May 2014

Revision LWT-14C

NAC-LWT

Legal Weight Truck Cask System

ANSTO OPAL RAI Response Package

NON-PROPRIETARY VERSION

Docket No. 71-9225

NAC INTERNATIONAL

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Enclosure 1

RAI Responses

and Supporting References

No. 9225 for NAC-LWT Cask

NAC-LWT SAR, Revision LWT-14C

ANSTO OPAL Amendment

NAC INTERNATIONAL

RESPONSE TO THE

UNITED STATES
NUCLEAR REGULATORY COMMISSION

REQUEST FOR ADDITIONAL INFORMATION

FOR REVIEW OF THE CERTIFICATE OF COMPLIANCE NO. 9225, REVISION FOR THE MODEL NO. NAC-LWT PACKAGE TO INCORPORATE ANSTO OPAL

(TAC NO. L24875 DOCKET NO. 71-9225)

May 2014

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SHIELDING EVALUATION

5.1 Justify that the current analyses support the proposed change of the U-235 mass per element for all MTR element types covered in the proposed CoC Condition No. 5(b)(1)(iv)(c) table.

The CoC table includes MTR fuel element types with different characteristics (e.g., different active fuel widths and plate thicknesses), and the applicant proposes to change the maximum U-235 mass per element specification for all the element types in the table. The analyses provided in the application only appear to be applicable to one or fewer of the MTR fuel element types included in the CoC table. Thus, it is not clear that the analyses in the application support a change to the maximum U-235 mass per element limit for all the MTR element types covered by the listed CoC table.

This information is needed to verify compliance with 10 CFR 71.35.

NAC International Response to Shielding Evaluation RAI 5.1:

The request for higher fuel mass does not change any dimensional fuel characteristics outside those of the existing license. The current NAC-LWT license allows transport of fuel elements with a plate thickness ≥ 0.115 cm. The request modified the plate thickness to ≥ 0.130 cm due to criticality limitations. The thicker plate offsets the higher fuel mass but does not represent a change in the currently allowed generic (across all fuel types) fuel plate thickness.

The request for an increased fuel mass is limited to 20 grams per element, from 470 to 490 g ^{235}U, while previously licensed analysis with the identical models allows fuel mass up to 640 g ^{235}U.

For the shielding evaluation presented in Section 5.3.4 Paragraph 6, a design basis MTR element is employed in the analysis that is based on typical MTR parameters. No request was made to change fuel parameters (i.e. beyond fuel mass out of the range of previously licensed characteristics) and no changes, except for fuel mass were made to the shielding and source models.

This makes the mass change generically applicable to all LEU MTR fuel types except for the 640 grams type. Further discussion on the analysis is included in the RAI 5.2 response.

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5.2 Justify that the MTR element properties used in the shielding analysis result in a bounding source term for the proposed contents. Justify that the dose rate comparison between the proposed contents and the allowable HEU contents is for bounding cases for both the proposed contents and the HEU contents.

It is not clear from the application that the element properties for the proposed contents result in bounding dose rates for those contents. Nor is it clear that the HEU dose rates compared with those of the proposed contents are for HEU element properties that result in bounding HEU dose rates. The application should address the effects of active fuel width, fuel thickness, plate thickness, active fuel height, fuel composition (i.e., U-Al vs. the other compositions described in the application), enrichment, U-235 mass per plate, number of plates, U-235 mass per element, and position along the proposed decay heat loading curves (burnup and cooling time combinations).

This information is needed to verify compliance with 10 CFR 71.47 and 71.51.

NAC International Response to Shielding Evaluation RAI 5.2:

Fuel elements are evaluated at minimum enrichment for their respective group (e.g. LEU, MEU, or HEU) to maximize the source terms. For example, the LEU fuel element in the 490 g ^{235}U application is evaluated at 19 wt%, which represents a lower limit for LEU MTR fuel elements.

All fuel elements meat sections are primarily composed of uranium in an aluminum matrix material. Silicide and oxide forms are permitted by the SAR. Neither oxygen nor silicon have significant neutron absorption cross sections and present only a minor component of the overall matrix material. The analysis provides reasonable assurance that all allowed materials will meet 10 CFR 71 limits. The following note has been added to the material composition listing in Table 5.3.4-8:

> "Note: Fuel plate meat/core material is modeled as Uranium in an Aluminum matrix material. Uranium may also be in an oxide (U_3O_8) or silicide (U_xS_2) form. Neither oxygen nor silicon has a significant neutron absorption cross section or produce activation products significant to the shielding analysis. Oxygen or silicon represents a minor component of the overall fuel matrix composition."

Maximum dose rates are calculated at the maximum burnup. As previously noted in Section 5.3.4, HEU material maximum depletion was restricted during analysis that increased fuel mass from 380 to 460 g ^{235}U (from 80% depletion to 70%). At 80% depletion 460 g ^{235}U dose rates were higher than 10 CFR 71 limits. This statement documents an increase in dose rates at increasing burnup and documents that the

use of the maximum ^{235}U mass is bounding. To address a potential bump in dose rates associated with short-lived fission products, Section 5.3.4 contains a dose comparison of maximum burnup dose rates to dose rates obtained at 90 days and its associated maximum allowed depletion. Added as a response to this RAI is a comparison for the LEU element (490 g ^{235}U) source across all burnup levels demonstrating that the previously discussed end-points (maximum burnup and minimum 90-day cool time) are suitable to justify that rates for MTR fuel are calculated at the right (maximum burnup) location on the burnup curves.

