "... Section V, Article 1 and 4. ...", was "... Section V, Article 1 and 5. ..."

Enclosure 4

Supporting Calculations

No. 71-9356 for the MAGNATRAN Cask

MAGNATRAN SAR, Revision 16A

All Calculations Withheld in their Entirety Per 10 CFR 2.390

Enclosure 4 Contents

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2. 71160-5508, Revision 1

Enclosure 5

MAGNATRAN SAR

LOEP and SAR Page Changes

No. 71-9356 for the MAGNATRAN Cask

MAGNATRAN SAR, Revision 16A

May 2016

Revision 16A

MAGNATRAN

(**M**odular **A**dvanced **G**eneration **N**uclear **A**ll-purpose **TRANsport**)

SAFETY ANALYSIS REPORT

NON-PROPRIETARY VERSION

Docket No. 71-9356

NAC INTERNATIONAL

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36 drawings (see Section 1.4.3)

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prior to GTCC initial loading. Any dross material (fines and debris) generated by the cutting operations will be disposed of as low-level radioactive or GTCC waste.

Each GTCC waste basket liner may contain up to 55,000 pounds of GTCC waste including the weight of strainer baskets and pipe spacers. The GTCC waste basket liner is transported in a GTCC TSC with a welded closure lid. The GTCC waste basket liners have twelve 1.0-inch diameter holes in the bottom plate, and outer ring and middle supports under the bottom plate to facilitate free flow drainage from the liner. The GTCC TSC has a sump in the bottom plate, and the closure lid includes a drain tube assembly to enable draining and vacuum drying of the loaded TSC. Consequently, no hydrogen generation occurs as a result of residual water.

The radionuclide composition of the waste was determined based on radiochemical assay of samples and dose rate measurements. The isotope that primarily contributes to the radiological source term is ^{60}Co. The source terms applied in the evaluation of the GTCC waste are presented in Chapter 5 of this SAR.

Fuel and GTCC Content Limits

Spent fuel and GTCC waste shipments in the MAGNATRAN shall be subject to the following limits:

1. The maximum contents weight for the MAGNATRAN transport cask shall not exceed 106,000 pounds.
2. The design basis fuel characteristics shall be in accordance with Table 1.3-6 and Table 1.3-19.
3. The total decay heat of the cask cavity contents shall not exceed 23 kW for PWR fuel and 22 kW for BWR fuel. For GTCC waste content, the decay heat limit is 1.7 kW.
4. The total weight of the PWR fuel assemblies in the TSC, including standard nonfuel hardware and spacers (if used), shall not exceed 62,160 pounds.
5. The total weight of the PWR fuel assemblies in the DF PWR TSC, including standard nonfuel hardware and spacers (if used), shall not exceed 61,184 pounds.
6. The total weight of the BWR fuel assemblies in the TSC, including channels (if applicable), shall not exceed 62,656 pounds.
7. GTCC waste consists of solid, irradiated, and contaminated hardware provided the quantity of fissile material does not exceed a Type A quantity and does not exceed the mass limits of 10 CFR 71.15.

   The specific Curie content source of the GTCC shall be limited to:

   a. a maximum of 2.7 Ci ^{60}Co/lb averaged over GTCC contents
   b. a localized peak 16.1 Ci ^{60}Co/lb
   c. a total ^{60}Co activity of 85,760 Ci at transport.

The maximum allowed weight of this waste is 55,000 lbs.

8. Any number of MAGNATRAN casks may be shipped at one time by rail, ship, barge or heavy-haul vehicle with the exception of a PWR-DF basket with DFC which requires only one cask to be shipped at one time.
9. Radiation levels shall not exceed the requirements of 10 CFR 71.47 and 10 CFR 71.51 for a closed transport vehicle.
10. Surface contamination levels shall not exceed the requirements of 10 CFR 71.87(i)(1).
11. Cask contents transported in a TSC with a PWR fuel basket shall be uranium undamaged PWR fuel assemblies in accordance with the limiting values shown in Table 1.3-6 and Table 1.3-7 and shall meet the following specifications:
    a. Zirconium-based alloy cladding.
    b. Enrichment, post-irradiation cooling time and burnup credit load curves in accordance with Tables 1.3-6, 1.3-8 through 1.3-11, and Figure 1.3-6.
    c. Maximum assembly average burnup shall be ≤ 45,000 MWd/MTU. A fuel assembly with maximum assembly average burnup > 45,000 MWd/MTU shall be treated as damaged fuel and placed in a damaged fuel can for transport.
    d. Decay heat per fuel assembly: 622 watts (includes non-fuel hardware contribution)
    e. Nominal fresh fuel dimensions: assembly length (in.) ≤ 178.3; assembly width (in.) ≤ 8.54
    f. Fuel assembly weight (lbs.): ≤ 1,765 (including nonfuel hardware and fuel spacers)
    g. Spent fuel contents shall be loaded in accordance with the loading tables in Chapter 5, Section 5.8.3, of this SAR.
    h. Quantity per TSC: up to 37 undamaged PWR fuel assemblies shown in Figure 1.3-6. Figure 1.3-6 indicates the fuel storage locations that shall be empty, at a minimum, when implementing the 36, 35 and 33 loading patterns for burnup credit purposes.
    i. Undamaged PWR fuel assemblies may contain nonfuel hardware (NFHW). Fuel assembly lattices not containing the nominal number of fuel rods specified in Table 1.3-7 must contain solid filler rods that displace a volume equal to, or greater than, that of the fuel rod that the filler rod replaces. Fuel assemblies may have stainless steel rods inserted to displace guide tube "dashpot" water. Nonfuel hardware cool times shall be in accordance with Tables 1.3-16 through 1.3-18. Alternatively, the ^{60}Co curie limits in Table 1.3-17 and Table 1.3-18 may be used to establish site-specific nonfuel hardware constraints. Note that fuel assemblies defined as CE14 and CE16 are not allowed to contain BPRA or TP type nonfuel hardware.

j. Fuel spacers may be used in the TSCs to reduce axial gaps for the spent fuel assemblies and non-fuel hardware.

k. Unenriched and unirradiated (i.e., not inserted in-core) fuel assemblies are not authorized for loading. Unenriched axial blankets are permitted, provided that the nominal length of the blanket is not greater than six inches. An unenriched rod may be used as a replacement rod to return a fuel assembly to an undamaged condition.

l. Reactor control components (RCC) are restricted to fuel storage locations No. 11, 12, 13, 18, 19, 20, 25, 26 and 27 (Figure 1.3-6). Minimum RCC cool times are:

Minimum Cool Time (years)	Maximum Exposure (GWd/MTU)
10	180
14	270
20	360

Interpolation is not allowed between data points.

m. One Neutron Source or Neutron Source Assembly (NSA) is permitted to be loaded in a TSC in fuel storage locations No. 11, 12, 13, 18, 19, 20, 25, 26 or 27 (Figure 1.3-6). Neutron source assemblies may contain source rods attached to hardware similar in configuration to guide tube plug devices (thimble plugs) and burnable absorbers, in addition to containing burnable poison rodlets and/or thimble plug rodlets. For NSAs containing absorber rodlets, the BPRA cool time and burnup/exposure or hardware ^{60}Co curie limit listed in Table 1.3-17 are applied to the neutron sources. NSAs having only thimble plug rodlets require the thimble plug restriction in Table 1.3-18 to be applied. Combination NSAs, containing both thimble plug and burnable absorber rodlets must apply the more limiting of the two minimum cool time/curie limit. Fuel assemblies loaded with the NSAs must apply the additional cool times listed in Table 1.3-16. Fuel types indicated as CE14 and CE16 are not permitted to be loaded with NSAs.

n. Fuel assemblies may contain any number of unirradiated (i.e., not inserted in-core) nonfuel solid filler fuel replacement rods. Activated stainless steel rods are limited to five per assembly, one assembly per basket, at a maximum steel rod burnup/exposure of 32.5 GWd/MTU. Fuel assemblies with activated stainless steel rods must be cooled either a minimum of 21 years or the Section 5.3 loading table minimum cool time plus one year, whichever is greater.

o. Westinghouse fuel assemblies may contain a hafnium absorber assembly (HFRA) at a maximum burnup/exposure of 4.0 GWd/MTU and a minimum cool time of 16 years. Fuel assemblies loaded with an HFRA must apply the additional cool times listed in Table 1.3-16.

p. Under-burned (assemblies with burnup less than that dictated by the burnup credit loading curve) Westinghouse 15×15 PWR fuel assemblies may be loaded provided that they include Ag-In-Cd full-length RCCAs and are loaded in the basket locations that RCCs are allowed (see item l for RCCA loading). Burnup must be greater than or equal to 12,000 MWd/MTU. Enrichment must be equal to or less than 4.05 wt. % ^{235}U. The basket must include absorber sheets with an effective ^{10}B areal density of 0.036 g/cm^2. For the loading of low burnup fuel, the RCCAs must be full length (i.e. spider component included). RCCA exposure must be equal to or less than 200,000 MWd/MTU. Any assemblies loaded without an RCCA inserted must meet the burnup credit loading curve for the applicable assembly loading profile.

12. Cask contents transported in a TSC with a DF Basket Assembly shall be uranium undamaged PWR fuel assemblies and damaged fuel (damaged PWR fuel assemblies or PWR fuel debris) in accordance with the limiting values shown in Table 1.3-6 and Table 1.3-7 and shall meet the following specifications:

a. Zirconium-based alloy cladding.

b. For the 33 non-DFC fuel locations in the DF Basket Assembly, enrichment, post-irradiation cooling time and burnup credit load curves in accordance with Tables 1.3-6, 1.3-12 through 1.3-15, and Figure 1.3-6 for a TSC with a DF Basket Assembly containing DFCs. For a TSC with a DF Basket Assembly that does not contain any DFCs, the enrichment, post-irradiation cooling time and burnup credit load curves in accordance with Tables 1.3-6, 1.3-8 through 1.3-11, and Figure 1.3-4 may be used for all fuel locations.

c. For the up to four DFC locations in a DF Basket Assembly containing damaged fuel, the damaged fuel shall have a minimum burnup of 5 GWd/MTU, a maximum enrichment of 4.05 wt % ^{235}U, and a minimum cool time of 15 years.

d. Maximum assembly average burnup shall be $\leq$ 45,000 MWd/MTU. A fuel assembly with maximum assembly average burnup > 45,000 MWd/MTU shall be treated as damaged fuel and placed in a damaged fuel can for transport.

e. Decay heat per fuel assembly: 622 watts (590.5 watts for burnup > 45,000 MWd/MTU includes non-fuel hardware contribution)

f. Nominal fresh fuel assembly: length (in.) ≤ 167.0

g. Nominal fresh fuel assembly: width (in.) ≤ 8.54

h. Fuel assembly weight (lbs.): ≤ 1,765 (including nonfuel hardware, DFCs and fuel spacers)

i. Spent fuel contents shall be loaded in accordance with the loading tables in Section 5.8.3 with additional cool time for damaged fuel found in Table 5.8-49 of this SAR. The additional cool time from Table 5.8-49 applies to all assemblies loaded in a damaged fuel TSC with damaged fuel. High burnup fuel is treated as damaged fuel and must apply the damaged fuel delta cool time as applicable.

j. Quantity per TSC: Up to a total of 37 undamaged PWR fuel assemblies, including up to four DFCs containing undamaged PWR fuel assemblies, damaged PWR fuel assemblies, and/or PWR fuel debris loaded in DFC location Nos. 4, 8, 30 and 34, as shown on Figure 1.3-4, for the DF Basket Assembly. Figure 1.3-6 indicates the fuel storage locations that shall be empty, at a minimum, when implementing the 36, 35 and 33 loading patterns for burnup credit purposes.

k. The contents of a DFC must be less than, or equivalent to, one undamaged PWR fuel assembly. PWR fuel assemblies loaded in a DFC shall not contain nonfuel hardware with the exception of instrument tube tie components, guide tube anchors or other similar devices, and steel inserts.

l. Undamaged PWR fuel assemblies not loaded in a DFC may contain nonfuel hardware consistent with Table 1.3-16. Fuel assembly lattices not containing the nominal number of fuel rods specified in Table 1.3-7 must contain solid filler rods that displace a volume equal to, or greater than, that of the fuel rod that the filler rod replaces. Fuel assemblies may have stainless steel rods inserted to displace guide tube "dashpot" water. Nonfuel hardware cool times shall be in accordance with Tables 1.3-16 through 1.3-18. Alternatively, the ^{60}Co curie limits in Tables 1.3-17 and 1.3-18 may be used to establish site-specific nonfuel hardware constraints. Note that fuel assemblies defined as CE14 and CE16 are not allowed to contain BPRA or TP type nonfuel hardware.

m. Fuel spacers may be used in the TSCs to reduce axial gaps for the spent fuel assemblies, non-fuel hardware or damaged fuel cans.

n. Unenriched and unirradiated (i.e., not inserted in-core) fuel assemblies are not authorized for loading. Unenriched axial blankets are permitted, provided that the nominal length of the blanket is not greater than six inches. An unenriched rod may be used as a replacement rod to return a fuel assembly to an undamaged condition.

o. Reactor control components (RCC) are restricted to fuel storage location Nos. 11, 12, 13, 18, 19, 20, 25, 26 and 27 (Figure 1.3-4). Minimum RCC cool times are:

Minimum Cool Time (years)	Maximum Exposure (GWd/MTU)
10	180
14	270
20	360

Interpolation is not allowed between data points.

p. One Neutron Source or Neutron Source Assembly (NSA) is permitted to be loaded in a TSC in fuel storage location Nos. 11, 12, 13, 18, 19, 20, 25, 26 or 27 (Figure 1.3-4). Neutron source assemblies may contain source rods attached to hardware similar in configuration to guide tube plug devices (thimble plugs) and burnable absorbers, in addition to containing burnable poison rodlets and/or thimble plug rodlets. For NSAs containing absorber rodlets, the BPRA cool time and burnup/exposure or hardware ^{60}Co curie limit listed in Table 1.3-17 are applied to the neutron sources. NSAs having only thimble plug rodlets require the thimble plug restriction in Table 1.3-18 to be applied. Combination NSAs, containing both thimble plug and burnable absorber rodlets must apply the more limiting of the two minimum cool time/curie limit. Fuel assemblies loaded with the NSAs must apply the additional cool times listed in Table 1.3-16. Fuel types indicated as CE14 and CE16 are not permitted to be loaded with NSAs.

q. Fuel assemblies may contain any number of unirradiated (i.e., not inserted in-core) nonfuel solid filler fuel replacement rods. Activated stainless steel rods are limited to five per assembly, one assembly per basket, at a maximum steel rod burnup/exposure of 32.5 GWd/MTU. Fuel assemblies with activated stainless steel rods must be cooled either a minimum of 21 years or the item 12.i indicated minimum cool time plus one year, whichever is greater.

r. Westinghouse fuel assemblies may contain a hafnium absorber assembly (HFRA) at a maximum burnup/exposure of 4.0 GWd/MTU and a minimum cool time of 16 years. Fuel assemblies loaded with an HFRA must apply the additional cool times listed in Table 1.3-16.

r. Under-burned (assemblies with burnup less than that dictated by the burnup credit loading curve) Westinghouse 15×15 PWR fuel assemblies may be loaded provided that they include Ag-In-Cd full-length RCCAs and are loaded in the basket locations that

RCCs are allowed (see item o for RCCA loading). Burnup must be greater than or equal to 12,000 MWd/MTU. Enrichment must be equal to or less than 4.05 wt. % ^{235}U. The basket must include absorber sheets with an effective ^{10}B areal density of 0.036 g/cm^2. For the loading of low burnup fuel, the RCCAs must be full length (i.e. spider component included). RCCA exposure must be equal to or less than 200,000 MWd/MTU. Any assemblies loaded without an RCCA inserted must meet the burnup credit loading curve for the applicable assembly loading profile.

s. Damaged CE 16×16 fuel assemblies are not to be loaded in the MAGNATRAN system.

13. Cask contents transported in a TSC with a BWR fuel basket shall be uranium undamaged BWR fuel assemblies in accordance with the limiting values shown in Table 1.3-19 and Table 1.3-20 and shall meet the following specifications:

a. Zirconium-based alloy cladding.

b. Enrichment, post-irradiation cooling time and average assembly burnup in accordance with Tables 1.3-19, 1.3-21, and 1.3.-22 and Figures 1.3-5, 1.3-7 and 1.3-8.

c. Decay heat per fuel assembly: uniform loading 253 watts

d. Nominal fresh fuel dimensions: assembly length (in.) $\leq$ 176.2

e. Assembly width (in.) $\leq$ 5.52

f. Fuel assembly weight (lbs.) $\leq$ 739 lbs (including channel and fuel spacers) with a maximum contents weight of 62,656 lbs.

g. Spent fuel contents shall be loaded in accordance with the loading tables in Chapter 5, Section 5.8.4, of this SAR.

h. Quantity per TSC: up to 87 undamaged BWR fuel assemblies as shown in Figure 1.3-7.

i. Allowable fuel assembly locations for the 82-assembly BWR fuel basket configurations are shown in Figure 1.3-5 (location numbering for the 82-assembly basket is the same as that shown for the 87-assembly basket in Figure 1.3-7).

j. Prior to use of the 82-assembly configuration, the center cell weldment and upper weldments with blocking strap must be in place to physically block the designated nonfuel locations (shown in Figure 1.3-5). Less than 82 assemblies may be loaded when implementing the 82-Assembly configuration provided the required fuel storage locations are empty, at a minimum.

k. BWR fuel assemblies may be unchanneled, or channeled with zirconium-based alloy channels.

l. BWR fuel assemblies with stainless steel channels are not authorized.

m. Fuel assembly lattices not containing the assembly type-specific nominal number of fuel rods specified in Table 1.3-20 must contain solid, unirradiated, filler rods that displace a volume equal to, or greater than, that of the fuel rod that the filler rod replaces

n. Spacers may be used in the TSCs to fill axial gaps and provide support for the spent fuel assemblies.

o. Unenriched and unirradiated (i.e., not inserted in-core) fuel assemblies are not authorized for loading. Unenriched axial blankets are permitted, provided that the nominal length of the blanket is not greater than six inches.