MTR source evaluations are based on a SAS2H Path B model that homogenizes the assembly for transport calculations. Relevant parameters for this evaluation are the ratio (volume/material) of the moderator in the homogenized fuel region versus the fuel plate/assembly material mass (SAS2H uses a cell weighted cross section from the unit cell). Reductions in moderator quantity tend to produce a harder spectrum, which has the potential to increase the source (minor effects on gamma and heat sources, but potentially larger effects on neutron source). The licensed parameter set (in minimum plate thickness) provides a higher moderator to fuel volume ratio than that employed in the source model. The trade-off between the number of plates and plate thickness will not significantly affect dose rate conclusions as the cross section adjustment (resonance and/or self-shielding) are secondary effects in the analysis. As a comparison statement, an LEU 490 gram element (ANSTO-OPAL element which this amendment is being processed for) was modeled at its 21 plate (0.135 cm thickness) configuration and resulted in a < 1% (decrease) in heat load and gamma source and a < 4% (decrease) in neutron source. It should be noted that the SAS2H model contains two conservatisms:

a.) No element to element spacing, which hardens the spectrum and thereby produces a bounding source, and

b.) Applying a uniform power history throughout the 70% - 80% depletion and not crediting reduced power levels after depletion of the majority of fissile material which results in two conservative effects: a.) not crediting extended operating time and the associated in-core decay of short lived nuclides, and b.) requiring increased flux levels to maintain power level specified for input into ORIGEN.

The generic MTR dimension definition was implemented in NAC-LWT CoC No. 26 where NRC SER states:

> "The NRC staff reviewed the applicant's evaluation and agrees with its conclusion that the changes will not impact the ability of the package to meet the shielding requirements of 10 CFR Part 71."

This conclusion was based on an NRC confirmatory calculation. Rev. 28 of the CoC was generated to support the increase in HEU mass to 460 g ^{235}U and the NRC SER states:

> "The staff reviewed the applicant's analysis and performed independent confirmatory calculations of the source term and shielding evaluations" and "The staff's calculation for the source term agreed with applicants."

CoC Rev. 32 SER contains a similar conclusion for the LEU mass change to 470 g ^{235}U. The SER for Rev. 45 of the CoC for the 640 g ^{235}U element states that the applicant:

> "has correctly modeled and analyzed the shielding safety of these packages" and that the staff has "reasonable assurance" that the package will meet 10 CFR 71 limits.

Based on the use of the source generation method that has been reviewed by the NRC staff and the minor change in mass requested (an intermediate fuel element mass of 490 g ^{235}U versus the 470 and 640 g ^{235}U currently licensed), NAC believes the application contains sufficient information to provide reasonably assurance that 10 CFR 71 limits will be met.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SHIELDING EVALUATION

5.3 Provide the following information regarding the shielding analysis:

a. Confirm that the shielding analysis does not credit the presence of impact limiters in any way (i.e., axial surface dose rates are on the surface of the cask lid) otherwise clarify the analysis descriptions and justify, particularly for HAC, including the impact limiters.

b. Confirm that the MTR elements are positioned at the top of the cask cavity (i.e., touching the cask lid), or justify the position of the elements in the model.

c. Explain how the material densities used in the SAS4 model (see Calculation Package R-224204, Figure H-2) were determined.

d. Confirm that the SAS4 model does not contain any boron in the neutron shield (see Table 5.3.4-8) of the application.

The descriptions of the analysis, including figures and tables, regarding the analysis models are not clear or appear to be inconsistent. For item b, if the elements are able to move in the axial direction, the model should place the elements in the position that maximizes dose rates. For item c, it is not clear how the material densities in the input model were derived from the contents descriptions in the application and calculation package.

This information is needed to verify compliance with 10 CFR 71.35, 71.47, and 71.51.

NAC International Response to Shielding Evaluation RAI 5.3:

a.) Impact limiters are not included in any MTR shielding analysis. The last paragraph in Section 5.3.4 states, "...and it ignores the presence of the impact limiters."

b.) Last paragraph of Section 5.3.4 includes the statement that elements are pushed towards the cask top, "The model assumes that the fuel is at the highest point in the basket module..." A graphic of this model configuration can be seen in Figure 4-1 of calculation 14100.005.4.1.2.2. Later revision of the calculations (performed in support of later licensing amendments) previously incorporated into the NAC-LWT SAR, revised the models by shortening the non-fuel material (aluminum) section of the element. The fuel/source material axial location was retained in these models resulting in a model gap between the plate and lid. Movement of the source region further towards the ends of the cask cavity would not only present a non-typical element configuration but would also artificially inflate the analysis critical 2-meter dose value. SAS4 requires a symmetric around center line model which produces a double counting of the shifted

source region as the cask lead shield extends to the bottom of the cask cavity and does not contribute the same to the 2-meter value as the top region.

c.) The calculation of the fuel material densities in Figure H-2 are based on the material homogenization performed in the Excel file, Mtr_Xeu_calc_v17.xls, provided as a proprietary data disk to the initial submittal of the amendment request. See sheet "Fuel".

d.) The SAS4 models do not contain boron in the neutron shield. This can be confirmed within the proprietary input files provided with the amendment request. A statement reflecting this was added to the last paragraph of Section 5.3.4.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SHIELDING EVALUATION

5.4 Justify the appropriateness of linear interpolation between the analyzed burn up and cooling time combinations for defining the decay heat curves used to determine allowable MTR contents.