Table 1.3-14 Maximum Initial Enrichment – PWR Damaged Fuel Configuration – 0.027 g/cm^2 ^{10}B Absorber

Assembly ID	Zero (0) Burnup Max. Enr. (wt %)	Max Initial Enrichment (wt % ^{235}U) = C_4 × Burnup (GWd/MTU) + C_5							
		Burnup (GWd/MTU) < 18		18 ≤ Burnup (GWd/MTU) ≤ 30		30 < Burnup (GWd/MTU) ≤ 50		50 < Burnup (GWd/MTU)	
		C_4	C_5	C_4	C_5	C_4	C_5	C_4	C_5
BW 15×15	1.5	0.0471	1.30	0.0666	1.19	0.0725	0.857	0.0725	0.581
BW 17×17	1.5	0.0474	1.36	0.0652	1.27	0.0724	0.918	0.0724	0.639
CE 14×14	1.8	0.0486	1.68	0.0696	1.61	0.0778	1.32	0.0778	1.32
CE 16×16	1.8	0.0493	1.66	0.0660	1.64	0.0761	1.33	0.0761	1.33
WE 14×14	1.8	0.0535	1.71	0.0694	1.75	0.0805	1.52	0.0805	1.52
WE 15×15	1.5	0.0465	1.33	0.0664	1.24	0.0710	0.968	0.0710	0.685
WE 17×17	1.5	0.0447	1.31	0.0647	1.25	0.0714	0.846	0.0714	0.564

Table 1.3-15 Maximum Initial Enrichment – Damaged Fuel Configuration WE15 – Optional Configurations

# of Assemblies	Zero (0) Burnup Max. Enr. (wt %)	Max Initial Enrichment (wt % ^{235}U) = C_4 × Burnup (GWd/MTU) + C_5							
		Burnup (GWd/MTU) < 18		18 ≤ Burnup (GWd/MTU) ≤ 30		30 < Burnup (GWd/MTU) ≤ 50		50 < Burnup (GWd/MTU)	
		C_4	C_5	C_4	C_5	C_4	C_5	C_4	C_5
0.036 g/cm^2 ^{10}B Absorber									
36	1.6	0.0483	1.53	0.0721	1.35	0.0750	1.17	0.0750	0.851
35	1.7	0.0532	1.51	0.0722	1.45	0.0778	1.14	0.0778	1.14
33	1.7	0.0524	1.60	0.0734	1.52	0.0791	1.22	0.0791	1.22
0.030 g/cm^2 ^{10}B Absorber									
36	1.6	0.0483	1.48	0.0707	1.32	0.0739	1.15	0.0739	0.811
35	1.6	0.0499	1.48	0.0722	1.34	0.0733	1.20	0.0733	0.847
33	1.7	0.0523	1.52	0.0728	1.40	0.0780	1.19	0.0780	1.19
0.027 g/cm^2 ^{10}B Absorber									
36	1.6	0.0473	1.42	0.0668	1.33	0.0731	1.02	0.0731	0.693
35	1.6	0.0477	1.46	0.0736	1.27	0.0738	1.13	0.0738	0.775
33	1.7	0.0491	1.51	0.0718	1.41	0.0784	1.09	0.0784	1.09

Table 1.3-16 Additional Fuel Assembly Cool Time Required to Load Nonfuel Hardware

Core (Assembly)	Additional Cool Time (years)			
	BPAA/HFRA	GTPD	RCC	NSA
CE 14×14	--	--	0.4	--
WE 14×14	1.1	0.1	0.3	1.1
WE 15×15	1.3	0.1	6.9	1.3
B&W 15×15	0.1	0.2	0.3	0.2
CE 16×16	--	--	0.4	--
WE 17×17	1.4	0.2	6.7	1.4
B&W 17×17	0.1	0.2	0.3	0.2

Note: Additional fuel assembly cooling time to be added to the minimum fuel assembly cool time based on fuel assembly initial enrichment and fuel assembly average burnup listed in the loading tables in Chapter 5.

Table 1.3-17 Allowed BPRA Burnup and Cool Time Combinations

Limiting Basis	Fuel Assembly				
	WE 14×14	WE 15×15	B&W 15×15	WE 17×17	B&W 17×17
Min. Cool Time (yr) for Exposure ≤ 70 GWd/MTU	8.0	8.0	8.0	8.0	8.0
Max ^{60}Co Activity (Ci)	704	901	26	894	27

Note: Specified minimum cool times for BPRAs are independent of the required minimum cool times for the fuel assembly containing the BPRA.

Table 1.3-18 Allowed GTPD Burnup and Cool Time Combinations

Limiting Basis	Fuel Assembly				
	WE 14×14	WE 15×15	B&W 15×15	WE 17×17	B&W 17×17
Min. Cool Time (yr) for Exposure ≤ 180 GWd/MTU	8.0	8.0	8.0	8.0	8.0
Max ^{60}Co Activity (Ci)	60.5	73.1	99.2	93.3	107.8

Note: Specified minimum cool times for thimble plugs are independent of the required minimum cool times for the fuel assembly containing the thimble plug.

1.4.3 License Drawings

This section presents the list of License Drawings for MAGNATRAN.

Drawing Number	Title	Revision No.
71160-500	Shipping Configuration, Transport Cask, MAGNATRAN	1NP
71160-501	Assembly, Transport Cask, MAGNATRAN	0
71160-502	Transport Cask Body, MAGNATRAN	4NP
71160-504	Misc. Details, Transport Cask, MAGNATRAN	1
71160-505	Lid Assembly, Transport Cask, MAGNATRAN	5NP
71160-506	Cask Cavity Spacer, MAGNATRAN	1
71160-511	Personnel Barrier, Shipping Configuration, Transport Cask, MAGNATRAN	1
71160-512	Nameplate, MAGNATRAN	1
71160-530	Misc. Details, Impact Limiter, MAGNATRAN	1
71160-531	Impact Limiter, Transport Cask, MAGNATRAN	2P*
71160-551	Fuel Tube Assembly, MAGNASTOR – 37 PWR	10NP
71160-559	Lifting Trunnion, Transport Cask, MAGNATRAN	0
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	8
71160-585	TSC Assembly, MAGNASTOR	11
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

* License drawing is proprietary in its entirety and not included in the non-proprietary version of the SAR. It is included on the List of License Drawings for reference only.

1.4.3 License Drawings (cont'd)

Drawing Number	Title	Revision No.
71160-620	Top Fuel Spacer, MAGNASTOR	1P*
71160-671	Details, Neutron Absorber, Retainer, For DF Corner Weldment, MAGNASTOR – 37 PWR	0
71160-673	Damaged Fuel Can (DFC), Spacer, MAGNASTOR	1
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
71160-684	Details, DF Closure Lid, MAGNASTOR	2
71160-685	DF, TSC Assembly, MAGNASTOR	5
71160-711	GTCC Waste Basket Liner, MAGNASTOR	1
71160-781	Shell Weldment, GTCC TSC, MAGNASTOR	1
71160-785	GTCC TSC, Assembly, MAGNASTOR	3

R-229187

REV	CHANGE
0	INITIAL ISSUE
1NP	INC DCR 0A
2NP	INC DCR 1NPA
3NP	INC DCR 2NPA
4NP	INC DCR 3NPA

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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NAC INTERNATIONAL

TRANSPORT CASK BODY, MAGNATRAN

UNLESS OTHERWISE STATED

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NEXT ASSEMBLY 71160-501

DRAWING TYPE: LICENSE

PROJECT 71160

DRAWING 502 REV 4NP

SH 1 OF 8

Security-Related Information Figure
Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

TRANSPORT CASK BODY, MAGNATRAN

PROJECT 71160 DRAWING 502

SH 2 OF 8

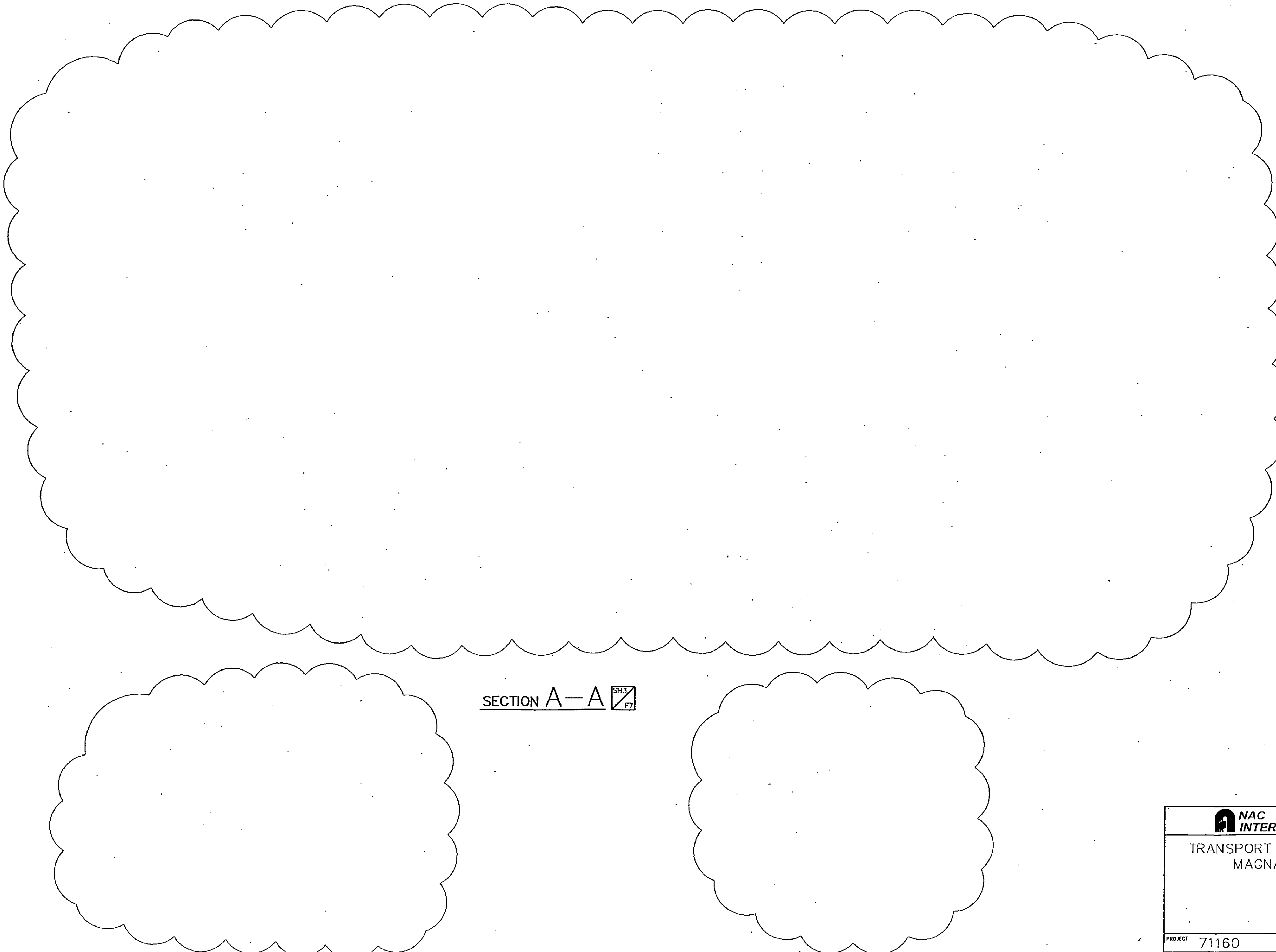
Security-Related Information Figure
Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

TRANSPORT CASK BODY,
MAGNATRAN

71160

502



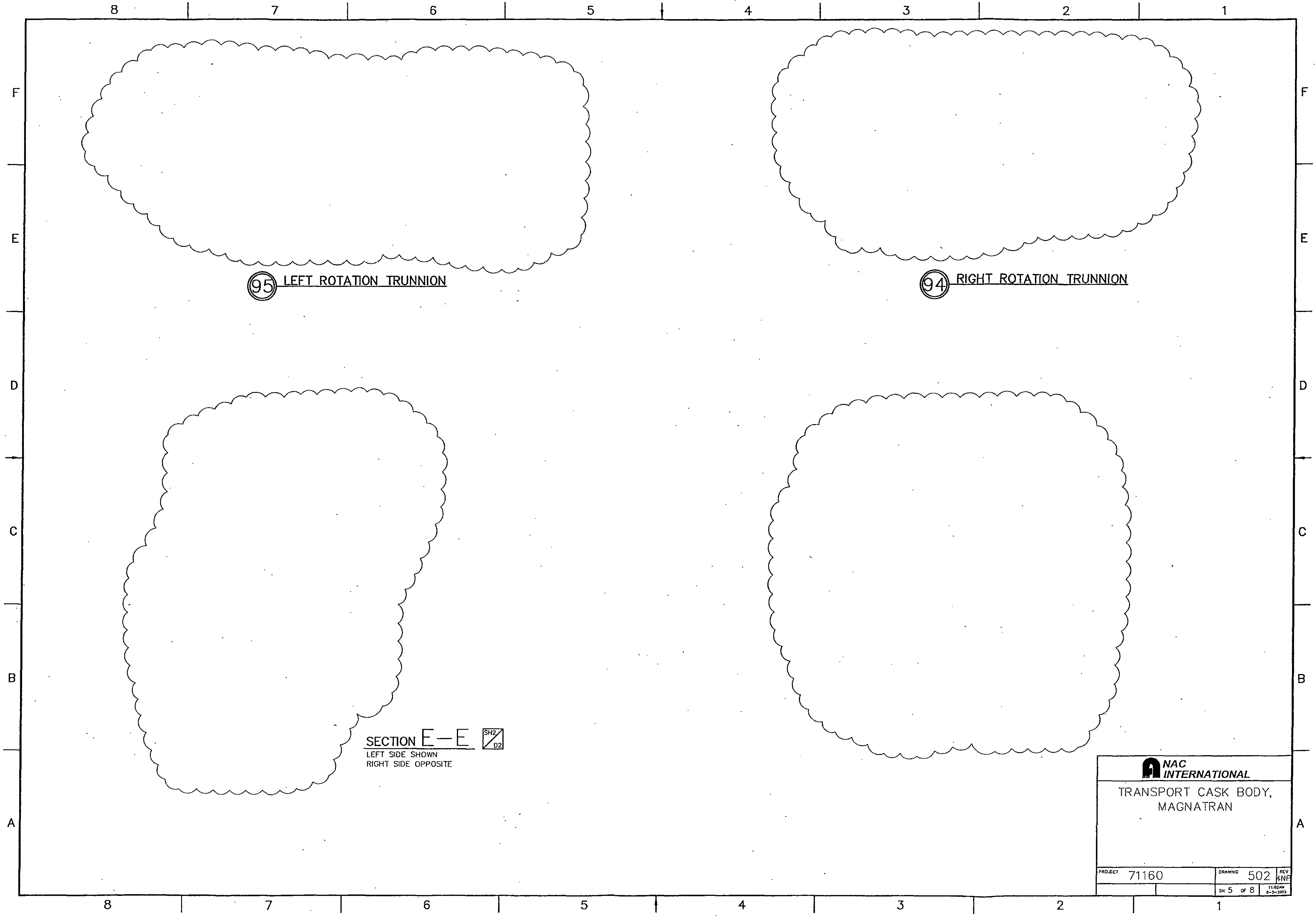
SECTION A—A SH3/F7

NAC INTERNATIONAL

TRANSPORT CASK BODY
MAGNATRAN

PROJECT	DRAWING	REV
71160	502	4NP

SH 4 OF 8 11:05AM 8-5-2015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PROJECT 71160
DRAWING 502
REV NP
SH 5 OF 8
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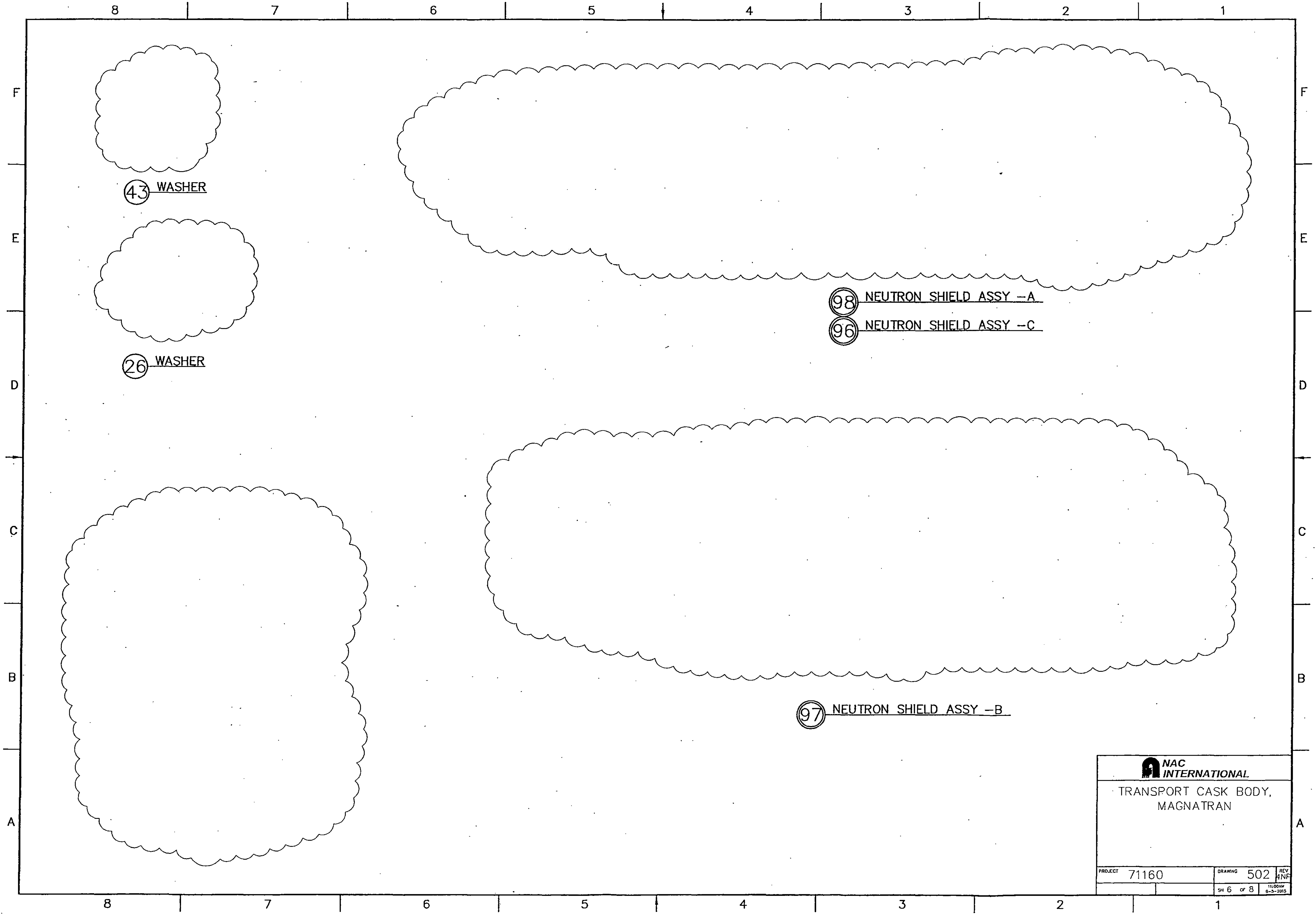
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DRAWING 502
REV 4NP
SH 6 OF 8
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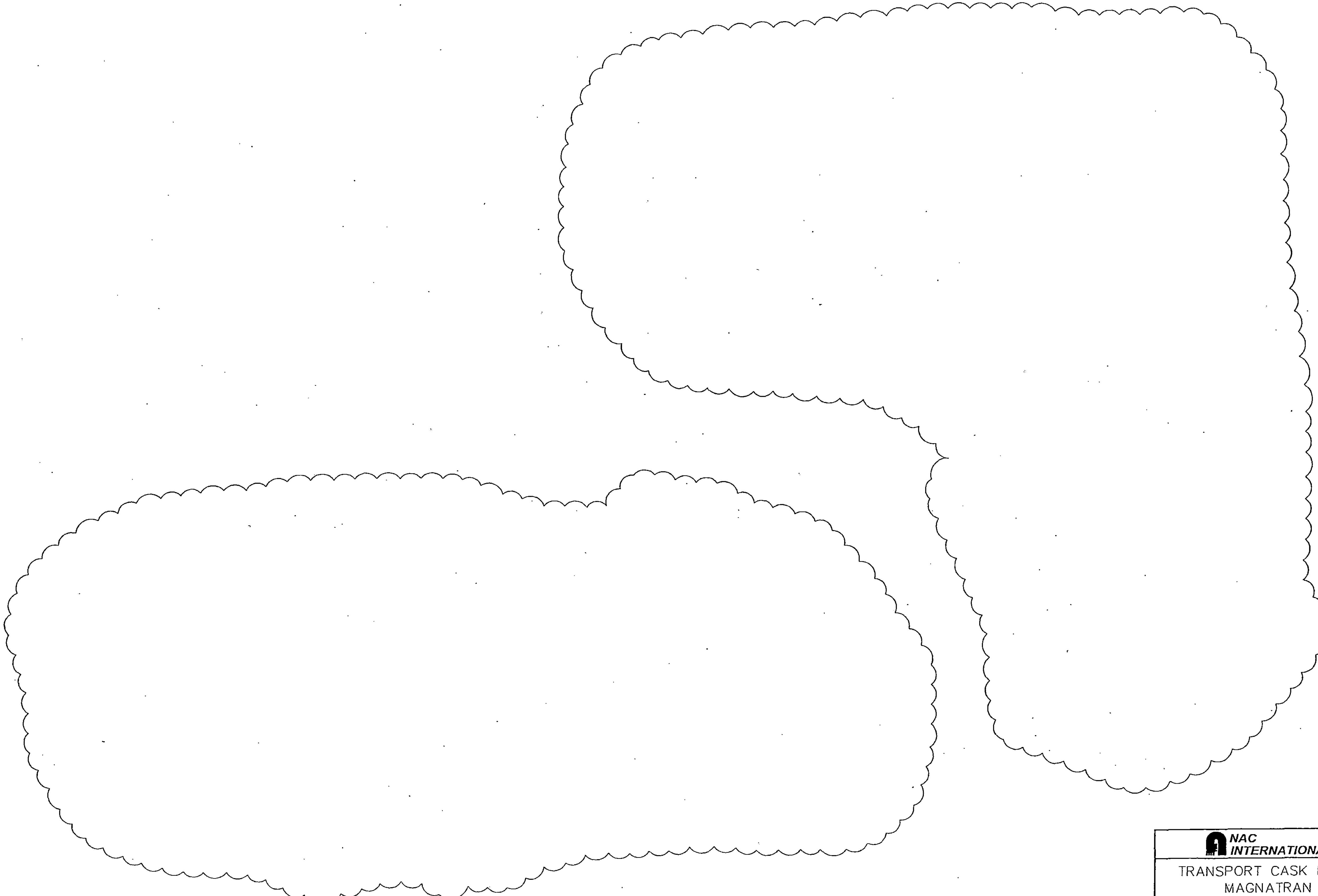

SECTION K—K SH3/B8

NAC INTERNATIONAL

TRANSPORT CASK BODY, MAGNATRAN

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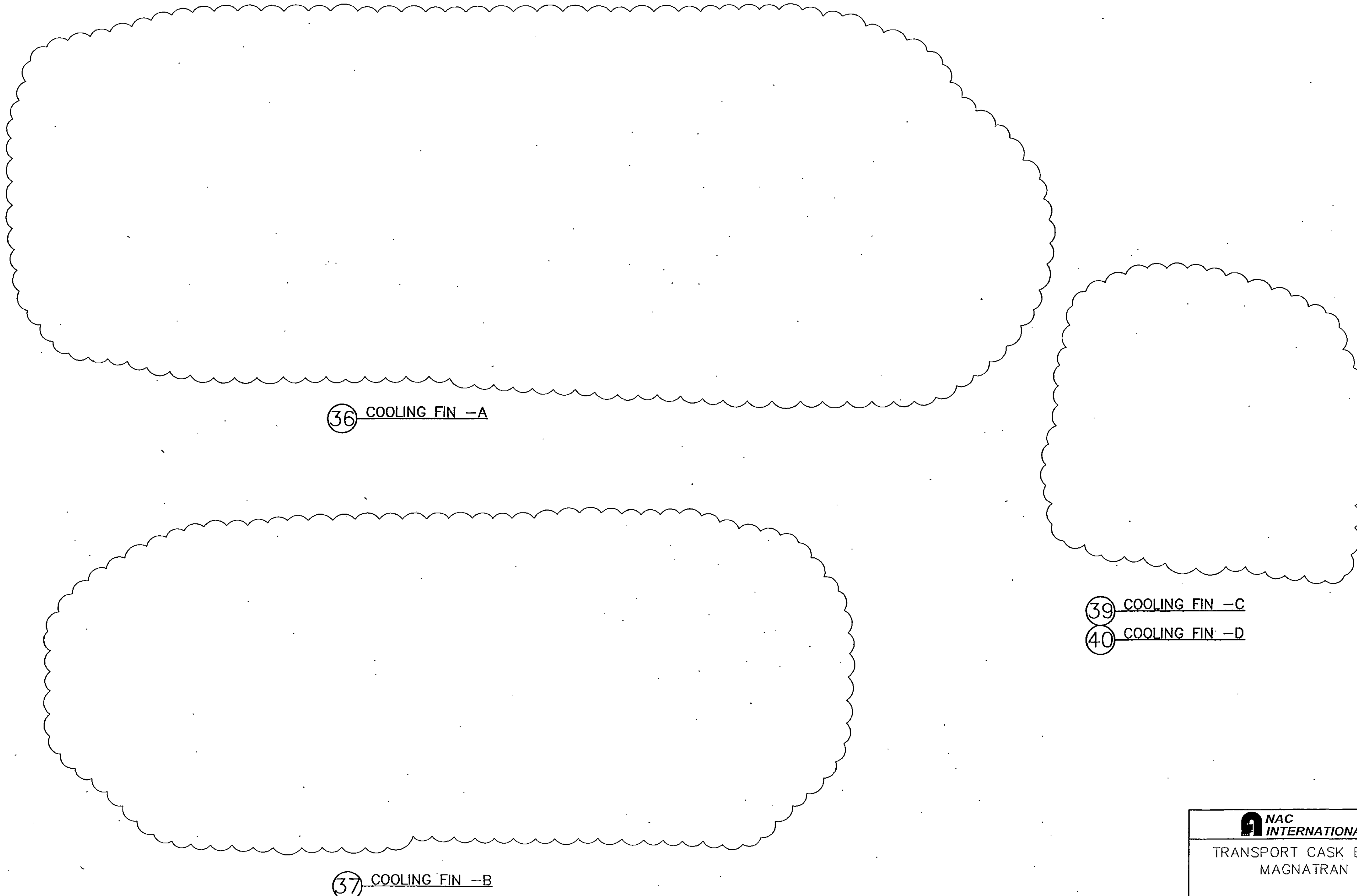

NAC INTERNATIONAL

TRANSPORT CASK BODY, MAGNATRAN

PROJECT 71160	DRAWING 502	REV 1NP	SH 8 OF 8

R-22876A

REV	CHANGE
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2	INC DCR 1A
3	INC DCR 2A
4	INC DCR 3A
5	INC DCR 4A

Security-Related Information Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

SHELL WELDMENT, TSC, MAGNASTOR

UNLESS OTHERWISE STATED

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	Roy V. Bass	6/19/15

NEXT ASSEMBLY 71160-585

DRAWING TYPE: LICENSE

PROJECT 71160 | DRAWING 581 | REV 5

SH 1 OF 2

Security-Related Information Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

SHELL WELDMENT,
TSC,
MAGNASTOR

71160 | 581 | 3

R- 228765

REV	CHANGE
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1	INC DCR 0A

Security-Related Information Figure Withheld Under 10 CFR 2.390.

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NEXT ASSEMBLY 71160-601

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	Roy W. Rose	9/19/15

NAC INTERNATIONAL

DAMAGED FUEL CAN (DFC), DETAILS, MAGNASTOR

PROJECT 71160 DRAWING 602 REV 1

SH 1 OF 2

Security-Related Information Figure
Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

DAMAGED FUEL CAN (DFC),
DETAILS,
MAGNASTOR

PROJECT 71160	DRAWING 602	REV 1

R-228766

REV	CHANGE
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1	INC DCR OA

Security-Related Information Figure Withheld Under 10 CFR 2.390.

UNLESS OTHERWISE STATED	GROUP	NAME	DATE
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			6/19/15

NAC INTERNATIONAL

DF, SHELL WELDMENT,
TSC,
MAGNASTOR

PROJECT 71160 | DRAWING 681 | REV 1 | SH 1 OF 2

Security-Related Information Figure Withheld Under 10 CFR 2.390.

NAC INTERNATIONAL

DF, SHELL WELDMENT,
TSC,
MAGNASTOR

PROJECT 71160

DRAWING 681 REV 1

SH 2 OF 2

2.7.1.2 30-Foot Side Drop

In accordance with the requirements of 10 CFR 71.73(c)(1), the MAGNATRAN transport cask is structurally evaluated for the hypothetical accident 30-ft side drop condition. In this event, the cask, with its payload, spacer (if appropriate), and impact limiters, falls 30 feet onto a flat, unyielding, horizontal surface. The package strikes the surface in a horizontal position; consequently, a side impact occurs. The loading for a side drop accident includes the closure lid bolt preload, internal pressure, and inertial body load.

The 30-ft side drop conditions are evaluated using the model described in Section 2.12.2.6 with elastic-plastic material properties. The elastic-plastic model is implemented, per ASME Code Appendix F, to confirm that the cask body stresses are below the allowable stresses.

As shown in Table 2.7.1-9 through Table 2.7.1-12, the factors of safety are greater than one for the 30-ft side drop accident. The minimum factor of safety for primary membrane stress intensity is 1.35 in section location 29, located at the base of the cask flange (the portion of the top forging that forms the recess for the lid) (Table 2.7.1-11). The minimum factor of safety for primary membrane plus bending stress intensity is 1.72 in section location 22, located in the outer shell (Table 2.7.1-10).

For the results presented in Table 2.7.1-11 and Table 2.7.1-12, plastic stresses are obtained by identifying the maximum nodal plastic equivalent stress at each section location. The membrane stress is taken as the nodal equivalent stress value nearest the center of the section, and the peak stress is taken as the maximum stress value for the inner and outer nodes. Based on the difference in the equivalent stress from the finite element results $[(\sigma^2 + 3\tau^2)^{1/2}]$ versus the ASME Code, Section III stress intensity criterion $[(\sigma^2 + 4\tau^2)^{1/2}]$, the maximum nodal plastic equivalent stresses are conservatively factored $(4/3)^{1/2}$. If yielding has not occurred along the section, the membrane and membrane plus bending stress intensities are determined using linearized stresses.

Table 2.7.1-9 P_m Stresses – 30-Foot Side-Drop, ksi

Case[1]	Sect.[2]	Angle (deg)	Stress Components						Stress Int.	Stress Allow.	FS
			Sx	Sy	Sz	Sxy	Syz	Sxz			
1	1	101.2	-3.05	-4.04	0.07	-0.21	0.21	-0.05	4.17	42.88	Large
3	2	101.2	-0.13	-7.26	-0.47	-1.57	0.04	-0.18	7.85	42.99	5.48
1	3	0	-6.78	-16.98	4.28	0.06	-0.08	-0.05	21.26	43.72	2.06
3	4	0	-10.08	-12.21	-0.79	0.12	0.07	-0.61	11.47	43.70	3.81
3	5	105	-0.71	3.15	1.00	-0.92	-9.31	0.48	18.83	43.84	2.33
4	6	37.5	-1.80	-3.74	1.29	-3.43	-11.41	0.23	34.65	47.33	1.37
4	7	37.5	-0.07	-0.22	1.19	-0.01	-16.98	0.03	34.66	47.26	1.36
4	8	45	-0.11	3.63	1.03	-0.25	-17.25	-0.10	34.76	50.41	1.45
4	9	48.8	0.00	5.10	1.05	-0.42	-16.71	-0.11	34.66	50.23	1.45
1	10	0	-0.74	11.42	21.48	-0.45	-0.39	0.06	22.25	46.15	2.07
1	11	0	-0.85	12.26	30.23	-0.43	0.03	0.00	31.10	46.05	1.48
1	12	56.2	0.02	6.61	1.85	-0.46	11.85	0.11	24.20	46.17	1.91
4	13	60	-0.10	4.24	1.25	-0.57	17.06	0.09	34.68	50.22	1.45
4	14	52.5	-0.13	5.50	1.20	-0.40	17.14	0.25	34.84	50.37	1.45
4	15	52.5	-0.24	2.16	-1.20	0.00	17.18	-0.66	34.86	47.24	1.36
4	16	60	-5.28	-39.44	-18.03	1.09	0.43	-2.73	34.84	47.33	1.36
3	17	67.5	-3.24	3.31	5.03	-3.45	-12.00	0.02	31.10	44.07	1.42
3	18	0	0.04	3.91	4.12	-0.11	-14.55	-0.89	31.10	44.07	1.42
1	19	56.2	-0.02	2.90	5.61	-0.10	-16.13	-0.25	32.38	66.98	2.07
1	20	52.5	0.01	4.10	6.58	-0.12	-15.26	-0.20	30.63	66.99	2.19
1	21	0	-0.32	7.18	29.39	-0.29	-0.50	0.16	29.74	66.89	2.25
1	22	0	-0.39	6.52	38.30	-0.31	-0.08	0.01	38.70	66.81	1.73
1	23	0	-0.30	7.22	33.67	-0.29	0.35	-0.13	33.99	66.89	1.97
1	24	56.2	0.06	5.59	5.92	-0.09	13.43	0.15	26.86	66.99	2.49
1	25	56.2	-0.02	7.59	5.89	-0.23	15.61	0.51	31.29	66.99	2.14
3	26	52.5	-0.17	-13.61	17.42	0.36	0.32	-1.02	31.12	44.09	1.42
3	27	0	0.48	-15.88	15.03	0.33	0.13	-1.88	31.17	44.05	1.41
4	28	0	-9.41	-32.00	-0.08	0.82	-0.07	-5.88	34.91	47.33	1.36
4	29	0	-9.77	-32.79	1.02	2.49	0.12	-3.12	35.03	47.28	1.35
3	30	78.8	0.37	-2.55	-0.16	0.54	0.17	0.16	3.18	93.81	Large
3	31	0	-3.30	-0.76	0.18	-0.03	-0.33	1.89	5.19	94.50	Large
4	32	33.8	0.61	-1.58	-7.83	0.28	-0.91	-1.20	8.96	94.50	Large

Notes:

1. The case number identifies the thermal and internal pressure condition for the maximum sectional stress: (1) hot with internal pressure, (2) cold with internal pressure, (3) hot without internal pressure and (4) cold without internal pressure.
2. Section locations are presented in Figure 2.12.2-31.

2.7.1.7 Closure Analysis

Section 2.6.7.6 provides a general description of the analysis approaches employed to demonstrate the structural integrity of the MAGNATRAN transport cask closure assembly. The materials of construction and the geometry of the components of the closure assembly are also identified in Section 2.6.7.6.

The MAGNATRAN transport cask closure lid and the lid bolts are required to satisfy two criteria: (1) calculated maximum stresses must be less than the allowable stress limit (the material yield strength is conservatively selected); and (2) lid deformation or rotation at the O-ring must be less than the elastic rebound of the O-rings. Analysis of the cask closure system in accordance with NUREG/CR-6007 is summarized in the following section. Using consistently conservative assumptions, the analysis demonstrates that the cask closure assembly satisfies the performance and structural integrity requirements of 10 CFR 71.73(c)(1) for hypothetical accident conditions.

Accelerations for accident conditions are based on the impact limiter analysis for 30-ft drops. An acceleration of 40*g* bounds the calculated values for the 30-ft end drops. The following calculations are a summary of the NUREG/CR-6007 evaluation based on a calculated preload of 182,278 lb/bolt as presented in Section 2.6.7.6. Maximum stresses result during the top end drop in the cold condition. Therefore, the bolt evaluation presented is for the 90° drop orientation, cold condition (-40°F ambient), with the maximum preload torque.

Two load cases are considered for this evaluation. The first case includes the accident conditions including top end impact (30-ft drop), but excluding puncture. The second case includes the top end 40-inch puncture accident, but excludes the 30-ft top end impact. The second case (puncture) conservatively ignores internal pressurization (for prying loads only), since the puncture load counters the moment produced by internal pressurization. This ensures that the closure bolts experience the maximum prying effect.

2.7.1.7.1 Closure Bolt Stress Evaluation

Case 1—Accident Conditions (30-foot top end drop, no puncture)

The tensile bolt force per bolt, $F_{a/pt}$, due to preload and thermal is:

$$F_{a/pt} = P_L + P_{th} = 199{,}993 \text{ pounds}$$

where:

P_L = 182,278 pounds, preload

P_{th} = 17,715 pounds resulting from thermal expansion

The total tensile force per bolt, $F_{a/al}$, is:

$F_{a/al} = P_o + P_i + P_{40} = 169{,}013$ pounds

where:

$P_o = 13{,}754 + 157 = 13{,}911$ lbs, load resulting from O-ring compression and operation

$P_i = 12{,}001$ lbs, load resulting from internal pressure of 135 psig

$P_{40} = 143{,}101$ lbs, load resulting from 40 g top-end impact

Since $F_{a/pt}$ is greater than $F_{a/al}$, the total tensile bolt load, F_a, is equal to $F_{a/pt}$:

$F_a = 199{,}993$ pounds

The shear load is:

$F_s = |P_i + P_{th} + P_{40}| = 60{,}839$ lb

where:

$P_i = 42{,}611$ lb, load resulting from internal pressure (135 psi)

$P_{th} = 18{,}228$ lb, load resulting from temperature difference between the cask lid and upper forging, and

$P_{40} = 0$ lb, load resulting from 40 g top-end drop

The bending moment is:

$M_b = -1561$ inch-pounds, due to thermal load (other loads do not contribute due to cask lid design)

The load resulting from torsion is:

$M_t = 28{,}818$ inch-pounds.