Information provided with the application includes some statements that the interpolation is conservative; however, there is little information provided to support this statement. The provided information applies to a single burnup and cooling time combination for only one of the heat load curves.

This information is needed to verify compliance with 10 CFR 71.35, 71.47, and 71.51.

NAC International Response to Shielding Evaluation RAI 5.4:

This response is discussed in relation to Section H-3 of the proprietary shielding calculation "14100.005.4.1.3.2" provided to NRC staff.

Heat load, as a function of cool time, is always an exponential decreasing curve (heat load on y-axis, time on x-axis); therefore, a linear interpolation between any two points on the curve will always produce a data point above the curve (i.e., heat load is overestimated). Generating source terms using the interpolated cool time will produce lower than allowed heat load at the interpolated cool time. This is conservative when constructing the minimum cool time curve. The amount of conservatism is dependent on the exponential slope and distance between data points used in the interpolation. For this particular analysis, the conservatism is ~2% in heat load.

NAC evaluations do not interpolate on neutron and gamma source terms. Rather, NAC uses the interpolated cool time to generate a single time specific set of sources. This will result in a heat load lower than allowed. If restricting the user to the load curves/tables, this would not be an issue as heat load and the neutron and gamma source term would be decreased at the longer required cool time. The MTR system allows users to employ a known heat load, when available, to verify acceptability for loading rather than employing the cool time curves. Therefore, it is important not to underestimate the source at a fixed heat load. For this reason, the calculated heat load is compared to the allowable heat load. While a 2% difference could be considered insignificant to the safety conclusions of the analysis, the analyst performing the analysis increased the heat load back to CoC limitation levels to assure bounding sources are generated.

The listed state point is the maximum burnup allowed and previous calculations produce the bounding dose profile. Therefore, it is the only state point discussed in this section.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SHIELDING EVALUATION

5.5 Explain and justify how lead slump was addressed in the HAC models for MTR fuel.

It is not clear from the application that lead slump was addressed in the HAC shielding analysis models for the MTR contents. The analysis should account for this slump in a way that is supported by, or conservative versus, the structural analysis for lead slump.

This information is needed to verify compliance with 10 CFR 71.51.

NAC International Response to Shielding Evaluation RAI 5.5:

Lead slump was not included in the shielding evaluation. A similar question was raised during the generation of the NRU/NRX amendment (Revision LWT-12D) and was resolved by including the following text in the shielding analysis section. The text has been added to Section 5.3.4, page 5.3.4-5 (MTR Shielding):

> "NAC procedures dictate that the lead is allowed to cool from the lowest point with molten lead from the top filling gaps formed during solidification. Therefore, no gap is expected to occur and further accident analyses detailing potential shifting of the lead gap are not necessary."

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SHIELDING EVALUATION

5.6 Provide descriptions of the conveyance, ISO container and personnel barrier and the assumptions regarding these items that are relied on for the shielding analysis. Also, include the dose rates for all relevant locations, as specified in the regulations for the type of transport assumed in the analysis.

The application, including the shielding analysis, mentions the conveyance and the use of an ISO container or a personnel barrier. However, there is no description of these items. In particular for the shielding analysis, the configuration of the package with respect to the conveyance, the ISO container, and the personnel barrier needs to be described. This includes the distances, both axial and radial, from the package to the ISO container, personnel barrier, and conveyance surfaces assumed in the analysis. The staff understands that a personnel barrier may be used instead of an ISO container; thus, the analysis should determine the dose rates that are bounding for use of either of these items.

It is also not clear that the dose rates for all locations were addressed. For example, the surface and 2 meter dose rate limits apply to all four directions (i.e., radial and axial directions) from the package, the ISO container (or personnel barrier) and the conveyance for exclusive-use transportation. The analysis in the application only addresses dose rates at 2 meters from the package's radial side and at the cab location. The analysis also needs to show the dose rates comply with the 2 meter limits at the axial ends of the package as well.

This information is needed to verify compliance with 10 CFR 71.47 and 71.51.

NAC International Response to Shielding Evaluation RAI 5.6:

The draft CoC was revised to indicate the requirement to transport MTR contents within an ISO container and not the use of a personnel barrier. All shielding evaluations are based on this premise. MTR fuel has never been transported in the personnel barrier configuration. Width and length of the ISO applied in the analysis is also added to Section 5.3.4, page 5.3.4-5.