These loads and moments translate into the following stresses:

The tensile stress in the bolt is:

$$S_{ba} = \frac{1.2732 F_a}{D^2} = 72.2 \text{ ksi}$$

where:

$D = D_b - (0.9743/n)$

$= 1.8782$ in.,bolt diameter for stress calculations

$D_b = 2.0$ in., nominal closure lid bolt diameter

$n = 8$, number of threads per inch

The shear stress is

$$S_{bs} = \frac{1.2732 F_s}{D^2} = 22.0 \text{ ksi}$$

The bending stress is:

$$S_{bb} = \left|\frac{10.186M_b}{D^3}\right| = 2.4 \text{ ksi}$$

The stress resulting from torsion is:

$$S_{bt} = \frac{5.093M_t}{D^3} = 22.2 \text{ ksi}$$

For accident conditions, Table 6.3 of NUREG/CR-6007 requires that the average tensile stress is the smaller of 0.7 S_u or S_y. For this case,

$$\sigma_{t(ave)} = \sigma_a = 72.2 \text{ ksi} < 0.7\ S_u = 129.5 \text{ ksi}$$

Table 6.3 also requires that the average shear, which is comprised of the average direct shear (τ) is the smaller of 0.42 S_u or 0.6 S_y. This is expressed as:

$$\sigma_{s(ave)} = \tau = 22.2 \text{ ksi} < 0.42\ S_u = 77.7 \text{ ksi}$$

For the combined state of stress that includes tension plus shear, the square of the ratio of the average tensile stress to the allowable tensile stress, plus the square of the ratio of the average shear stress to the allowable shear stress must be less than one. This is expressed as:

$$\left(\frac{S_{ba}}{0.7S_u}\right)^2 + \left(\frac{S_{bs}}{0.42S_u}\right)^2 < 1.0$$

$$\left(\frac{72.2}{129.5}\right)^2 + \left(\frac{22.0}{77.7}\right)^2 = 0.39 < 1.0$$

For the combined state of stress that includes tensile, shear, and bending; the bolts must have a maximum stress intensity less than 1.0S_u (when the minimum tensile strength is greater than 100 ksi). The maximum bolt stress intensity is:

$$S_i = \sqrt{(S_{ba} + S_{bb})^2 + 4(S_{bs} + S_{bt})^2} = 116 \text{ ksi} < 1.0\ S_u = 185 \text{ ksi.}$$

The factor of safety for the ASME SB-637, Grade N07718 closure bolts is:

$$FS_{ult} = \frac{S_u}{S_i} = \frac{185}{116} = 1.6$$

Additionally, the bolt is evaluated against yield to determine whether the integrity of the cask lid seal is maintained:

$$FS_{yld} = \frac{S_y}{S_i} = \frac{150}{116} = 1.3$$

Since, the maximum stress in the bolt is less than the yield stress allowable, the cask lid seal is not broken during accident conditions of transport.

Case 2—Accident Conditions (with puncture)

The tensile bolt force per bolt, $F_{a/pt}$, due to preload and thermal is:

$$F_{a/pt} = P_L + P_{th} = 199{,}993 \text{ pounds}$$

where:

P_L = 182,278 pounds, preload

P_{th} = 17,715 pounds, load resulting from thermal expansion

The tensile force per bolt, $F_{a/al}$, from all other credible loads is:

$$F_{a/al} = P_o + P_i + P_{pun} = -1773 \text{ pounds}$$

where:

P_o = 13,754 + 157 = 13,911 lbs, load resulting from O-ring compression and operation

P_i = 12,001 lbs, load resulting from internal pressure of 135 psig

P_{pun} = -27,685 lbs, load resulting from puncture

Since $F_{a/pt}$ is greater than $F_{a/al}$, the total tensile bolt load, F_a, is equal to $F_{a/pt}$:

$$F_a = 199{,}993 \text{ pounds}$$

The shear load is:

$$F_s = \left| P_i + P_{th} + P_{pun} \right| = 60{,}839 \text{ lb}$$

where:

P_i = 42,611 lb, load resulting from internal pressure (135 psi)

P_{th} = 18,228 lb, load resulting from temperature difference between the cask lid and upper forging, and

P_{pun} = 0 lbs, load resulting from puncture

The bending moment is:

M_b = -27,799 inch-pounds, due to thermal and puncture loads (other loads do not contribute due to cask lid design)

The load resulting from torsion is:

$$M_t = 28{,}818 \text{ inch-pounds}$$

These loads and moments translate into the following stresses:

The tensile stress in the bolt is:

$$S_{ba} = \frac{1.2732 F_a}{D^2} = 72.2 \text{ ksi}$$

Table 2.7.8-1 Canister P_m Stresses – Internal Pressure (300 psig) – Model A[1]

	P_m Stresses (ksi)								
Section Location	Sx	Sy	Sz	Sxy	Syz	Sxz	SI (ksi)	Allowable Stress (ksi)	Factor of Safety
1	-0.26	3.55	9.88	-0.13	0.14	-0.46	10.19	45.92	4.51
2	2.22	-19.94	-3.28	0.74	-0.04	-1.54	22.61	45.92	2.03
3	-1.33	-19.26	10.58	0.55	0.10	2.33	30.30	45.55	1.50
4	-0.18	21.28	10.50	-0.84	0.00	0.00	21.53	43.40	2.02
5	-0.08	21.28	10.50	-0.84	0.00	0.00	21.43	42.70	1.99
6	-0.10	21.28	10.50	-0.84	0.00	0.00	21.44	42.00	1.96
7	-0.12	21.26	10.50	-0.84	0.00	0.00	21.46	42.70	1.99
8	-0.12	21.28	10.50	-0.84	0.00	0.00	21.46	43.40	2.02
9	-0.16	21.08	10.49	-0.83	0.00	0.10	21.31	45.55	2.14
10	-1.03	2.03	1.20	-0.12	0.06	0.77	3.31	45.70	Large
11	-0.38	2.30	1.36	-0.11	0.01	-1.28	3.38	36.44[2]	Large
12	0.90	0.89	-0.96	0.00	-0.04	-0.08	1.87	45.55	Large
13	0.10	0.10	-0.16	0.00	-0.01	0.00	0.25	44.80	Large
14	1.26	3.18	0.16	-0.08	0.04	-0.19	3.06	45.55	Large
15	0.01	2.70	0.05	-0.11	-0.04	-0.01	2.70	45.55	Large

1. See Section 2.6.12.2 for model description
2. Allowable stress includes a stress reduction factor for weld: 0.8 × allowable stress.

Table 2.7.8-2 Canister $P_m + P_b$ Stresses – Internal Pressure (300 psig) – Model A[1]

	$P_m + P_b$ Stresses (ksi)								
Section Location	Sx	Sy	Sz	Sxy	Syz	Sxz	SI (ksi)	Allowable Stress (ksi)	Factor of Safety
1	-1.932	-12.71	26.10	0.30	0.05	-0.65	38.83	65.65	1.69
2	6.24	-31.33	-45.95	1.30	-0.12	-2.72	52.51	65.65	1.25
3	-0.564	-9.46	43.09	-0.20	-0.12	2.94	52.76	65.10	1.23
4	-0.264	21.46	10.55	-0.85	0.00	-0.02	21.79	63.50	2.91
5	-0.156	21.46	10.54	-0.85	0.00	0.01	21.68	63.25	2.92
6	-0.18	21.46	10.54	-0.85	0.00	0.00	21.70	63.00	2.90
7	-0.192	21.44	10.54	-0.85	0.00	0.00	21.71	63.25	2.91
8	-0.192	21.46	10.54	-0.85	0.00	0.00	21.72	63.50	2.92
9	-0.108	22.27	15.07	-0.88	0.00	0.04	22.45	65.10	2.90
10	-2.052	1.12	-0.71	-0.11	0.07	2.66	5.50	65.32	Large
11	-0.084	3.36	5.17	-0.14	0.00	-1.88	6.48	52.08[2]	8.04
12	53.712	53.46	-1.01	0.01	-0.06	-0.10	54.72	65.10	1.19
13	6.108	6.10	0.02	0.00	-0.01	0.00	6.08	64.00	Large
14	1.284	3.02	-0.16	-0.07	0.01	-0.20	3.22	65.10	Large
15	-1.56	2.05	-0.78	-0.13	-0.05	0.16	3.65	65.10	Large

1. See Section 2.6.12.2 for model description
2. Allowable stress includes a stress reduction factor for weld: 0.8 × allowable stress.

Table 2.7.8-3 Canister P_m Stresses – Internal Pressure (300 psig) – Model B[1] and C[1]

FE Model	Section Location	P_m Stresses (ksi)						SI (ksi)	Stress Allowable (ksi)	Factor of Safety
		Sx	Sy	Sz	Sxy	Syz	Sxz			
C	9	-0.18	20.45	10.60	-0.80	0.01	0.10	20.69	45.55	2.20
B	10	-1.96	2.53	0.24	0.00	0.00	1.75	5.46	45.55	8.34
B	11	-0.85	3.77	5.38	-0.06	0.08	-0.76	6.42	36.44[2]	5.68
C	13	0.06	-0.11	-1.16	-0.02	0.11	0.14	1.26	44.80	Large
C	14	0.98	8.51	0.41	0.00	0.00	-0.19	8.17	45.55	5.57
C	15	-0.70	7.15	-0.36	0.00	0.00	0.17	7.92	45.55	5.75
C	16	0.02	0.02	0.00	0.00	0.00	0.00	0.02	45.55	Large

1. See Section 2.6.12.2 for model description
2. Allowable stress includes a stress reduction factor for weld: 0.8 × allowable stress.

Table 2.7.8-4 Canister $P_m + P_B$ Stresses – Internal Pressure (300 psig) – Model B[1] and C[1]

FE Model	Section Location	P_m Stresses (ksi)						SI (ksi)	Stress Allowable (ksi)	Factor of Safety
		Sx	Sy	Sz	Sxy	Syz	Sxz			
B	9	-0.13	22.03	16.15	-0.86	0.01	0.01	22.24	65.10	2.93
C	10	-0.42	7.26	16.57	0.00	0.00	-1.38	17.22	65.10	3.78
B	11	0.46	5.35	9.79	0.00	0.00	-1.78	9.98	52.08[1]	5.22
C	13	21.26	20.83	-2.83	-0.05	0.52	0.36	24.12	64.00	2.65
C	14	1.09	8.95	0.43	0.00	0.00	-0.11	8.54	65.10	7.62
C	15	-2.16	6.83	-1.18	0.00	0.00	0.30	9.07	65.10	7.18
B	16	6.01	5.99	0.02	0.00	0.00	0.00	5.99	65.10	Large

1. See Section 2.6.12.2 for model description
2. Allowable stress includes a stress reduction factor for weld: 0.8 × allowable stress.

where

α = the effective angle between the wood grain direction and the normal vector of the unyielding surface.
β = the angle between the installed wood grain and the symmetry plane of the cask assembly.
θ = etshallow angle (slap down angle) between the lowest sides of the impact limiter and the unyielding surface.

The effective redwood grain directions for each of the installed redwood segment for the selected shallow angle drops are listed in the following table below.

Wood Grain Direction as Installed Degree, β	Slapdown angle Degree, θ	Effective Wood Grain Angle Degree, α
0	2.5	**2.50**
15	2.5	**15.20**
30	2.5	**30.09**
0	5.0	**5.00**
15	5.0	**15.79**
30	5.0	**30.38**
0	10.0	**10.00**
15	10.0	**17.96**
30	10.0	**31.47**
0	15.0	**15.00**
15	15.0	**21.09**
30	15.0	**33.23**

Of the three shallow-angle drops, the 5° drop case represents the condition of greatest rotational moment after the initial impact. The acceleration traces for the two nodal positions simulating the installed accelerometers are shown in the Figure 2.12.2-13. The time delay between the leading edges of the acceleration output representing impacts of the bottom impact limiter and the top impact limiter is about 12.5 milliseconds.

The result are shown in Table 2.12.2-3, and presented in Figure 2.12.2-14 showing the peak accelerations against the shallow angle.

The peak accelerations increase as the drop angle decreases and reaches peak at 0° drop angle (side drop). This trend is observed for both the top and bottom accelerometers, which indicates that the side drop is the controlling drop. For shallow-angle drop cases with an angle greater than 5°, there is a pronounced time delay between the main impulse of the lower impact limiter and the upper impact limiter. The observations are made to support the result that the 0° (side drop) would be controlling.

For drop angles greater than 15°, the initial crushing of the impact limiter would produce less accelerations such as is observed in the corner drops. The reason is that more wood is actually available for crushing since the direction of crush is along a diagonal. This greater available crushable depth would result in lower crush forces since the strain resulting from wood crush would be smaller. Lower forces would result in lower torques available to produce an additional acceleration for the top impact limiter of the cask to impact the rigid plane.

For drop angles between 5° and 15°, the time delay between the crushing of the lower impact limiter and the upper impact limiter becomes smaller. The decrease in the period of delay reduces the effect of the additional torque applied to the cask CG to induce additional rotational acceleration.

Once the upper limiter becomes engaged with the plane, the potential effect of the slapdown is virtually eliminated.

For angles smaller than 5°, the main impulses become more overlapped, so that the crush force of both limiters are acting simultaneously to produce a larger total crush force to result in a larger acceleration.

2.12.2.3.17 Study of the Effect of Coefficient of Friction on Maximum Accelerations for the 5° Shallow Angle Drop

The study is performed using the STC-CY Side Drop Model. Friction may have a significant effect on the acceleration of the top of the cask. To examine the effect of friction, the 5° drop case is used, and additional analyses were performed for the frictions shown in Table 2.12.2-4. While the 0.0 and 1.0 friction values are not physically possible, they were included in the evaluation to provide the extreme values for the accelerations. The maximum accelerations versus the coefficient of friction of the impact plane are summarized in Table 2.12.2-4. For both the top and bottom accelerations, the peak values for each analysis increase as the friction decreases. This is in contrast to the top accelerations from SAND90-2187, which shows a maximum effect of the friction for values of 0.2 to 0.3. It should be noted that the increase of the maximum acceleration (at μ=0.0) to the minimum acceleration (at μ=1.0) is 14%, which is smaller than the 20% in SAND90-2187. The value for which the maximum effect for the top acceleration occurs is different between the two methodologies. The model employed in SAND90-2187, page 28, is described to be a simplification. In view of the detailed model employed in this evaluation, the interaction of the friction and the time varying force-deflection curve is more accurately modeled with a detailed 3D model as opposed to a single spring representation. The variation of the accelerations that follow are considered to be consistent. It is noted that the 0.0 friction case is still bounded by the side drop. For drop angles smaller than 5°, the maximum accelerations are expected to remain bounded by the side drop, since the main

An additional fire transient analysis is performed to demonstrate the conservatism of "ΔT method" to determine the maximum temperatures for the fuel and basket components for the fire accident as described at the beginning of this section. A half-length (360°) three-dimensional finite element model corresponding to the top half of the cask and loaded canister (including basket and fuel) for the PWR configuration is used for this transient analysis. The model is based on the three-dimensional models presented in Section 3.4.1.1.1 for the evaluation of normal conditions of transport. The transient analysis is performed for the same three phases as described above and the maximum temperature is 747°F for the fuel and 722°F for the basket, which are significantly lower than the temperatures reported in Table 3.5-1. Therefore, it is conservative to use the 'ΔT method' to determine the maximum temperatures for cask contents for the fire accident.

3.5.1.2 Test Model

The thermal analyses presented in Section 3.5-3 demonstrate that the MAGNATRAN transport cask is capable of meeting the design basis temperature requirements under hypothetical accident conditions. The methodology used in this analysis is conservative, consistent with those used in prior transport cask licensing, and sufficient to show that the cask meets the criteria set forth in Section 3.5. Therefore, no thermal test model is created.

3.5.2 Package Conditions and Environment

As demonstrated in Chapter 2, the MAGNATRAN transport cask body sustains no major damage as a result of the free drop and puncture events, and the impact limiters remain attached to the cask. Since the pin puncture only results in local damage to the neutron shield, the cask body is modeled in an undamaged configuration.

The emissivity of stainless steel is 0.36. The copper emissivity is 0.65. The aluminum emissivity of 0.22 is conservatively used for the aluminum plates on the cask surface. However, during the 30-min fire portion of the transient analysis, the emissivity is assumed to be 0.9. Also, the emissivity of the fire is assumed to be 1.0.

At the end of the fire, the NS-4-FR in the neutron shield is assumed to be destroyed. The result is a lower conductivity, and thus a greater resistance to heat leaving the cask. The emissivity of stainless steel of 0.36, the emissivity of aluminum of 0.22, and the emissivity of copper of 0.65 are again used, which also provides a greater resistance to heat leaving the cask. The cool-down is analyzed for a period of 64 hours after the end of the fire. At the end of the cool-down period, all cask components have already reached their maximum temperatures and have begun to cool down to their post-fire, steady-state temperatures.

3.5.3 Package Temperatures

The ANSYS computer code is used to evaluate the MAGNATRAN transport cask for the hypothetical accident fire. A steady-state initial temperature profile is calculated on the basis of a 100°F ambient temperature and solar insolance and used as initial condition for the 30-min fire transient, which considers exposure of the cask to a 1,475°F radiant environment. This exposure is followed by a 64-hour cool-down period, which considers exposure of the cask to a 100°F ambient temperature and solar insolance.

The safe operating temperature ranges of the components specified in Section 3.3.2 are also evaluated for the fire accident. These components include the metallic containment O-ring seals and lead gamma shielding. The radial neutron shield temperature is not considered to be significant; therefore its loss is assumed in this accident. The shielding consequences of the fire accident on the radial neutron shield are provided in Chapter 5.

The maximum component temperatures during the hypothetical fire accident and cool-down period are provided in Table 3.5-1 (PWR) and Table 3.5-2 (BWR). The tables also show the maximum component temperatures for the fuel cladding, and the lead in the cask body. None of the safety-related components, with the exception of the radial neutron shield, as noted previously, exceeds its safe operating temperature as a result of the fire accident. The temperature histories of the major cask components are shown in Figures 3.5-4 through 3.5-9 for the PWR configuration. The temperature histories of the major cask components for the BWR configuration are not shown due to the similarity of the histories to those for the PWR configuration.

3.5.4 Maximum Internal Pressures

The internal pressure analysis requires the calculation of the free volume of the canister, calculation of the releasable quantity of fill and fission gas in the fuel assemblies, BPRA gases, and the subsequent calculation of the pressure in the canister and cask if these gases are added to the backfill helium pressure (initially at 1.36 atm) already present in the TSC and cask (Sections 3.4.1.1 and 3.4.1.2). TSC and cask pressures are determined for the accident condition of 100% fuel failure and maximum temperature. The method employed in the accident analyses is identical to that employed in the normal condition evaluation of Section 3.4.1.

For the accident condition, the gas quantities associated with 100% fuel rod failure are combined with the bounding fire accident average gas temperatures of 662°F, rounded to 670°F, to determine the system pressures. The maximum TSC pressure for the 100% fuel rod failure and maximum temperature accident (fire) condition is 276.6 psig (DF-PWR). The maximum

transport cask pressure is 256.5 psig (DF-PWR), where the cask pressure assumes the loss of TSC confinement.

The maximum internal pressures for the hypothetical accident condition are summarized in Table 3.5-3.

3.5.5 Maximum Thermal Stresses

The maximum thermal stresses in the cask and the cask contents resulting from the hypothetical accident fire are not calculated. Thermal stresses are secondary stresses. Evaluation of secondary stresses is not required by the ASME code for accident conditions.

3.5.6 Evaluation of Package Performance for Hypothetical Accident Conditions

The MAGNATRAN transport cask thermal performance has been assessed for the hypothetical accident fire transient, as specified in 10 CFR 71. Except for the radial neutron shield, which is assumed to be lost, all cask components important to safety remain within their safe operating ranges. The ability of the cask to safely contain its radioactive contents is not compromised.

Figure 3.5-1 Three-Dimensional Finite Element Cask Model (PWR and BWR)

[redacted]

5 SHIELDING EVALUATION

The MAGNATRAN transport cask meets the 10 CFR 71 requirements for exclusive use dose rate limits. The optimized multiwall design of the transport cask provides an efficient shielding arrangement for the transportation of a TSC containing up to 37 undamaged PWR fuel assemblies in the 37 PWR basket assembly or up to 87 undamaged BWR fuel assemblies in the 87 BWR basket assembly. The cask is also designed to transport a TSC containing up to four damaged fuel cans (DFCs) in the DF Basket Assembly. The DF Basket Assembly has a capacity of up to 37 undamaged PWR fuel assemblies, including four DFC locations. DFCs may be placed in up to four of the DFC locations. Each DFC may contain an undamaged PWR fuel assembly, a damaged PWR fuel assembly, or PWR fuel debris equivalent to one PWR fuel assembly. Undamaged PWR fuel assemblies may be placed directly in the DFC locations of a DF Basket Assembly. The cask is also designed to transport a TSC containing up to 32,000 pounds of GTCC waste in a GTCC waste basket liner. The transport cask is assigned a Transport Index, maximum dose rate in mrem/hr at 1m from the package, of 14.4 (TI = 14.4) for undamaged fuel, 20.9 (TI = 20.9) for damaged fuel, and 2.4 (TI=2.4) for GTCC waste based on the requirement of 10 CFR 71.4 and the analysis presented in this chapter. The TI for damaged fuel is below that for undamaged fuel as bounding undamaged fuel radial dose rates are obtained from BWR and "long" TSC PWR payloads. Damaged fuel is restricted to the "short" TSC. A spacer above the "short" TSC will retain source below the region of minimum radial cask shielding.

The shielding design criteria for the transport cask are in accordance with the requirements established in 10 CFR Part 71.47 for normal conditions of transport and 10 CFR Part 71.51 for hypothetical accident events. The 10 CFR 71.47 requirements for the exclusive use transport of spent fuel under normal conditions of transport include the following:

- The dose rate on the surface of the enclosed package must not exceed 1,000 mrem/hr.
- The dose rate on the outer surfaces of the transport vehicle must not exceed 200 mrem/hr.
- The dose rate on a plane 2 meters from the lateral surfaces of the vehicle must not exceed 10 mrem/hr (NAC analysis limit 2-meter dose rates to 9.5 mrem/hr).
- The dose rate in any normally occupied positions of the vehicle must not exceed 2 mrem/hr.

The 10 CFR 71.51 requirements state that the dose rate under hypothetical accident events must not exceed 1 rem/hr at 1 meter from the surface of the transport cask.

The transport cask with its impact limiters is securely attached to the bed of a conveyance vehicle during transport. To restrict unauthorized personnel from gaining access to the transport cask during transport, a personnel barrier is installed around the transport cask. The personnel

barrier consists of a metal frame structure covered with expanded metal (i.e., a metal grating or screen) and is securely attached to the bed of the conveyance vehicle during normal transportation. Thus, the loaded transport cask, with the personnel barrier on the conveyance vehicle ready for transport, meets the exclusive use definition of a closed conveyance.

MAGNATRAN is designed as a single-length transport cask that will hold a TSC of various lengths. A top spacer is used for the short TSCs. TSCs may be closed with either an all stainless steel closure lid or a composite carbon steel and stainless steel lid assembly. BWR evaluations and PWR evaluations are performed with the composite closure lid assembly. The composite lid assembly bounds the all stainless steel lid in shielding evaluations due to the lower density of carbon steel.

This chapter describes the shielding design and the analysis used to establish bounding radiological dose rates for the transport of PWR and BWR fuel and GTCC waste. PWR fuel assemblies may contain non-fuel hardware (control) components as described in Chapter 1. Evaluated components are control element assemblies (RCCA/CEAs) or rod control cluster assemblies (RCCAs), burnable poison rod assemblies (BPRAs), thimble plugs (also referred to as flow mixers or guide tube plugging device [GTPD]), primary and secondary neutron sources, and hafnium flux reduction assemblies (HFRA). Fuel assemblies may contain up to five irradiated stainless steel rods in place of fuel rods. Transport of undamaged and damaged PWR fuel assemblies is permitted. Loading of damaged fuel is limited to short canisters requiring a cask cavity spacer. This configuration spaces damaged fuel away from the gap between the neutron shield and the upper impact limiter gap. BWR assemblies are limited to undamaged fuel.

Minimum cool times prior to fuel transport are specified as a function of minimum assembly average fuel enrichment and maximum assembly average burnup (MWd/MTU). To minimize the number of loading tables, PWR and BWR fuel assemblies are grouped by bounding fuel and hardware mass. Key characteristics of each assembly grouping are shown in Section 5.2. Refer to Section 5.8.3 for loading tables used to generate bounding system dose rates for the PWR system and Section 5.8.4 for the BWR system. Adjustments, as necessary, to PWR fuel assembly minimum cool time to account for PWR damaged fuel inclusion, non-fuel hardware insertion, and loading of irradiated stainless steel rods within the assembly are included in the relevant subsections to Section 5.8. Uncertainties in the SAS2H-generated heat loads for high burnup (> 45 GWd/MTU assembly average) fuel assemblies are accounted for in the loading tables by derating the system heat load by 5%.

Source terms for the various vendor-supplied fuel types are generated using the SCALE 4.4 sequence as discussed in Section 5.2. Three-dimensional MCNP shielding evaluations provide

5.5 Shielding Model

The MAGNATRAN transport cask 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 and lower plenum, and upper-end and lower-end fitting source regions. Within these axial volumes, the material masses of the fuel assembly are homogenized. In all models, the transport cask and TSC shield thickness and axial extents are explicitly represented, including streaming paths. Surface detectors are used to estimate the dose rate profiles at the transport cask surface, 1 foot from the transport cask, 1 meter from the transport cask, and 2 meters from the conveyance vehicle (e.g., railcar). Mesh tally analysis in Section 5.8.12 demonstrates that at the locations nearest licensing limits (2-meter NCT and 1-meter HAC) the resolution of the surface tallies are sufficient to capture dose rate peaking associated with system features. 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 transport cask radial surface. Axial biasing is used for transport cask top and bottom surface rates.

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.

5.5.1 Configuration of Source and Shielding

The three-dimensional shielding analysis allows detailed modeling of the source and shield regions, including potential streaming paths such as the aluminum and copper heat fin components and stainless steel walls of the neutron shield. Transport cask and TSC details include the axial extent of the radiation shields. This section includes system sketches, discussion of the general TSC shell (including closure lid and bottom plate) and features, and detailed information on the transport cask (package) shield configurations. Content-dependent TSC, basket and fuel-specific model details are included in Section 5.8.3 for 37-assembly PWR system and Section 5.8.4 for 87-assembly BWR system.

5.5.1.1 MCNP Assembly (Source), Basket and Canister Model

Key TSC shielding features are listed in Table 5.1-2. The TSC closure lid, shell and bottom plate are explicitly modeled. The TSC elevations, with respect to the transport cask shields, are illustrated in the transport cask shield configuration description. Fuel assembly and nonfuel hardware source characteristics and models, including dimensions and masses, are discussed in

detail in Section 5.8. PWR and BWR basket models are described in detail in Sections 5.8.3 and 5.8.4, respectively.

The basket and TSC is evaluated at its nominal dimensions. The basket contains a significant quantity of peripheral structural support that is not included in the model to offset any of the minor negative tolerances that are typically encountered on steel plate material. Plate used in the construction of the basket tubes, TSC shell and bottom plate has a small under allowance, 0.01 inch, with a significantly larger over tolerance (e.g., tubes and shell have a 0.03 inch over tolerance). As plate material allows a significant thickness increase within the tolerance band, and only a minor decrease, there is no expectation that the overall model of the TSC/basket has less than the nominal shield mass even without considering the corner and side weldment components. The TSC lid is the exception to the standard plate definition as it is defined as a plate/forging with an over/under tolerance of 0.03 inch permitted (bounding for single piece/duel piece lid options). A 0.03 inch reduction in material thickness will not impact the axial dose rates significantly. Top axial dose rates are significantly below limits. Impact limiter models are axially truncated and provide additional margin in material quantity modeled in the axial direction.

5.5.1.2 MCNP Transport Cask Model

The three-dimensional Monte Carlo analysis of transport dose rates permits explicit modeling of complicated transport cask geometric features and avoids approximations implicit in one-dimensional analyses, such as specification of buckling parameters. Detailed model parameters used in creating the three-dimensional model are taken directly from the relevant drawings. Key shielding features are listed in Table 5.1-1. Elevations associated with the three-dimensional model are established with respect to the bottom plate of the TSC for the global model. Sketches of the three-dimensional transport cask models are shown in Figure 5.5-1 through Figure 5.5-5. Key geometric features of the three-dimensional model include the following.

- Detailed treatment of transport cask transition regions, such as trunnion recesses and impact limiters.
- Detailed treatment of the neutron shield assembly compartments and any potential streaming through the aluminum and copper fins, expansion foam and thermal insulator. Expansion foam and thermal insulator are modeled as void space.
- Accurate representation of transport cask shield material axial and radial extents. Shield (e.g., inner/outer shell and lead) dimensions are toleranced to produce a minimum shield material thickness configuration. Neutron shield assemblies produce a multi-faceted outer surface. For the shielding model, neutron shield assembly dimensions are set to produce a cylindrical outer surface. "Rounding" of the neutron shield assembly is done

with the goal of producing a conservative (reduced) overall neutron shield assembly volume.

Detailed response profiles are obtained for fuel neutron and fuel gamma sources to assess the relative effect on dose rate responses for each source type.

To permit sufficient clearance for the transport cask skid retaining ring, the neutron shielding does not extend the full transport cask cavity length. This feature is accurately depicted in the transport cask model. For the "short" canister with upper spacers, the fuel material is located well below the elevation where the neutron shield ends.

For both the upper and lower impact limiters, a simplified model is employed. Limited detail of the fastening system is developed, as they are restricted to the voids. Further, the axial extent of the impact limiters is truncated to only include the lower 128-inch diameter section. The smaller top section of the limiter is conservatively removed from the model. The impact limiter radius modeled is limited to that of the modeled components of the neutron shield assemblies and cooling fins. All impact limiter wood material is conservatively modeled as balsa wood rather than higher density redwood that is part of the limiter design. Impact limiter steel shell is not included in the model.

The normal condition (NCT) 10 CFR 71.71 specified temperature, pressure, vibration and water spray conditions have no effect on the geometry of the cask per structural analysis presented in Chapter 2. Chapter 2 documents the steel cylinder penetration test to result in a localized crush of the impact limiter, with no penetration. There is no effect on the cask body or neutron shield from the penetration condition. As there is no decrease in the amount of impact limiter shield material associated with the cylinder drop – only crush – and the model removed a significant amount of radial and axial material from the limiters, the as-modeled cask bounds the post-cylinder drop normal conditions of transport (NCT) cask configuration. Cask free and corner drops similarly may deform the impact limiters, but do not remove shield material from the system. No lead slump occurs as a result of the normal condition drops. Deformation of the impact limiters during NCT documented in Chapter 2 of the MAGNATRAN SAR results in a configuration bounded by the truncated limiters shown in Figure 5.5-1. Cask internals, including the canister spacers, are designed to retain positive safety margins through all transport conditions, including 10 CFR 71.71 NCT evaluations, and remain in their as-evaluated configuration.

The hypothetical accident event is modeled by removing the aluminum cooling fins (copper cooling fins are retained) and deleting gaseous elements (i.e., hydrogen, nitrogen and oxygen) from the NS-4-FR material description of the base case normal conditions model. Testing of the NS-4-FR material exposed to 10 CFR 71.73 fire conditions, summarized in General Atomics report GA-A20770 titled "Thermal Testing of Solid Neutron Shielding Materials," demonstrates

only surface material changes (1/8- to 3/16-inch thick) with a material loss of 6 percent. This compares to a 50% material loss considered in the analysis. In addition to the NS-4-FR shield reduction, simultaneous axial and radial lead slumps are assumed to occur. Note that the 1-meter axial surface detectors are located with respect to the accident geometry of the transport cask (i.e., from the end of the cask and not the impact limiters for axial detectors). Normal condition shielding models include a 0.015-inch void between the lead and transport cask shell to account for the potential gap produced by differential thermal contraction between the lead gamma shield and the stainless steel transport cask inner and outer shells. For the lead slump conditions, voids are introduced in the lead gamma shielding on the basis of the redistribution of lead. As a result of the simultaneous application of radial and axial lead slumps in the accident event model, the total modeled lead volume is conservatively less than that actually present in the transport cask. The axial lead slump produces a gamma shield gap 0.87-inch high, while the radial slump reduces the radial gamma shield 0.47 inch. 10 CFR 71.73 also requires a puncture drop considering the cask drop on a vertical 6-inch diameter pin. The pin puncture on the neutron shield compartment, while not evaluated in the structural analysis section whose primary concern is the cask shell, may result in localized loss of neutron shielding material. As the evaluated accident model includes a 50% material loss over the entire cask surface (including all gaseous materials that served as the primary neutron shielding component), and accident dose rates are limited at 1 meter from the package where any localized peak would be significantly dispersed, the pin puncture condition is considered bounded by the evaluated accident configuration.

Model sketches for accident event analysis are shown in Figure 5.5-4 and Figure 5.5-5.

5.5.1.3 MCNP Detector Mesh Definition

MCNP surface detectors are used to calculate dose rates at various distances from the transport cask. The surface tallies are subdivided using the FS tally segmentation card. A graphical illustration of the detector overlay on a transport cask is shown in Figure 5.5-6. Depicted are 1 meter and 2 meter detectors. For clarity, the transport cask surface detector and azimuthal (angular) divisions are not shown. Typical detector grids for the normal transport condition and accident events analyses are shown in Table 5.5-1 and Table 5.5-2. The dose rate maps produced by this method completely enclose the accessible transport cask surfaces. The 2 meters from transport cask vehicle boundary is based on a typical railcar width of 124 inches. As this dimension is smaller than the cask with limiters installed, and cask transport is expected with a conveyance vehicle of a width equal to, or greater than, the cask diameter, the value of 124 inches is conservative.

To assess the effect of radiation streaming, which may not be captured by the surface tallies evaluated, additional evaluations are performed in Section 5.8.12 with detailed mesh tallies.

Cask features addressed in the mesh tallies are streaming paths associated with the cooling fins, neutron shield assembly voids and attachment bolts, and lower rotation trunnions.

5.5.2 Material Properties

Density and material compositions for structural components are primarily obtained from the standard composition library included with SCALE 4.4. The only exception to this rule is the density and composition of the neutron shielding material (NS-4-FR). The NS-4-FR composition is based on the material specification after curing. The neutron shield material description is modified to remove gaseous elements for the accident event evaluation. Note that the basket neutron absorber sheets are not included in the shielding model, except for the damaged fuel evaluation. Basket, TSC and transport cask material densities and compositions are shown in Table 5.5-3. Fuel region densities are calculated quantities dependent on the hardware and fuel masses in the assembly. A sample homogenized fuel assembly material description is shown in Table 5.5-4.

Figure 5.5-1 Normal Condition 3-D Model – Axial Detail

[redacted]

Figure 5.5-2 Normal Condition 3-D Model – Radial Detail

[redacted]

Figure 5.5-3 Normal Condition 3-D Model – Radial Detail – Neutron Shield Assemblies

[redacted]

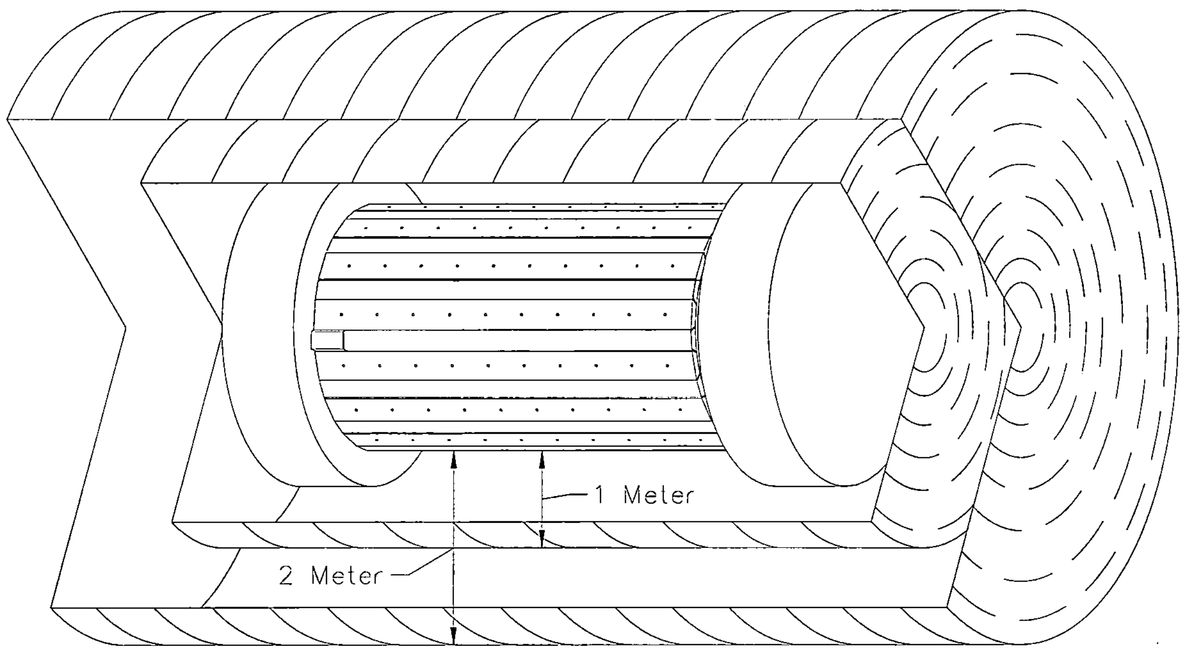
Figure 5.5-4 Accident Event 3-D Model – Axial Detail

[redacted]

Figure 5.5-5 Accident Event 3-D Model – Radial Detail

[redacted]

Figure 5.5-6 MCNP Surface Detector Grid Locations



Note: Transport cask surface detector mesh not shown for clarity. Surface tally mesh is simplified for clarity. A significantly finer mesh than shown is employed in the analysis. Azimuthal (angular) divisions are employed as listed in Table 5.5-1.

Table 5.5-1 Typical Radial Surface Detector Division

Location	Inner Radius [cm]	Axial			Azimuthal
		Lower [cm]	Upper [cm]	Div	Div
TopShellAzi	109.8650	451.5850	478.4995	1	36
Surface	126.1160	-89.2540	563.4720	100	1
HeatFinAzi	126.2160	176.0144	206.4944	1	60
TrunAzi	126.3160	-0.5080	34.4170	1	60
1ft	156.5960	-119.7340	593.9520	100	1
1mTopShellAzi	209.8650	451.5850	478.4995	1	36
1m	226.1160	-189.2540	663.4720	100	1
PunctureAzi	226.2160	246.3800	261.6200	1	60
2m+Railcar	357.4800	-289.2540	763.4720	100	1
4m	526.1160	-489.2540	963.4720	100	1

Note: GTCC waste is evaluated with a less refined mesh spacing. GTCC payload demonstrated significant margin to 10 CFR 71 dose rate limits. As demonstrated in Section 5.8.12, using a refined mesh tally, at the critical 2-meter distance no streaming related peaking can be resolved.