Discussion and data are added to Sections 5.3.4.1 and 5.3.4.2 to address the 10 CFR 71.47 and 71.51 dose requirements.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SHIELDING EVALUATION

5.7 Provide the rest of the calculation package R-224204, "MTR Source Term and Shielding Analysis," and identify the changes made to the other sections of this calculation package.

The applicant only provided Appendix H of the calculation package. The information in Appendix H does not contain complete information regarding the shielding analysis, methods and models, and refers to other sections of the calculation package. The remainder of the calculation package is needed to understand the analyses and make a finding regarding acceptability of the requested CoC changes. It also appears that other sections of the calculation package have changed and should have been included in the submittal.

This information is needed to verify compliance with 10 CFR 71.47 and 71.51.

NAC International Response to Shielding Evaluation RAI 5.7:

As a response to the RAI the complete calculation is provided. Revision control changes indicate modified calculation sections. No changes beyond fuel mass (470 to 490 g), heat load (30 W to 40 W), and minimum cool time (90 days) were made to the methods and models previously employed for MTR licensing. To support this effort Appendix H was generated (fuel mass and heat load change) and Appendix F was modified (minimum cool time).

Note that the calculation is not the starting point for MTR shielding evaluations and does not contain a full history of all MTR submittals. Initial evaluations for MTR fuel are over 20 years old. This calculation request was first generated in 2000.

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SHIELDING EVALUATION

5.8 Include the limit of U-235 mass per element together with the U-235 mass per plate limit in the operations descriptions in Chapter 7 of the application and the proposed CoC No. condition 5(b)(2)(iv) regarding the contents limits.

Both the mass per plate and the mass per element limits must be satisfied for the element to be acceptable. The analyses do not support relying on only one limit or the other to define the acceptable MTR contents. For example, the shielding analysis uses the mass per element limit. An element with 23 plates at the maximum mass per plate, would have a U-235 content that exceeds that mass per element limit.

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

NAC International Response to Shielding Evaluation RAI 5.8:

The mass limits requiring partial load are a result of the criticality analysis, which applied a mass per plate limit. As noted by NRC staff, this allows a much higher total element mass than used in the shielding analysis. All shielding analyses are based on full cask loads not requiring partial loading. There is no intent to only rely on one limit. Section 5(b)(1) of the CoC lists both plate and element limits and both must be met.

Section 5(b)(2)(iv) and similar text in Chapter 7 refer to the partial load cask configuration, which are criticality driven and are appropriately limited by mass per plate. As requested by the NRC, element mass limits are added into Chapter 7 and to the proposed CoC (Section 5(b)(2)(iv)).

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SHIELDING EVALUATION

5.9 Modify Section 7.1.5.4 of the application to:

a. Add a statement to the end of the first paragraph to explicitly state that elements above the curve in the respective figures are acceptable, but those below the curve are not.

b. Correct the figure reference in LEU MTR #1.

c. Modify the LEU MTR procedures to address elements in the 10 to 20 watt range (these elements aren't covered by the current text). The procedures should be clear that elements below or beyond the end of the 10 watt curve and above the 20 watt curve are loaded as 20 watt elements.

d. Add the element mass limit for U-235 to the MTR LEU procedures; both the plate and the element mass limits must be met.

These modifications are needed to ensure the package operations are consistent with the package analyses and the operations are clear.

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

NAC International Response to Shielding Evaluation RAI 5.9:

All requested changes have been made in Section 7.1.5.4.

a.) A new paragraph is added to address item.

b.) Figure reference is revised #1.

c.) Another bullet is added to address 10 W to 20 W elements. The newly created bullet also includes the statement that element beyond the end of the 10 W curve and above 20 W curve are to be loaded as 20 W elements.

d.) Per element mass limits are added throughout Section 7.1.5 (see RAI 5.8).

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SHIELDING EVALUATION

5.10 Address the uncertainties associated with using the figures in Chapter 7 to determine the allowable contents, and the contents heat load. Also clarify how the package operations descriptions in Chapter 7 ensure the minimum cooling time of 90 days and the maximum burnup limits for MTR fuel, such as 139.3 GWd/MTU for 40W LEU fuel, are met.

The procedures for determining whether an MTR element is allowed to be loaded into the package and the elements heat load rely on interpreting decay time vs. burnup curves (e.g., Fig. 7.1-2-7, 12, 13). The scales of these curves is quite large, introducing uncertainties into the determination with impacts on both heat load and dose rates, particularly for elements on or near the curve. The uncertainties should be evaluated and accounted for, as appropriate, in the package analyses. The scale of the figures and the lack of a statement of the minimum cooling time and maximum burn up limits elsewhere in Chapter 7 of the application also make it unclear that the minimum 90 day cooling time and the maximum burnups of the MTR elements (e.g., 139.3 GWd/MTU for 40W LEU fuel) will be met.

This information is needed to verify compliance with 10 CFR 71.47, 71.51, and 71.87.