Table 5.5-2 Typical Axial Surface Detector Division

Location	Axial [cm]	Radial			Azimuthal
		Inner [cm]	Outer [cm]	Div	Div
Surface	563.4720	0.0000	126.1160	25	1
1ft	593.9520	0.0000	156.5960	25	1
1m	663.4720	0.0000	226.1160	25	1
2m	763.4720	0.0000	326.1160	25	1
4m	963.4720	0.0000	526.1160	25	1

Table 5.5-3 Fuel Basket, TSC, and Transport Cask Material Description

Material	Density [g/cm³]	Nuclide / Element	Density [atom/barn-cm]
Carbon and Low-Alloy Steel	7.8212	CARBON	3.9250E-03
		IRON	8.3494E-02
Stainless Steel	7.94	CHROMIUM	1.7472E-02
		MANGANESE	1.7407E-03
		IRON	5.9505E-02
		NICKEL	7.7392E-03
Lead	11.344	LEAD	3.2967E-02
NS-4-FR	1.6316	HYDROGEN	5.849E-02
		BORON-10	8.227E-05
		BORON-11	3.375E-04
		CARBON	2.277E-02
		NITROGEN	1.403E-03
		OXYGEN	2.606E-02
		ALUMINUM	7.751E-03
NS-4-FR (Fire Accident)	0.8089	BORON-10	8.227E-05
		BORON-11	3.375E-04
		CARBON	2.279E-02
		ALUMINUM	7.751E-03
Aluminum	2.702	ALUMINUM	6.0306E-02
Copper	8.92	COPPER-63	5.8471E-02
		COPPER-65	2.6062E-02
Balsa	0.1250	CARBON	2.7871E-03
		HYDROGEN	4.6451E-03
		OXYGEN	2.3226E-03

Table 5.5-4 Sample Fuel Region Homogenized Material Description (17a PWR Assembly)

Material	Density [g/cm³]	Nuclide / Element	Density [atom/barn-cm]
Lower End-Fitting	1.8782	CHROMIUM	4.1330E-03
		MANGANESE	4.1176E-04
		IRON	1.4076E-02
		NICKEL	1.8307E-03
Lower Plenum[a]	2.6798	CHROMIUM	3.1036E-05
		TIN	2.0391E-04
		IRON	3.6120E-05
		NITROGEN	5.7622E-05
		ZIRCONIUM	1.7376E-02
Active Fuel[a]	3.8195	URANIUM-235	3.5714E-04
		URANIUM-238	6.6999E-03
		ZIRCONIUM	4.2594E-03
		CHROMIUM	7.6082E-06
		TIN	4.9986E-05
		NITROGEN	1.4125E-05
		OXYGEN	1.4110E-02
		IRON	8.8542E-06
Upper Plenum[a]	0.7412	CHROMIUM	1.1717E-03
		TIN	1.5972E-05
		MANGANESE	1.1648E-04
		IRON	3.9848E-03
		NITROGEN	4.5135E-06
		NICKEL	5.1791E-04
		ZIRCONIUM	1.3611E-03
Upper End-Fitting	1.8385	CHROMIUM	4.0456E-03
		MANGANESE	4.0305E-04
		IRON	1.3778E-02
		NICKEL	1.7920E-03

[a] Zirconium alloy composition homogenized in this region is based on SCALE 4.3 material composition.

Table 5.8-47 Damaged Fuel Material Summary – 14a PWR Fuel

Material Description	Element/ Isotope	Density [atom/b-cm]	Density [g/cm³]
Damaged Fuel (Active Fuel)	Zirconium	4.1417E-03	9.9151
	Chromium	7.3976E-06	
	Tin	4.8602E-05	
	Nitrogen	1.3734E-05	
	Iron	8.6093E-06	
	Uranium 235	4.1900E-04	
	Uranium 238	2.0272E-02	
	Oxygen	4.1388E-02	
Damaged Fuel (Lower Nozzle)	Chromium	3.6218E-03	9.8996
	Manganese	3.6083E-04	
	Iron	1.2335E-02	
	Nickel	1.6043E-03	
	Uranium 235	3.7282E-04	
	Uranium 238	1.8037E-02	
	Oxygen	3.6824E-02	
Damaged Fuel (Upper Plenum)	Zirconium	1.0830E-03	10.0830
	Chromium	1.6340E-03	
	Tin	1.2710E-05	
	Nitrogen	3.5916E-06	
	Manganese	1.6259E-04	
	Iron	5.5604E-03	
	Nickel	7.2289E-04	
	Uranium 235	4.1440E-04	
	Uranium 238	2.0049E-02	
	Oxygen	4.0931E-02	
Damaged Fuel (Upper Nozzle)	Chromium	3.9541E-03	9.8526
	Manganese	3.9393E-04	
	Iron	1.3466E-02	
	Nickel	1.7515E-03	
	Uranium 235	3.6388E-04	
	Uranium 238	1.7065E-02	
	Oxygen	3.5941E-02	

Table 5.8-48 PWR Damaged Fuel Comparison – Normal Conditions 2 Meter Radial Dose Rates

[redacted]

Table 5.8-49 Additional Cool Time Required for 23 kW Damaged PWR Fuel Contents

Max. Burnup [GWd/MTU]	Min. Enr. [wt% U-235]	CE 14x14 Δ Cool Time [years]	WE 14x14 Δ Cool Time [years]	WE 15x15 Δ Cool Time [years]	WE 17x17 Δ Cool Time [years]
35	2.1	N/A	N/A	2.5	N/A
	2.3	0.0	0.6	0.8	0.3
40	2.5	1.9	2.4	3.3	2.8
	2.7	0.3	2.1	1.2	0.8
	2.9	0.0	0.6	0.0	0.0
45	2.7	3.9	2.6	4.5	4.2
	2.9	2.5	2.6	2.7	2.2
	3.1	0.6	2.5	0.7	0.1
	3.3	0.0	1.0	0.0	0.0
50	2.7	N/A	N/A	4.8	N/A
	2.9	3.6	2.8	3.5	2.8
	3.1	1.7	2.8	1.2	0.5
	3.3	0.0	1.2	0.0	0.0
55	3.1	4.2	2.9	4.0	3.6
	3.3	2.2	3.0	1.9	1.5
	3.5	0.2	2.0	0.0	0.0
60	3.1	N/A	N/A	5.0	N/A
	3.3	4.6	3.0	4.9	4.1
	3.5	3.1	3.1	2.9	2.1
	3.7	1.3	2.8	0.8	0.0
	3.9	0.0	0.9	0.0	0.0

Note: For TSCs that include damaged fuel, the added cooling time shown in the table for a specific fuel type, burnup and enrichment applies to all the fuel in the TSC, the damaged and the undamaged fuel. Since high burnup fuel is always treated as damaged fuel, the added cooling times shown for damaged high burnup fuel always apply to TSCs containing high burnup fuel.

5.8.11 Greater than Class C (GTCC) Waste Shielding Evaluation

Greater than Class C (GTCC) waste may be transported in MAGNATRAN. The shielding evaluation of GTCC waste is based on quantities of waste from the decommissioning of Zion Nuclear Power Station (ZNPS). Bounding source terms were generated based on 32,000 lbs. of GTCC waste being loaded per TSC. This weigh is bounded by the maximum amount of weight that could be loaded in the TSC determined by the structural analysis (55,000 lbs).

5.8.11.1 Source Term

The source term for the GTCC waste is based on measured specific activities of three key isotopes at a characterization date of January 2008: Ni-63 (6 Ci/lb), Co-60 (13 Ci/lb), and Fe-55 (5 Ci/lb). Additional radionuclide isotopes typical of GTCC material do not significantly attribute to cask dose rates. Of the three isotopes included in the source generation model, Co-60 is the dominant isotope due to its combination of high source magnitude and high energy lines (>1 MeV). These specific activities were input into ORIGEN-S and decayed 12 years, which is assumed to be the minimum time between the measurement of the activity of the ZNPS waste and actual transport offsite. The ORIGEN-S file used to generate the source term is presented in Figure 5.8-64. The resulting specific source term is multiplied by the total mass of GTCC waste in the basket (32,000 lbs). The primary source of cask dose rates is the Co-60 component of the GTCC inventory, which at the decayed time represents a source of 2.68 Ci/lb. The resultant source spectrum is summarized in Table 5.8-52.

5.8.11.2 Shielding Model

The shielding model is based on a specialized basket that can be fit into a standard short TSC and MAGNATRAN transport cask. The basket is assumed to obtain a homogenized mix of stainless steel GTCC waste that has reduced density to account for the maximum loading within the basket (see Table 5.8-53). The canister model is identical to the composite lid canister model employed for the short MAGNATRAN TSC, with a 2-inch radial stainless steel liner added to shield the contents. Similarly, the normal condition and accident event cask models, including the streaming paths, are similar to those described in Section 5.5.1.2. For GTCC analysis the impact limiters are conservatively not included in the shielding model. The Section 5.5 model also contains shield material reductions on the top forging of the cask (attachment area for impact limiter). These reductions are not included in the GTCC model. Dose rates in this region of the cask are negligible (~0.1 mrem/hr on surface). Material reduction compensated for by the presence of the impact will not affect the safety conclusions of the analysis. The GTCC evaluation also used nominal, rather than minimum material thickness). The primary shield for the GTCC source is the lead cask shield. The lead shield of the MAGNATRAN cask is dimensioned to maintain the evaluated (nominal) size with all tolerances result in increases to

lead shielding. The evaluated system, when combined with the low calculated dose rates, provides reasonable assurance that dose rate limits will be met. GTCC models use the same detector descriptions as the fuel assembly contents. The canister and cask materials are the same as those summarized in Section 5.5.2.

A dimensioned sketch of the model is shown in Figure 5.8-65, with a VISED sketch shown in Figure 5.8-66. A sample input file is provided in Figure 5.8-67.

5.8.11.3 Dose Rates and Decay Heat

Maximum dose rates are computed for the GTCC waste in the MAGNATRAN system and presented in Table 5.8-54 for the normal condition and Table 5.8-55 for the accident condition. Results in Table 5.8-54 for the normal condition and Table 5.8-55 are based on the 2.68 Ci/lb Co-60. GTCC material may contain peak Co-60 concentration higher than this value as a result of conditions such as radial and axial flux profiles within the core or Co-59 variations in the materials. As dose rates documented are well below limits higher Co-60 activities can be accommodated in the system. For this evaluation a localized increase in the cobalt content by a factor of 6 is considered (16.1 Ci/lb). Conservatively dose rate effects of this increase can be made by increasing all dose rates by a factor of 6 conservatively neglecting spatial attenuation resulting from a localized, versus global, increase in content. Notes are included on Table 5.8-54 and Table 5.8-55 documenting maximum dose rates assuming a global Co-60 increase.

As shown in the tables, the dose rates are well below the 10 CFR 71 limits. The 1-meter normal condition maximum dose rate, which defines the transport index (TI) for the cask, is 2.4 mrem/hr based on the average Co-60 content and 14.4 assuming a higher content of 16.1 Ci/lb.

Shielding limitations on the GTCC content are therefore:

a.) a maximum of 2.7 Ci ^{60}Co/lb averaged over GTCC contents
b.) a localized peak 16.1 Ci ^{60}Co/lb
c.) a total ^{60}Co activity of 85,760 Ci at transport.

Based on the analyzed weight of 32,000 lbs of stainless steel, the total decay heat of the GTCC waste is 1.7 kW, which is much less than the allowed loading of 23 kW in the PWR MAGNATRAN system.

Table 5.8-52 GTCC Source Spectrum

E Lower [MeV]	E Upper [MeV]	Source [γ/sec/lb]
1.00E-02	2.00E-02	2.109E+09
2.00E-02	5.00E-02	1.602E+09
5.00E-02	1.00E-01	5.363E+08
1.00E-01	2.00E-01	1.293E+08
2.00E-01	3.00E-01	6.421E+06
3.00E-01	4.00E-01	8.425E+06
4.00E-01	6.00E-01	5.325E+05
6.00E-01	8.00E-01	1.849E+05
8.00E-01	1.00E+00	6.973E+06
1.00E+00	1.22E+00	1.047E+11
1.22E+00	1.44E+00	9.937E+10
1.44E+00	1.66E+00	2.788E-01
1.66E+00	2.00E+00	0.000E+00
2.00E+00	2.50E+00	1.049E+06
2.50E+00	3.00E+00	1.627E+03
3.00E+00	4.00E+00	0.000E+00
4.00E+00	5.00E+00	0.000E+00
5.00E+00	6.50E+00	0.000E+00
6.50E+00	8.00E+00	0.000E+00
8.00E+00	1.00E+01	0.000E+00
1.00E+01	1.20E+01	0.000E+00
1.20E+01	1.40E+01	0.000E+00
Total		2.085E+11

Table 5.8-53 GTCC Material Description

Material	Density [g/cm^3]	Nuclide / Element	Density [atom/barn-cm]
GTCC	1.49	CHROMIUM	3.2818E-03
		MANGANESE	3.2696E-04
		IRON	1.1177E-02
		NICKEL	1.4537E-03

Table 5.8-54 Normal Condition Maximum GTCC Waste Dose Rates

[redacted]

Table 5.8-55 Accident Condition Maximum GTCC Waste Dose Rates

[redacted]

7.1.2 Loading of Contents

Note: The MAGNATRAN transport cask is dry loaded with a fuel and GTCC waste TSC directly following TSC loading and closure, or following a period of on-site storage in the spent fuel building or facility, or at the onsite ISFSI using the MTC and attendant support hardware. Operation of the MTC is described in the approved site-specific procedures and the MAGNASTOR® FSAR. Site-specific procedures shall comply with the requirements of the SAR. Potential alternate procedures and site-specific hardware are described when necessary.

1. Install appropriate work platforms, scaffolding or lifts to allow access to the top of the MAGNATRAN transport cask.
2. Detorque and remove the lid port coverplate bolts and store the coverplate and associated bolts to prevent damage.
3. Detorque the cask lid bolts in the reverse order of the torquing sequence indicated on the lid.
4. Remove the lid bolts, inspect the bolts for thread damage and store to prevent damage.
5. Install the two lid alignment pins in their designated threaded holes (#s 14 and 36) and hand-tighten.
6. Install and tighten the swivel hoist rings (or equivalent approved site-specific lifting system) in the four threaded lifting holes in the cask lid and torque to the values specified in Table 7.1-1.
7. Attach an appropriate lifting sling set to the swivel hoist rings and to a crane hook. Lift the lid from the cask and store it to prevent damage.
8. Remove the two alignment pins. Using a crane and suitable slings, install the transfer shield ring into the lid recess.

   Note: The transfer shield ring aligns the transfer cask adapter to the cask cavity, provides additional side shielding and protects the cask lid seating surface from damage.

   Note: The following loading procedures are based on the dry transfer of a loaded and closed TSC containing spent fuel assemblies or a loaded and closed TSC containing GTCC waste either immediately following loading or following a period of interim storage. All TSCs shall be independently verified to be in compliance with the CoC content conditions.

   Note: An evaluation of TSCs containing spent nuclear fuel shall be performed to verify that the installed neutron absorbing materials required to assure criticality safety are acceptable for transport conditions.

   Note: TSCs containing spent nuclear fuels that are to be retrieved from storage for off-site transport in the MAGNATRAN transport cask will be evaluated to ensure that the specific TSC stored in the storage overpack, which may have been subject to 10 CFR

72 normal and off-normal, accident and natural phenomena events, retains its ability to satisfy functional and performance requirements of the MAGNATRAN packaging certified content conditions. Dry storage systems that have been maintained within an Aging Management Program will include system specific review and assessment of this information record as part of the off-site transport evaluation to ensure that the MAGNATRAN packaging certified content conditions are validated.

TSCs containing spent nuclear fuel and experiencing only normal or off-normal events during storage will be evaluated for potential corrosion at the welds and any damage caused by removal of the TSC from the storage overpack.

In addition to the evaluation done for normal/off-normal storage, TSCs containing spent nuclear fuel that have experienced accident or natural phenomena events must be evaluated for potential degradation of the fuel, basket, and neutron absorbers. This evaluation will be performed for each TSC as part of the preparation for loading for off-site transport using: 1) the annual inspection and surveillance records and off-normal and accident event reports that are maintained by the licensee for each loaded MAGNASTOR system in compliance with 10 CFR 72 requirements; and 2) in the case of storage accidents and natural phenomena events, any necessary examinations performed at the time of transfer to ensure the condition of the TSC and contents.

Maximum assembly average burnup for fuel assemblies to be transported off-site as undamaged is limited to ≤ 45,000 MWd/MTU. A fuel assembly to be transported off-site having a maximum assembly average burnup > 45,000 MWd/MTU but ≤ 60,000 MWd/MTU shall be loaded in a MAGNASTOR damaged fuel can (DFC).

TSC loading into the MAGNATRAN transport cask will be observed by operations staff noting any system interferences that occur during TSC retrieval from the storage overpack and during placement of the TSC into the transport cask. The cause of the interference and potential damage caused by the interference will be determined prior to shipment. Noted interferences will be made part of the TSC evaluation record to the extent required to validate that MAGNATRAN packaging content conditions are satisfied when the spent fuel canister is placed within the MAGNATRAN transport cask containment boundary for off-site transport.

9. The following procedures apply to fuel and GTCC waste TSC loading into the MAGNATRAN transport cask after an on-site storage period or immediately following TSC loading:

   9.a. For TSCs to be loaded in the MAGNATRAN transport cask following storage operations, remove the loaded TSC from the concrete cask (CC) and close the MTC

shield doors. Record the time the TSC is lifted off the CC pedestal. Install the shield door locking devices.

9.b. For TSCs to be loaded immediately following loading and closing, prepare the TSC for transfer operations. Record the time the ACWS cooling of fuel TSC is terminated.

Caution: In order to ensure that the spent fuel clad temperatures do not exceed 400°C in accordance with ISG-11, Revision 3, the time allowed for transfer of a loaded TSC containing spent fuel to the MAGNATRAN cask is limited. The following time limits apply as noted:

Condition 1) For the maximum transportable fuel TSC heat loads of 23 kW for PWR and 22 kW for BWR, the maximum time from lifting the TSC off the CC pedestal (Section 7.1.2, Step 9) for placement in the MTC through completion of the preparation of the MAGNATRAN for transport and placement in a horizontal orientation on the transport vehicle (Section 7.1.3, Step 4) shall be $<$ 41 hours;

Condition 2) For maximum heat load fuel TSCs loaded and closed immediately prior to loading into the MAGNATRAN cask, the maximum time from completion of TSC closure operations, including helium backfill time and termination of external cooling (for 24 hours) of the TSC (Section 7.1.5, Step 17) through completion of the preparation of the MAGNATRAN for transport and placement in a horizontal orientation on the transport vehicle (Section 7.1.3, Step 4), shall be $<$ 65 hours.

Note: These maximum transfer and preparation times are not applicable to the loading of GTCC waste TSCs as the ISG-11 temperature limits are not applicable.

Note: In the event that the transfer and MAGNATRAN preparation procedures through placement of the cask in a horizontal orientation are not completed within the specified time period, corrective actions shall be implemented to return the TSC to the MAGNASTOR Transfer Cask (MTC) where active cooling of the TSC can be completed in accordance with procedures established in the MAGNASTOR FSAR and Operating Manual. The corrective actions shall be implemented with sufficient time to ensure that the maximum transfer and preparation times are not exceeded. The external cooling of the TSC shall be continued for a minimum of 24 hours to reduce the fuel clad and TSC internal component temperatures to allow re-start of MAGNATRAN loading procedures. The maximum time limit is 31 hours for both Condition 1 and 2 for each subsequent TSC transfer and transport preparation activity.

Note: The time limits specified in Step 9 are for the maximum allowable heat loads in the MAGNATRAN transport cask. Although transfer and cask preparation times would be longer for lower content decay heat loads, the limits for the maximum heat loads

(PWR - 23 kW; BWR - 22 kW) will be conservatively implemented to all content decay heat loads.

10. Connect lift slings to the transfer adapter, lift the adapter, and place it on the top of the MAGNATRAN cask. Visually verify proper fit-up with the transfer shield ring positioned in the lid recess.
11. Connect and verify operation of the transfer adapter auxiliary hydraulic system.
12. Install the TSC lifting hoist rings and sling set (or equivalent TSC lifting system meeting the facility's heavy load program) in the TSC closure lid threaded holes. Torque the hoist rings to the torque specified in Table 7.1-1.
13. Using the MTC lift yoke, engage the lifting trunnions and position the MTC containing the loaded TSC on the transfer adapter positioned on the MAGNATRAN transport cask. Remove the shield door stops.
14. Install a stabilization system for the MTC, if required by the facility heavy load handling or seismic analysis programs.
15. Disengage the MTC lift yoke from the MTC trunnions and move the lift yoke from the area.
16. Connect TSC sling set(s) (or site-specific approved TSC lifting system meeting the facility's heavy load program) to the crane hook. Verify that the MTC retaining components are in the engaged position.
17. Lift the TSC off the MTC shield doors (approximately ½ inch) and open the doors using the auxiliary hydraulic system.
18. Lower the loaded TSC into the MAGNATRAN cask until the TSC rests on the bottom of the cask cavity.
19. Disengage the lifting sling set(s) from the hook or disengage the site-specific approved lifting system meeting the facility's heavy load program from the TSC. Close the MTC shield doors and install the door stops.
20. Retrieve the MTC lift yoke, engage the lifting trunnions, remove the stabilization system (if used), and lift the MTC off the top of the MAGNATRAN cask. Move the MTC and lift yoke from the area and store.
21. Disconnect the auxiliary hydraulic system connections, attach lifting slings to the transfer adapter and lift and move the transfer adapter from the area and store.
22. Remove the TSC lifting sling set(s), hoist rings or other site-specific approved TSC lifting system components from the top of the TSC.
23. Attach lifting slings, lift and remove the transfer shield ring. Inspect the cask lid O-ring seating surface for cleanliness and integrity.

24. Engage the cask lid lifting sling set to the crane and position the lid for seal inspection and replacement.
25. Remove and replace the lid metallic O-ring with an approved spare. Inspect the lid outer O-ring seal and, if it is damaged, replace it with an approved spare. Ensure that the replaced O-rings are properly installed and seated.
26. For the transport of shorter length TSCs install the cask cavity spacer to the bottom side of the lid with the four attachment bolts and lock washers. Torque the attachment bolts to the value specified in Table 7.1-1.
27. Install the two lid alignment pins in their designated threaded hole locations (#s 14 and 36) in the cask and hand-tighten.
28. Lift the cask lid and position the lid to engage the alignment pins. Slowly lower the lid into position. Remove the lid lifting equipment and alignment pins.
29. Inspect the 48 lid bolts for damage and replace, as required, with approved spares. Lubricate the bolts with nuclear-grade Never-Seeze, or equivalent, and install the lid bolts to hand tight. In a minimum of four passes of increasing torque, torque the 48 lid bolts to the final value specified in Table 7.1-1 following the torquing sequence pattern marked on the lid.
30. Connect a vacuum pump and helium gas backfill system to the lid port quick-disconnect valve. Evacuate the cask cavity to a vacuum pressure of < 3 torr and backfill the cavity with helium gas to a pressure of 17.5, +2.5,-0 psia.
31. Disconnect the vacuum pump and backfill system from the lid port quick-disconnect valve.
32. Remove and replace the port coverplate metallic O-ring with an approved spare. Inspect the coverplate outer O-ring seal and, if damaged, replace it with an approved spare. Ensure that the replaced O-rings are properly installed and seated.
33. Install the coverplate in the lid port recess, purge the volume under the coverplate with helium prior to final seating, and torque the coverplate bolts to the value specified in Table 7.1-1.
34. Remove the cask lid test port plug and connect a Helium Mass Spectrometer Leak Detector (He MSLD) to the test port to perform the helium leakage test.
35. Using the He MSLD evacuate the volume between the cask lid metallic inner O-ring and the outer O-ring to a vacuum of < 0.1 torr. Operate the He MSLD to detect for helium in the evacuated volume to confirm the lid leakage rate is less than or equal to 2.0×10^{-7} cm^3/s, helium with a minimum test sensitivity of 1.0×10^{-7} cm^3/s, helium.

36. Upon completion of an acceptable lid helium leakage test, disconnect the He MSLD from the lid test port connection. Replace test port plug metallic seal with an approved spare, install the lid test port plug and torque to the value specified in Table 7.1-1.
37. Remove the coverplate test port plug and connect the He MSLD to the port to perform the helium leakage test.
38. Using the He MSLD evacuate the volume between the coverplate metallic inner O-ring and the outer O-ring to a vacuum of < 0.1 torr. Operate the He MSLD to detect for helium in the evacuated volume to confirm the lid port coverplate leakage rate is less than or equal to 2.0×10^{-7} cm^3/s, helium with a minimum test sensitivity of 1.0×10^{-7} cm^3/s.

    Note: If a helium leakage rate exceeding the specified leakage rate is measured during either the lid or lid port coverplate leakage test, determine the source of the leak, repair (i.e., replace O-ring with approved spare, clean seating surfaces), reinstall and torque, and retest to original acceptance criteria.
39. Upon completion of an acceptable lid port coverplate leakage test, disconnect the He MSLD from the coverplate test port connection. Replace test port plug metallic seal with an approved spare, install the coverplate test port plug and torque to the value specified in Table 7.1-1.

7.1.3 Preparation for Transport

1. Remove scaffolding or work platforms from around the top of the MAGNATRAN transport cask.
2. Connect the cask lift yoke to the cask handling crane and engage the lift yoke arms to the two transport cask lifting trunnions.
3. Lift the cask and move it into position over the transport frame/vehicle rear support structure.
4. Lower the cask to engage the rotation trunnions in the transport frame/vehicle rear support structure, rotate the cask to the horizontal orientation and disengage the lift yoke.

    Note: The rotation trunnions are offset from the centerline to ensure rotation of the cask in the proper direction.
5. Using slings and a suitable crane, detorque and remove the nine lifting trunnion attachment bolts from one trunnion. Remove, clean and inspect the trunnion and bolts, observing for damage/wear. Repeat for the second lifting trunnion and bolts and store the trunnions and trunnion bolts.
6. Clean and inspect the trunnion recess and bolt holes. Position and install the trunnion plug. Apply nuclear-grade lubricant, such as Never-Seeze, or equivalent, to the three trunnion plug

bolts, and torque the bolts to the value specified in Table 7.1-1. Repeat for the second trunnion recess and plug.

7. Decontaminate and clean the surfaces of the transport cask to ensure removable contamination limits for transport are met.
8. Install the transport tie-downs over the top forging and on the rotation trunnions.
9. Using the impact limiter lifting sling set, lift and install the lower (rear) impact limiter. Install retaining rods and attachment and jam nuts, and torque all the components to the values specified in Table 7.1-1. Install the retaining rod lock wires.
10. Repeat the installation sequence for the upper (front) impact limiter.
11. Install a tamper indicating device (TID) to the upper impact limiter attachment rods. Record the TID identification numbers on the cask loading checklist and shipping papers.
12. Perform final visual inspection of the cask to ensure proper package assembly in accordance with the CoC.
13. Complete radiation and contamination surveys of the package external surfaces and record the data. Ensure removable contamination and radiation dose rates survey results comply with the limits specified in 10 CFR 71.87(i) and (j) to verify removable contamination levels are in compliance with 49 CFR 173.443 and radiation dose rates comply with 10 CFR 71.47, respectively.
14. Measure the dose rate in millirems per hour at one meter from the package surface to determine the Transport Index (TI). Indicate the TI on the Radioactive Material labels applied to the package in accordance with 49 CFR 172, Subpart E.
15. Determine the appropriate Criticality Safety Index (CSI) assigned to the package contents in accordance with the CoC, and indicate the correct CSI on the Fissile Material label applied to the package per 49 CFR 172, Subpart E.
16. Measure and record the temperature of the MAGNATRAN shield shell outer surface at the top center of the package in the horizontal position and verify that the measured package external temperature meets the exclusive use shipment temperature limit of 85°C (185°F) per 10 CFR 71.43(g).
17. Install the personnel barrier to the transport vehicle and verify all access points are locked.
18. Perform a radiation survey of the package and the transport vehicle to assure radiation levels are in compliance with 49 CFR 173.441.
19. Apply placards to the transport vehicle in accordance with 49 CFR 172 Subpart F.

20. Review the cask loading inspection checklist and verify all required steps, tests and verifications have been satisfactorily completed, and all routine determinations have been satisfactorily completed in accordance with 10 CFR 71.87.
21. Complete the shipping documentation for an Exclusive Use Shipment and provide special instructions to the carrier to maintain an Exclusive Use Shipment.
22. The MAGNATRAN transport cask (package) is now ready for release and transport.

7.1.4 Loading the Transportable Storage Canister with Spent Fuel Contents

1. Visually inspect the TSC to ensure that it is clean and free of debris.
2. Place the TSC in the MTC.
3. Place the MTC containing the TSC into the spent fuel pool.
4. Load the previously designated fuel assemblies into the TSC in accordance with applicable CoC requirements.

   Note: The fuel assemblies and authorized nonfuel hardware shall be selected in compliance with the requirements of the approved contents specified in the CoC including limitations on fuel assembly, damaged fuel assemblies in Damaged Fuel Cans (DFCs), and nonfuel hardware positions within the basket. Assembly, DFC, and nonfuel hardware selection and placement within the basket shall be independently verified.

   Note: Verification of the location of high reactivity fuel (i.e., fresh or severely underburned fuel) in the spent fuel pool shall be performed prior to and after TSC loading to ensure appropriate fuel assemblies have been loaded.

   Note: A qualitative visual verification that a fuel assembly has been burned shall be performed prior to or during TSC loading operations.

   Note: A verification of the TSC or package fuel inventory and loading records shall be performed under a 10 CFR 71 quality assurance program prior to shipment for previously loaded (i.e., TSCs transferred from 10 CFR 72 storage facilities) TSCs.

   Note: Fuel assemblies without visible identification shall only be loaded after quantitative measurement of the fuel assembly.

   Note: Fuel assemblies may use burnup credit to demonstrate criticality acceptability. When applying burnup credit the documented fuel assembly burnup must be adjusted downward (decreased) to account for reactor record or measurement uncertainty prior to comparison to CoC minimum requirements

Note: 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.

Note: Up to four DFCs containing authorized PWR contents may be loaded in a TSC with a DF Basket Assembly. A DFC spacer is required to be positioned in the designated DF Basket Assembly corner locations for the shorter length DFCs. Independently, visually verify proper placement and correct orientation of each required DFC spacer.

Note: At the option of the user, install fuel assembly spacers for the axial positioning of the PWR fuel assembly types to be loaded.

Note: For fuel spacer use mandated by the CoC content conditions, verify spacer identification and install fuel spacers in each intended fuel loading location based on the fuel spacer plan prepared, which is based on the fuel assembly inventory and nonfuel hardware to be loaded. Independently, visually verify proper placement and correct orientation of each required fuel spacer.

5. Place the closure lid on top of the loaded TSC.
6. Remove the MTC with the loaded TSC from the spent fuel pool.
7. Insert the drain tube assembly, torque to 200 ± 25 ft-lb (115, ± 5 ft-lb for DF 1" drain tube) and remove approximately 70 gallons of water. Attach a hydrogen detector to the vent line. Ensure that the vent line does not interfere with the operation of the weld machine. Sample the gas volume below the closure lid and observe hydrogen detector for H_2 concentration prior to commencing closure lid welding operations. Monitor H_2 concentration in the TSC until the root pass of the closure lid-to-shell weld is completed.

   Note: If H_2 concentration exceeds 2.4% prior to or during root pass welding operations, immediately stop welding operations. Evacuate the TSC gas volume or purge the gas volume with helium. Verify H_2 levels are <2.4% prior to restarting welding operations.

   Note: In place of continuous H_2 monitoring, continuous gas purging of the volume below the lid may be used in concert with initial (prior to start of welding) and intermittent

H_2 monitoring (upon termination of gas purging and prior to re-starting welding operations).

8. Weld the closure lid in place and verify the adequacy of welds with root, mid-plane, and final surface visual and liquid penetrant examinations. Record results of examinations as required.
9. Refill TSC and hydrostatically test the TSC.
10. Release the pressure and drain the cavity water from the TSC by pumping or helium gas blowdown ensuring fuel cladding is not exposed to air.
11. Vacuum dry the TSC using vacuum drying methods as follows.

    Note: Ensure heat load-dependent vacuum drying time limits are not exceeded so that fuel cladding temperatures are maintained below 752°F.

    a. Connect the vacuum drying system to the vent and drain port openings.
    b. Operate the vacuum pump until a vapor pressure of < 10 torr is achieved in the TSC.
    c. Isolate the vacuum pump from the TSC and turn off the vacuum pump. Observe the vacuum gauge connected to the TSC for an increase in pressure for a minimum period of 10 minutes. If the TSC pressure is ≤ 10 torr at the end of 10 minutes, the TSC is dry of free water. If pressure is > 10 torr at end of 10 minutes, continue vacuum drying until dryness criteria are met.
12. Following successful completion of drying verification, evacuate TSC to a vacuum of < 3 torr and immediately backfill the TSC with the required mass of high purity helium (99.995% minimum). Disconnect drying and helium backfill system from vent and drain ports.
13. Install inner vent and drain port covers purging volume behind the port cover with helium gas prior to completion of welding inner port covers in place, and perform visual and liquid penetrant examinations of final weld surface. Perform leakage test of inner port cover to verify the leakage rate is $\leq 2.0 \times 10^{-7}$ cm^3/s, helium to a sensitivity of $\leq 1.0 \times 10^{-7}$ cm^3/s, helium. Record results of examinations as required.
14. Install closure ring and weld the closure ring to the closure lid and TSC shell. Verify the adequacy of welds with final surface visual and liquid penetrant examinations. Record results of examinations as required.
15. Install outer vent and drain port covers, weld port covers in place, and perform visual and liquid penetrant examinations of final weld surface.
16. Install the MTC retaining device.

17. Decontaminate the external surface of the MTC and TSC to the limits established for the site, as required, and terminate TSC external cooling operations.

    Note: The loaded TSC is now properly loaded for transfer either directly to the MAGNATRAN transport cask in accordance with CoC No. 9356 or to the MAGNASTOR concrete cask (CC) for interim storage in accordance with CoC No. 1031.

7.1.5 Loading the Transportable Storage Canister with GTCC Waste Contents

1. Visually inspect the GTCC waste TSC and GTCC waste basket liner to ensure that they are clean and free of debris.
2. Place the GTCC waste basket liner into the flooded reactor cavity or other designated waste loading location.
3. Load the authorized quantity of GTCC waste into the GTSC waste basket liner in accordance with CoC No. 9356 content limits and requirements.
4. Place the MTC containing the TSC into the flooded reactor cavity or other designated waste loading location.
5. Using the crane and slings installed on the loaded GTCC waste basket liner lift the GTCC waste basket liner and position it over the MTC/TSC.
6. Lower the GTCC waste basket liner into the TSC until it seats on the TSC baseplate.
7. Place the closure lid on top of the loaded GTCC waste TSC.
8. Remove the MTC with the loaded TSC from the flooded reactor cavity or other designated waste loading location.
9. Insert the GTCC waste TSC drain tube assembly through the drain port opening and torque to 200 ± 25 ft-lb. Drain approximately 70 gallons of water from the cavity.
10. Weld the closure lid in place and verify the adequacy of the weld root and final weld passes with visual and liquid penetrant examinations. Record results of examinations as required. Install the closure ring and weld the closure ring to the closure lid and TSC shell. Verify the adequacy of the welds with final surface visual and liquid penetrant examinations. Record results of examinations.
11. Drain the cavity water from the TSC.
12. Vacuum dry the TSC and verify dryness as follows:
    a) Connect the vacuum drying system to the vent and drain port openings.

b) Operate the vacuum pump until a vapor pressure of < 10 torr is achieved in the TSC.

c) Isolate the vacuum pump from the TSC and turn off the vacuum pump. Observe the vacuum gauge connected to the TSC for an increase in pressure for a minimum period of 10 minutes. If the TSC pressure is ≤ 10 torr at the end of 10 minutes, the TSC is dry of free water. If pressure is > 10 torr at end of 10 minutes, continue vacuum drying until dryness criteria are met.

13. Evacuate the TSC to a vacuum of less than 3 torr and backfill the TSC with high purity (≥ 99.9% pure) helium to 15.0 + 2, - 0 psig. Disconnect the drying and helium backfill system from the vent and drain ports.

14. Install inner vent and drain inner port covers, weld port covers in place, and perform visual and liquid penetrant examinations of final weld surfaces. Install outer vent and drain port covers, weld port covers in place, and perform liquid penetrant examinations of the final weld surfaces. Record results of examinations as required.

15. Install the TSC retaining device in the MTC.

16. Decontaminate the external surface of the MTC and TSC to the limits established for the site, as required.

Note: The loaded GTCC waste TSC is now properly loaded for transfer directly to the MAGNATRAN transport cask in accordance with CoC No. 9356 or for on-site storage.

8. Attach impact limiter slings to the upper impact limiter and a suitable crane hook and take up the slack in the slings.
9. Remove the impact limiter lock wires and the jam and attachment nuts. Remove the impact limiter retaining rods.
10. Remove the upper impact limiter and store it in the upright position in a clean area.
11. Repeat Steps 8-10 for the lower impact limiter.
12. Release the front tie-down assembly from the top forging of the cask and remove the rotation trunnion tie-downs.
13. Remove the two trunnion plugs and store the plugs and bolts to prevent damage. Visually inspect the trunnion recesses for any damage.
14. Using a crane and slings, lift and position a lifting trunnion, install the attachment bolts, and torque the bolts to the value specified in Table 7.1-1. Repeat for the second lifting trunnion.
15. Attach the cask lifting yoke to the cask handling crane hook. Verify the proper operation of the lift arm pneumatic actuation system.
16. Position the cask lifting yoke arms adjacent to the lifting trunnions and close the arms using the actuation system. Visually verify proper yoke arm engagement.
17. Lift and rotate the cask to the vertical orientation on the rotation trunnions. Lift the cask from the transport frame/vehicle rear support structure and position the cask vertically in the designated unloading area.
18. Disengage the yoke from the cask lifting trunnions and remove it from the immediate area.
19. Install appropriate work platforms, scaffolding or lifts to facilitate access to the top of the cask.

7.2.2 Removal of Contents

1. Detorque and remove the lid port coverplate bolts. Visually inspect the bolt threads for damage and store them. Remove the coverplate and store it.
2. Attach a pressure fixture, including a pressure gauge, evacuated gas sample bottle and a valve to the lid port quick-disconnect valve. Measure the cask internal pressure.
3. Withdraw a sample of the cavity gas using the evacuated sample bottle and determine the cask cavity's gaseous activity. If activity and pressure levels are acceptable per facility criteria, vent the cavity gas to an appropriate filter/system.
4. Disconnect the pressure fixture from the lid port.
5. Detorque and remove the cask lid bolts using the reverse of the torquing sequence shown on the lid. Clean and inspect the bolt threads for damage and store them.