NAC International Response to Shielding Evaluation RAI 5.10:

The system user determines the acceptability of fuel to meet the system requirements. In this case it is the CoC and SAR Section 7.1.5. This includes accounting for any uncertainties within the fuel data, be that physical characteristics, calculated characteristics such as burnup, and/or interpretation of the load curves (including maximum burnup allowed by the curves). A note clarifying this responsibility has been added to SAR Section 7.1.5.4, page 7.1-22:

> "Uncertainties associated with burnup/depletion assignment for use with the load curves must be taken into account. Should an element be near the minimum load time determined by the load curves, or maximum burnup applicable to the curve, uncertainties in reading the curves must be taken into account."

A minimum 90-day load requirement has been added to Section 7.1.5.1 and is applicable to all MTR payloads. For LEU fuel, which is the modified payload for this application, a note has been added to Figure 7.1-13:

> "Maximum burnup allowed is 139.3 GWd/MTU and minimum cool time is 90 days".

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5.11 Justify the apparent extension of some of the curves in the Chapter 7 figures for determining the acceptability of fuel elements for shipment.

The curves in at least some of the figures in Chapter 7 (e.g., Figs. 7.1-4, 6, 7, 12) appear to have been extended beyond their currently approved form. No analysis was provided to support this extension.

This information is needed to verify compliance with 10 CFR 71.47, 71.51, and 71.87.

NAC International Response to Shielding Evaluation RAI 5.11:

Curves were extended in Chapter 7 to match the minimum 90-day cool time applied in the analysis. While Chapter 5 included MTR text referring to both 30 days (SAR Section 5.3.4) and 90 days (SAR Section 5.1), the curves in Chapter 7 reflected neither correctly (terminated prior to reaching the minimum cool time). The analysis presented in SAR Section 5.3.4 (Figure 5.3.4-6 through Figure 5.3.4-8) was added to justify acceptability of MTR elements at 90 days. Chapter 7 curves were generated to reflect the 90-day minimum justified in Chapter 5.

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SHIELDING EVALUATION

5.12 Modify Section 7.1.4 of the application to be consistent with the request, as supported by the analyses.

There is information in this section that is affected by the proposed changes. For example, the element and plate mass limits in #15 on page 7.1-16 need to be updated.

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

NAC International Response to Shielding Evaluation RAI 5.12:

The chapter was reviewed for "gram" and "g" labels associated with MTR LEU fuel. The element and mass indicated by the RAI were included in the only bullet not updated. The data was replaced by the updated mass request (max. 23.5 g ^{235}U per plate, max. 490 g ^{235}U per element).

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SHIELDING EVALUATION

5.13 Address the following, modifying the application as needed:

a. Confirm the 1 wt% boron content requirement for the neutron shield. The CoC states the neutron shield contains 1 wt% boron; however, the neutron shield specification in the drawings (315-40-02, Sht. 1 of 2) appears to result in a boron concentration that is much less than this concentration.

b. Clarify the weight of the MTR elements. Table 1.2-4 indicates 30 lbs while Table 5.1.1-2 says 13 lbs.

c. Explain the change to the maximum uranium mass values in Table 1.2-4. The 2.474 max kg U/element value for LEU MTR was deleted from this table; however, it is still in Table 5.1.1-2. The basis for the change is not clear.

d. Explain why note 4 of Table 1.2-4 is not part of the proposed CoC content conditions for MTR fuel. It appears it should be.

e. Correct the discussions of the maximum LEU MTR burn up to state the value is 139.3 GWd/MTU, which is the analyzed value (not the 140 GWd/MTU stated on page 5.3.4-3 of the application).

f. Correct the table references on page 5.3.4-3 of the application. The currently referenced tables do not show the information discussed where these tables are referenced.

g. Modify Figure 5.3.4-8 and/or the statement on page 5.3.4-2 that HEU cases bound MEU dose rates. The current Figure 5.3.4-8 does not support that statement. In addition, the figure also appears to conflict with the note at the bottom of Table 5.3.4-9. Modify, as necessary, the evaluations and conclusions that are based on the figure and its underlying analysis.

h. Ensure the correct regulatory limits are referenced in Section 7.3, in the note for step 3. If the objective of Section 7.3 is to ship an unloaded package as an empty package, as it would qualify in that regard per DOT requirements, the note in step 3 should refer to 49 CFR 173.428 vs. the current regulatory references.

This information is needed to verify compliance with 10 CFR 71.47, 71.51, and 71.87.

<u>NAC International Response to Shielding Evaluation RAI 5.13:</u>

a.) Table 8.2-1 includes the requirement for testing of the liquid neutron shield to assure that minimum required boron levels are maintained. This assures CoC limits are maintained. As noted by the RAI,

the Drawing No. 315-40-02 composition calculates out to less than 1%. To assure that the shield material contained the minimum CoC required 1 wt. % boron, additional potassium tetraborate was typically added to the solution. In 1998, the design drawing composition was modified to increase potassium tetraborate levels to assure compliance on initial mix. The updated requirement for potassium tetraborate specifies a range of 70 lb. (min) to75 lb. of per 100 gallon of solution. This calculates to approximately 7.4% by weight of the solution and exceeds the 1 wt% boron CoC requirements. As a response to this RAI, the Drawing No. 315-40-02 note on solution composition is updated to reflect values required to meet the CoC 1% boron.

b.) At the time Chapter 5 was constructed, MTR fuel element mass reference information indicated the fuel element mass at less than 13 lbs. Later variations showed the potential for slightly higher masses. As additional non-fuel hardware (aluminum for MTR elements) has no significant effect on the shielding safety analysis (fuel element overall mass is not used in the analysis), it was deemed by NAC not necessary to revise Chapter 5 values. The structural analysis used a significantly higher mass for its analysis. Table 2.2.1-1 of the SAR lists the following:

> "For conservatism, a design basis MTR fuel weight of 30 lbs./assy. is used in the structural analysis. The maximum MTR element weight is 13.2 lbs. for an intact element and 9.7 lbs. for the cut elements in the 42-element configuration."

As neither thermal nor criticality analysis would be impacted by additional hardware mass, the basket safety performance critical structural evaluation value was placed into the Chapter 1 summary table.

c.) Table 1.2-4 row entry is termed maximum U mass. The maximum U mass allowed is the 640 g ^{235}U LEU element, evaluated at a 19% ^{235}U enrichment, resulting in a maximum mass of 3.368 kg U. The 2.474 kg U mass was applicable to 470 g ^{235}U per element application. Rather than revising the mass to correspond to the 490 g ^{235}U (2.579 kg U) application, it was removed because at the higher mass level it still does not represent the maximum LEU Uranium mass. Table 5.1.1-2 was overlooked when the change was made. For consistency in response to RAI 2, the 2.4737 kg value is removed from Table 5.1.1-2.

d.) When the MTR HEU fuel type was added, which required Note 4 to Table 1.2-4, CoC Section 5(b)(1)(iv)(b) Generic MTR fuel Content Description was modified to add what is listed as Note 1 in the current CoC to mandate the minimum 2 cm of hardware.

e.) The 140 GWd/MTU LEU burnup value is replaced by 139.3 GWd/MTU throughout Chapters 1 and 5.

f.) References to Tables "5.4.3-x" were intended to reference Tables "5.3.4-x". No references to Section 5.4.3 tables were intended or required. They have been corrected. An editorial correction was made in this section when referencing the tables to also clarify the paragraph content.

g.) Table 5.3.4-9 contains dose data for the bounding HEU configuration, which is a preferentially loaded condition. Figure 5.3.4-6 through Figure 5.3.4-8 are only used to demonstrate that maximum burnup produces bounding source terms when compared to the minimum 90-day cool time source terms,

which includes short lived fission products. The fuel types and their evaluated fuel mass and heat load are listed on SAR page 5.3.4-3. The 30 W and 40 W MEU and LEU evaluations apply a uniform loading configuration (i.e. 42 loaded assemblies) totaling 210 W per basket for the 30 W MEU pattern and 280 W for the LEU 40 W pattern. The HEU plot shows dose comparisons based on a 120 W element placed into the center basket location (center element of Configuration 1) and not for the total 210 W total basket. Comparisons illustrate the effect on source magnitude and spectrum as cool time is reduced to minimum values and are not designed to total to the maximum dose rates. The maximum heat load element was chosen as maximum heat load allows the highest burnup to be evaluated at a fixed minimum heat load. Table 5.3.4-9 contains the maximum preferential loaded HEU dose rates. Section 5.3.4 was revised to clarify that the HEU case comparison does not represent total basket heat load/source. While maximum dose shown in Figure 5.3.4-8 is less than that of the MEU elements, this does not negate the statement that for the limiting preferentially loaded configuration the HEU material produces higher dose rates (Table 5.3.4-9) then the uniformly loaded MEU elements.

h.) The objective is to quantify the minimum required steps to prepare the empty NAC-LWT for shipment. The section is not meant to provide limitations to the empty shipment. No changes are required to this text.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

CRITICALITY EVALUATION

6.1 Clarify the intended content and provide appropriate criticality safety analysis to support this amendment request.

The application states that the amendment request is to allow up to 23.5 grams of U-235 per MTR plate and 23 plates per fuel element or 23 elements per fuel basket for loose plates and a maximum weight of 490 grams of U-235 per element or basket. The staff observed that these numbers do not match, i.e., 23 x 23.5 (grams) = 540.5 grams, the total weight of U-235 exceeds the 490 grams per fuel element/basket limit. Yet even with the lowest U-235 load per plate, the total uranium-235 load exceeds the 490 grams per element limit. The intended content should be clarified and the criticality safety analysis revised if necessary.

This information is needed to verify compliance with 10 CFR 71.55.

NAC International Response to Criticality Evaluation RAI 6.1:

The application documents that up to 23 plates with 23.5 g ^{235}U per plate is acceptable for criticality safety analysis. As documented, a reduced number of plates (< 23) are allowed to exist in the fuel element. MTR fuel elements are designed with various fuel plates. The MTR element that is part of this amendment request contains 21 fuel plates at a maximum 23.3 g ^{235}U (with a maximum per element mass of 486 g). The licensing evaluation could therefore have been based on a maximum 21 plates. As the 23 assembly configuration could be shown to be criticality safe, it was conservatively applied. Since it was evaluated to be criticality safe, it was placed within the CoC limitations. This approach is consistent with previously approved MTR amendment requests.