6. Install and torque swivel hoist rings to the value specified in Table 7.1-1 (or equivalent lid lifting device) in the four threaded lifting holes in the cask lid.
7. Install and hand-tighten the lid alignment pins in their designated hole locations (#s 14 and 36).
8. Attach an appropriate lid sling set to the swivel hoist rings (or equivalent site-specific approved lid lifting system) and a suitable crane.
9. Lift and remove the cask lid. Decontaminate and store the lid to prevent damage to the seal surfaces and cask cavity spacer, if installed. Record the time the lid is removed.

   Caution: In order to ensure that the fuel clad temperatures do not exceed 400°C, as established by ISG-11, Revision 3, a fuel TSC containing maximum heat load contents (i.e., PWR - 23 kW; BWR - 22 kW) shall be removed from the MAGNATRAN following cask lid removal and placed in a safe condition (i.e., in a MTC or equivalent transfer device). The maximum time to complete the operational sequence from Section 7.2.2, Step 9 through Step 18 shall be < 6 hours. This maximum transfer and preparation time is not applicable to the loading of GTCC waste TSCs as the ISG-11 temperature limits are not applicable.

   In the event that the MAGNATRAN unloading procedure, through removal of the TSC from the cavity, is not completed within the specified time period, corrective actions shall be implemented to cool the TSC in the MAGNATRAN cask through introduction of demineralized water into the cask cavity either directly into the cask or through the vent port if the lid is still installed. The corrective actions shall be implemented with sufficient time to ensure that the maximum TSC unloading time is not exceeded. The external cooling of the TSC shall be continued for a minimum of 24 hours to reduce the fuel clad and TSC internal component temperatures to allow re-start of MAGNATRAN unloading procedures. The maximum time limits of < 6 hours is in effect for each attempted unloading sequence. If cooling of the TSC is required while the TSC is in the MAGNATRAN cask, the cask cavity shall be appropriately drained and dried prior to returning the cask to service.

   Note: The time limits specified in Step 9 are for the maximum allowable heat loads in the MAGNATRAN transport cask. Although TSC unloading times would be longer for lower content decay heat loads, the limits for the maximum heat loads (PWR - 23 kW; BWR - 22 kW) will be conservatively implemented to all content decay heat loads.
10. Remove the lid alignment pins, and using a suitable crane and sling set, install the transfer shield ring in the lid recess.

    Note: The transfer shield ring aligns the transfer adapter to the cask cavity, provides additional side shielding and protects the cask lid seating surface from damage.

external surface of the shell at 30° intervals and at five points along the height of the shield (a total of 60 measuring points). In addition, neutron and gamma dose rate measurements are made at the trunnion areas above the neutron shield, at four points below the neutron shield, and at the edges and center of the cask top and bottom surfaces. Dose rates at the top and bottom of the cask are measured with the impact limiters installed. The dose rates measured at contact and at 2.3 m are recorded on the test data sheet. Additional date recorded for the shielding effectiveness test include the total power of the loaded fuel assemblies; date, time and location of test; identification and calibration of instrumentation; and identification of test engineer and operators. To enable the measured dose rates to be evaluated, the burnup and cool time for the actual fuel assemblies loaded into the cask are determined and recorded. From this fuel history data, the total actual neutron and gamma source terms are estimated by using ORIGEN or similar calculations. Neutron and gamma source terms applied in these dose rate calculations are to be based on the fuel type, MTU, burnup, and initial enrichment of the fuel loaded in the cask at the time dose rate measurements are taken. The package configuration (including materials and geometry) to be applied in the dose rate calculation must represent the minimum shielding effectiveness configuration discussed in Chapter 5. Utilizing the neutron and gamma source terms estimated (i.e., calculated) gamma and neutron dose rates are developed in order to properly evaluate the measured dose rates.

If the measured dose rates exceed the estimated dose rates corresponding to the MAGNATRAN fuel contents, the cask User shall notify the NRC in accordance with 10 CFR 71.95. Appropriate corrective measures shall be taken including unloading the TSC from the MAGNATRAN and correction of identified shielding deficiencies. Following corrective actions, the shield effectiveness test shall be re-performed to the original acceptance criteria prior to final cask acceptance for transport operations.

8.1.7 Thermal Acceptance Test

Prior to acceptance of each MAGNATRAN transport cask, a thermal test using electric heaters will be performed on a fabricated packaging to verify that the fabricated and assembled transport cask possesses the heat rejection capabilities evaluated in the thermal analyses in Chapter 3. The thermal test will be performed in accordance with approved written procedures.

8.1.7.1 Thermal Test Setup

A typical thermal test set-up is shown in Figure 8.1-1. As depicted, the thermal test will be performed with the cask positioned horizontally on a test frame. The transport impact limiter or equivalent insulating material will be installed on each end of the cask to simulate the transport configuration. The cask will be located in a covered building in a still environment. The

contents heat will be simulated by using electric heaters to apply 23 kW to the inner surface of the transport cask. The electric heating elements will be mounted on a metallic shell and will extend for the full length of the cask cavity except for approximately 6 inches from each end. The metallic heater-mounted test shell will radiate and conduct heat to the inner surface of the cask cavity. The cask bottom or top will receive negligible heat. Due to the small radial gap between the metallic heater-mounted test shell and the inner cask surface, the heat transfer by convection is negligible compared to the heat transfer by radiation and conduction. Electrical heaters are spaced to provide a uniform heat flux, circumferentially to the cask wall and permit power input to be measured for heating element.

As described below and Figure 8.1-1, six calibrated thermocouples will be installed on the inner surface of the MAGNATRAN transport cask and six calibrated thermocouples will be installed on the cask external surface at the same angular and axial locations as the thermocouples on the cask inner surface.

- Four thermocouples located at approximately 90° intervals (see Figure 8.1-1) on the inner shell surface 88 inches from the inner surface of the cask bottom
- One thermocouple at the upper region (180° location as shown in Figure 8.1-1) of the inner shell surface at 21 inches from the inner surface of the cask bottom
- One thermocouple at the upper region (180° location as shown in Figure 8.1-1) of the inner shell surface at 154 inches from the inner surface of the cask bottom
- Four thermocouples located at approximately 90° intervals (see Figure 8.1-1) on the neutron shell outer surface with the axial location at 88 inches from inner surface of cask bottom and at the thermocouples on the inner shell surface
- One thermocouple at the upper region of the neutron shield shell (180° location as shown in Figure 8.1-1) with the axial location at 154 inches from the inner surface of cask bottom and at the same angular location as the thermocouple on the inner shell surface
- One thermocouple at the upper region of neutron shield shell surface (180° location as shown in Figure 8.1-1) with the axial location at 154 inches from inner surface of cask bottom and at the same angular location as the thermocouple on the inner shell surface

An additional thermocouple is required to measure the ambient temperature. The thermocouples will be attached to strip chart recorders, which may have multiple input channels, or another similar device to allow for continuous monitoring and recording of temperatures during the test. These records will be part of the quality assurance acceptance records for the cask under test.

The nominal test conditions are ambient temperature and with the initial cask body temperatures being 70°F, no solar insolation, still air, and no external radiant heat sources. At these test conditions, the cask surface temperature will be bounded by the calculated steady-state equilibrium temperature of 178°F. It will take about 110 hours for the system to approach steady

state condition. The thermal test procedure will provide a thermal transient heat-up curve to show the time at which equilibrium is expected to be established, and a table, or set of curves, that correlates equilibrium neutron shield assembly surface temperature with a range of ambient temperatures. For purposes of the thermal test, equilibrium temperature is assumed to be established when the change in neutron shield assembly surface temperature no longer exceeds 2°F in a two-hour period.

8.1.7.2 Thermal Test Acceptance Criteria

The purpose of the thermal test is to confirm that the heat rejection capabilities of the as-built MAGNATRAN transport cask are acceptable. Cask thermal test acceptance is based on the demonstration that the measured temperature gradients are less than, or equal to, the thermal gradients calculated in the thermal analyses, as described in Section 8.1.7.3, and that the total heat rejection rate is equal to, or greater than, the cask design basis heat rejection rate.

8.1.7.3 Thermal Analyses for Thermal Test

A three dimensional half-symmetry model based on the full-length model described in Section 3.4.1.1.1 (Figure 3.4-13) is utilized to perform steady state and transient analyses for the usage of the thermal test. The steady state analysis evaluates the temperatures at the thermocouple locations of the thermal test, while the transient analysis identifies the duration for the system to reach a steady state condition.

The model boundary conditions described in Section 3.4.1.1.1 were modified to reflect the actual testing conditions of the transport cask. The main boundary conditions were listed below:

1) A uniform heat flux is applied to the entire inner surface of the cask inner shell based on the design heat load of 23kW.
2) Convection film coefficient for the model, as described in Section 3.2.3, is used.
3) No solar insolance is considered in this analysis.
4) An ambient temperature of 70°F is considered.

In order to compare the analytical results with the thermal test results, the maximum component temperatures and temperatures at three axial locations of the cask inner and outer surfaces are post processed for the steady state condition. The transient thermal analysis confirms that approximately 110 hours are needed for the cask to reach thermal steady state condition.

Figure 8.1-1 Thermal Test Arrangement

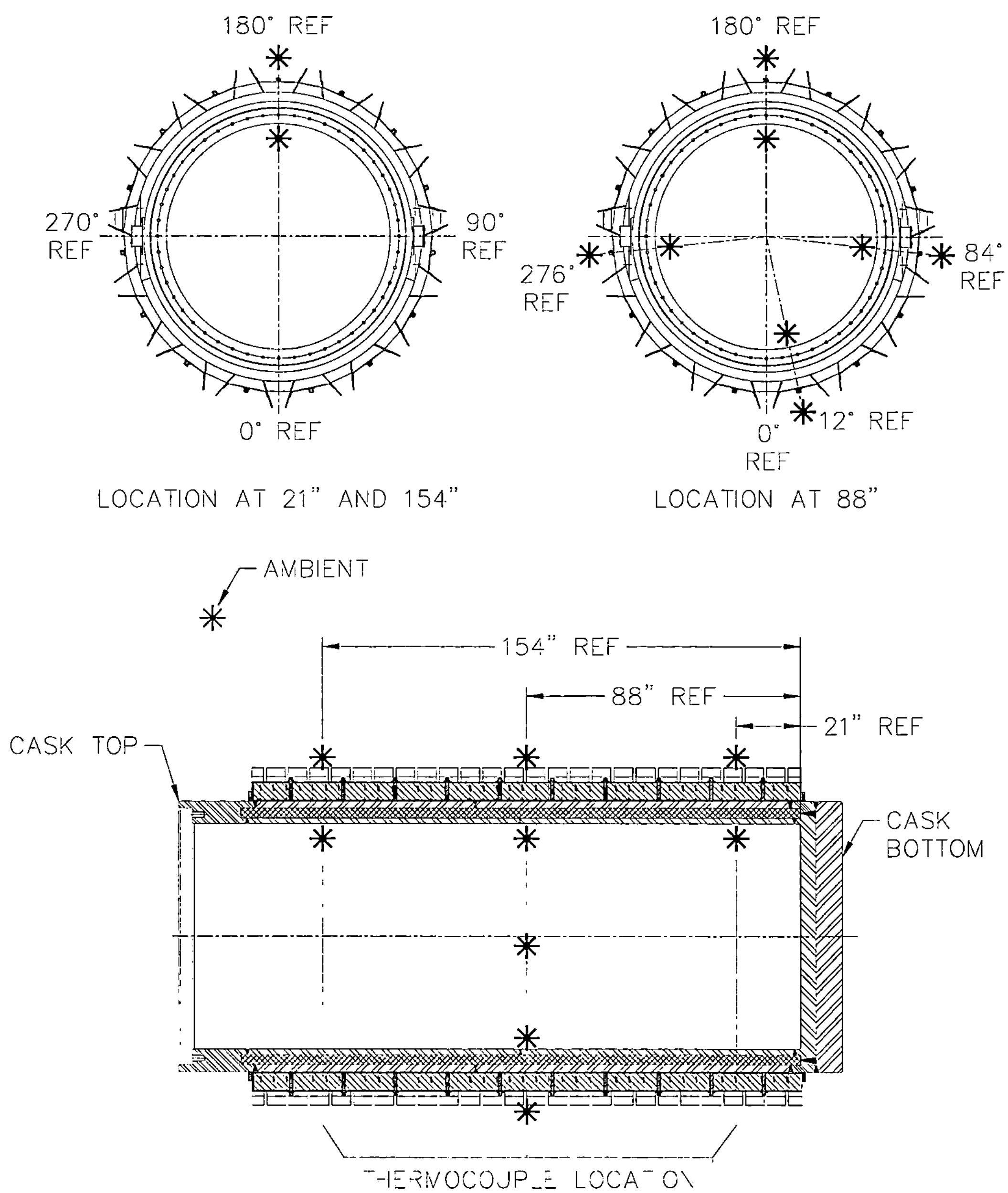


Table 8.2-1 MAGNATRAN Maintenance Schedule

Task/Activity	Frequency
Visual inspection of cavity	Prior to loading
Visual inspection of O-rings	Prior to loading
Visual inspection of neutron shield shell segments for structural or penetration damage	Prior to loading
Visual inspection of cask lid bolts and lid port coverplate bolts	Prior to installation (each use)
Visual and Proper Function Inspection of Cask	Prior to and during each use
Visual inspection of lifting trunnions and rotation trunnions	Prior to and during each use
Liquid penetrant inspection of lifting trunnion and rotation trunnion weld surfaces	Annually during use
Periodic leakage rate test of cask lid and lid port coverplate containment O-rings	Annually during use
Periodic Gamma and Neutron Shield Effectiveness Tests	Every 5 years during operation and use
Pre-shipment leakage rate test of cask lid and lid port coverplate containment O-rings	Prior to each loaded transport
Maintenance leakage rate test of containment system	After replacement or repair of containment boundary components
Replacement of lid and lid port coverplate metallic O-rings	Prior to each loaded transport
Visual inspection of impact limiters for structural or penetration damage	Prior to each loaded transport
Inspection of quick disconnect for proper function	Each cask use
Liquid penetrant inspection of impact limiter shell weld surfaces	Every five years or as required by visual inspection results during operation and use
Liquid penetrant inspection of neutron shield shell assemblies weld surfaces	Every five years or as required by visual inspection results during operation and use
Replacement of quick disconnect	Every two years or as required by performance during operations
Replacement of non-containment O-ring	Annually, or as required by inspection during operations
Replacement of lid port coverplate bolts	Every 20 years, or as required due to thread damage
Replacement of cask lid bolts	Every 20 years or after 350 applications of the specified torque, or as required due to thread damage

8.2.3 Component and Material Tests

Each MAGNATRAN transport cask impact limiter will be visually inspected for damage prior to each loaded transport and will be repaired, as required, using written procedures to return it to its licensed condition in accordance with the applicable License Drawing as referenced in the CoC.

The external surface of the MAGNATRAN transport cask neutron shield will be visually inspected for damage prior to each loading operation and will be repaired, as required, using written procedures to return the affected neutron shield segment to its licensed condition in accordance with the applicable License Drawing as referenced in the CoC.

No valves providing a containment function are present on the MAGNATRAN transport cask packaging. One quick-disconnect is provided in the cask lid port for ease of cask operation. The MAGNATRAN transport cask containment vessel has no rupture disks. The quick-disconnect will be inspected for proper performance and function during each cask use and will be replaced as necessary. The quick-disconnect shall be replaced every two years during transport operations.

The cask lid and lid port cover non-containment O-rings are visually inspected for damage during each cask closure operation. Any identified damage, or failure to seal, is cause for replacement of the O-ring. The cask lid and lid port cover containment boundary metallic O-rings are replaced and leak tested as specified in Table 8.2-1 prior to each loaded transport.

The cask lid and lid port cover bolts are inspected for damage during each cask use, and replaced as required. The cask lid and lid port cover bolts will be completely replaced every 20 years of service.

The gamma and neutron shields of the MAGNATRAN transport cask are not expected to degrade with time or usage. However, to confirm the continued effectiveness of the solid gamma and neutron shields, a separate gamma and neutron radiation shield effectiveness test will be performed on each MAGNATRAN transport cask every five (5) years as identified on Table 8.2-1 or prior to the next loaded transport. The gamma and neutron shield effectiveness test will be performed using approved written procedures and calibrated radiation measurement instrumentation utilizing the procedures, methods, equipment, and acceptance criteria as defined in Section 8.1.6.3. Utilizing the neutron and gamma source terms estimated (i.e., calculated) gamma and neutron dose rates are developed in order to properly evaluate the measured dose rates. Neutron and gamma source terms applied in these dose rate calculations are to be based on the fuel type, MTU, burnup, and initial enrichment of the fuel loaded in the cask at the time dose rate measurements are taken. The package configuration (including materials and geometry) to be applied in the dose rate calculation must represent the minimum shielding effectiveness

configuration discussed in Chapter 5. If the measured dose rates exceed the estimated dose rates corresponding to the MAGNATRAN fuel contents, the cask User shall notify the NRC in accordance with 10 CFR 71.95. Appropriate corrective measures shall be taken including unloading the TSC from the MAGNATRAN and correction of identified shielding deficiencies. Following corrective actions, the shield effectiveness test shall be re-performed to the original acceptance criteria prior to returning the cask to service.

The sealed neutron shield assemblies and the impact limiters welded stainless steel enclosure welds shall be examined by dye penetrant examination every five years or after identification of potential damage to the component as identified on Table 8.2-1 and using the methods and acceptance criteria described in Section 8.1.8.

There are no other MAGNATRAN components or materials that are susceptible to degradation during normal conditions of transport activities.

8.2.4 Thermal Test

The heat transfer capability of the MAGNATRAN transport cask does not degrade over the lifetime of its use for normal conditions of transport. Therefore, no periodic thermal test is required.

8.2.5 Miscellaneous Tests

As summarized in the MAGNATRAN Maintenance Schedule, Table 8.2-1, a number of routine inspections and maintenance activities are performed on the MAGNATRAN cask during use and on defined frequencies. These inspections include visual inspection of the cask cavity and exterior surfaces for foreign material and damage, inspections of the lifting and rotation trunnions for damage prior to and after use. Foreign material and obstructions shall be discarded or appropriately removed. Damage to any containment boundary sealing surface on the cask lid or upper forging seal surface, or lid port cover and corresponding recessed seal surface, or inner shell shall be assessed and repaired, if necessary, including performance of a maintenance leakage rate test of the affected area or component in accordance with Section 8.2.2.2. All repairs and retesting shall be performed in accordance with approved procedures and an approved QA program. The final condition of the cask repaired areas shall be in compliance with the applicable License Drawing(s) as referenced in the CoC.

In addition, the maintenance schedule defines a periodic inspection, test and equipment replacement schedule for key operational components of the cask system and for components that may be damaged during use (e.g., impact limiters, neutron shield sections, lifting and rotation trunnions, etc.) to ensure continued proper functioning in accordance with the analyses

in the SAR. For each MAGNATRAN transport cask loaded for transport, the following information is included in the cask loading report: results of the visual inspections; leak test results; shielding and radiological contamination surveys; identification information for the package contents; date, time, and location of the cask loading operations; and remarks regarding replaced components. The specific requirements of a recommended cask loading report will be detailed in the MAGNATRAN transport cask operations and maintenance manual.