Shielding evaluations provide the effective limit on fuel mass; therefore, limits the number of plates at 23.5 grams per plate a fuel element may have. A 490 gram element was chosen to bound the element to be transported without unduly restricting the element load time (heat load is related to fuel mass at a fixed burnup; therefore, increases in fuel mass at a fixed burnup require increased cool time). The limits, as written, match the analysis and do not provide an inconsistency (i.e., an element may have lower fuel mass per plate and more plate, or vice versa, provided the shielding mass limit is maintained).

Both plate and element limits are within the CoC and must be met prior to transport. No revision to the criticality safety analysis is necessary.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

CRITICALITY EVALUATION

6.2 Review and justify or correct the statement on page 6.4.3-13.

Page 6.4.3-13 of the safety analysis report states: "Section 6.4.3.12 has demonstrated an active fuel width of 7.3 cm yields a k_s of greater than 0.95." This appears to be a typographical error and that the intended meaning is: "Section 6.4.3.12 has demonstrated an active fuel width of 7.3 cm yields a k_s of NOT greater than 0.95."

This information is needed to verify compliance with 10 CFR 71.55.

NAC International Response to Criticality Evaluation RAI 6.2:

The statement was reviewed and found to be correct within the context provided. The NAC-LWT MTR evaluations evolved over multiple iterations as variables were adjusted to accommodate various fuel types. SAR Section 6.4.3.14 contains extended characteristics for LEU elements and refers to SAR Section 6.4.3.12 as its baseline. SAR Section 6.4.3.12 includes LEU analysis set "H" which demonstrates that k_s for LEU fuel at a 6.6 cm width is below 0.95 and at a 7.3 cm width is greater than 0.95. Text to reflect this is included on SAR page 6.4.3-12 with data in Table 6.4.3-20. Per Table 6.4.3-20 at a 7.3 width the evaluated LEU element produced a k_s of 0.96082, i.e. greater 0.95.

Enclosure 2

List of Changes

NAC-LWT SAR, Revision LWT-14C

ANSTO OPAL Amendment RAI Responses

List of Changes, NAC-LWT SAR, Revision LWT-14C

Note: The List of Effective Pages and the Chapter Tables of Contents, including the List of Figures and the List of Tables, were revised as needed to incorporate the following changes.

Chapter 1

- Page 1-iii, changed Drawing 315-40-02 revision number from "24" to "25".
- Page 1.2-41, changed "Maximum Burnup, MWd/MTU" in the "TRIGA Cluster Rod" column from "140,000" to "139,300".

Chapter 2

- No changes.

Chapter 3

- No changes.

Chapter 4

- No changes.

Chapter 5

- Page 5.1.1-11, deleted "2.4737" from the "U Weight (kg/element)" in the "MTR (LEU)" column.
- Page 5.3.4-3, changed "140,000" MWd/MTU to "139,300 MWd/MTU" in the first full paragraph; changed last four sentences in the first full paragraph; added one new column "Heat per Element (W)" and note to the loading combination table.
- Page 5.3.4-4, added the first full paragraph.
- Page 5.3.4-5, added four new sentences to the middle of the paragraph, "The neutron shield material...the lead gap are not necessary." Added new text to the first and second bullets.
- Pages 5.3.4-6 thru 5.3.4-7, added new text and bulleted points.
- Page 5.3.4-7, added the last sentence to the second full paragraph in Section 5.3.4.2.
- Pages 5.3.4-8 thru 5.3.4-12, text flow changes.
- Page 5.3.4-13, added new Figure 5.3.4-9, "Assembly Total Neutron Source at Various Burnups – 490 grams ^{235}U LEU Fuel with 40 W Heat Load".
- Page 5.3.4.-14, added new Figure 5.3.4.-10, "Assembly Total Gamma Source at Various Burnups – 490 grams ^{235}U LEU Fuel with 40 W Heat Load".
- Pages 5.3.4-15 thru 5.3.4-21, text flow changes.
- Page 5.3.4-22, added a note to the bottom of the table.

Chapter 5 (cont'd)

- Pages 5.3.4-23 thru 5.3.4-24, text flow changes.
- Page 5.3.4-25, added "Notes:", note lettering "a", and note "b" to the bottom of the table.
- Pages 5.3.4-26 thru 5.3.4-28, text flow changes.

Chapter 6

- No changes.

Chapter 6 Appendices

- No changes.

Chapter 7

- Page 7.1-16, changed the first note content weight for line 15 from "470 g" to "490 g" and ">22 g" to "> 23.5 g"; editorial change from "black" to "block".
- Page 7.1-19, added "(490 g ^{235}U per element)" and "(640 g ^{235}U per element)" to the text in the second full paragraph of Section 7.1.5.
- Page 7.1-20, added the last sentence to item 1, "The minimum allowed...be 90 days." Added measurements to item 4 in Section 7.1.5.1.
- Page 7.1-21, added "(> 490 g ^{235}U per element)" to the item 1 in Section 7.1.5.2; added ", greater than 490 g ^{235}U per element" to the end of item 3 in Section 7.1.5.3.
- Page 7.1-22, added new second paragraph to Section 7.1.5.4; added "(up to 23.5 ^{235}U gram per plate)" to the fourth paragraph; changed item 1 reference from "Figure 7.1-12" to "Figure 7.1-13".
- Page 7.1-23, added new item 3, and renumbered downstream items.
- Pages 7.1-24 thru 7.1-34, text flow changes.
- Page 7.1-35, added "Note: Maximum burnup allowed is 139.3 GWd/MTU and minimum cool time is 90 days." beneath Figure 7.1-13.
- Pages 7.1-36 thru 7.1-58, text flow changes.

Chapter 8

- No changes.

Chapter 9

- No changes.

Enclosure 3

List of Drawing Changes

NAC-LWT SAR, Revision LWT-14C

ANSTO OPAL Amendment

List of Drawing Changes, NAC-LWT SAR, Revision LWT-14C

Drawing 315-40-02, Revision 25

Sheet 1:

1. Revised Delta Note 8 as follows: "THE NEUTRON SHIELD TANK IS FILLED WITH A WATER/ETHYLENE GLYCOL/POTASSIUM TETRA-BORATE MIXTURE THAT WILL NOT FREEZE AT-40°F (MIN) AND CONTAINS AT LEAST 1 WT.% BORON.", was "THE NEUTRON SHIELD TANK IS FILLED WITH A LIQUID CONSISTING OF 58 WT. % ETHYLENE GLYCOL, 39 WT.% DEMINERALIZED WATER, 3 WT.% POTASSIUM TETRA-BORATE ($K_2B_4O_7$)."

All Sheets:

2. Revised the title block.

Enclosure 4

Supporting Calculation:

Calculation 14100.005.4.1.2.2, Rev. 7

NAC-LWT SAR, Revision LWT-14C

ANSTO OPAL Amendment RAI Responses

NAC PROPRIETARY CALCULATION
14100.005.4.1.2.2, REV. 7
IS WITHHELD IN ITS ENTIRETY VIA
10 CFR 2.390

Enclosure 5

Proposed Changes for Revision 59 of Certificate of Compliance

No. 9225 for NAC-LWT Cask

NAC-LWT SAR, Revision LWT-14C

ANSTO OPAL Amendment RAI Responses

CoC Sections (revised)

CoC Page 2 of 31

5.(a)(2)(3) Drawings

LWT 315-40-02, Rev. 25 (Sheets 1-2) Body Assembly

CoC Page 8 of 31:

5.(b)(1) Type and form of material (continued)

(iv) (c) Expanded LEU MTR Fuel Content Description

Parameter	Base	≤7.0 cm Active Fuel Width				≤7.1 cm Active Fuel Width		≤7.15 cm Active Fuel Width		
Enrichment, wt. % ^{235}U	≤25	≤25				≤25		≤25		
Number of fuel plates	≤23	≤23				≤17	≤23	≤22	≤23	≤23
^{235}U content per plate	≤22	≤22	≤22	≤21.5	≤23.5	≤22		≤22	≤21.5	≤22
Plate thickness (cm)	≥0.115	≥0.119	≥0.115	≥0.115	≥0.130	≥0.115	≥0.200	≥0.119		
Clad Thickness (cm)	≥0.02									
Active fuel width (cm)	≤6.6	≤7.0				≤7.1		≤7.15		
Active fuel height (cm)	≥56	≥56	≥63	≥56		≥56		≥56	≥56	≥61
^{235}U content per element (g)	≤490	≤490				≤490		≤490		

CoC Page 20 of 31:

5.(b)(2) Maximum quantity of material per package (continued)

(iii) Deleted.

(iv) For MTR fuel elements as described in Item 5.(b)(1)(iv):

Up to 42 fuel elements positioned within the MTR fuel assembly basket (7 fuel elements per basket module). Each of the MTR basket cell openings may contain a loose plate canister. The contents of each loose plate canister are limited to the number of fuel plates, dimensions, and masses that are equivalent to an intact MTR fuel element, as specified in Item 5.(b)(1)(iv).

(a) The maximum decay heat is not to exceed 1.26 kilowatts per package, with each MTR fuel assembly basket module not to exceed 210 watts.

(b) HEU, MEU, and LEU MTR fuel elements with decay heat not exceeding 40 watts per element may be loaded in any basket position.

(c) Mixed HEU, MEU, and LEU MTR contents, with decay heat limits as specified above, are authorized.

(d) MTR fuel elements with degraded or mechanically damaged cladding are authorized, provided the total surface area of through-clad corrosion and/or mechanical damage does not exceed 5% of the total surface area of the damaged element.

(e) For HEU-MTR fuel elements only, the center fuel element in any basket module is not to exceed 120 watts. The two exterior fuel elements vertically in-line with the center assembly for transport are not to exceed 70 watts.

(f) MTR fuel elements containing more than 23.5 g ^{235}U per plate (490 g ^{235}U per element) are limited to up to four elements loaded in basket positions 4, 5, 6, and 7 of a seven-element basket per Figure 7.1-1 of the application. Basket positions 1, 2, and 3 are to be blocked by spacer hardware.

CoC Page 30 of 31

12. A personnel barrier must be used when shipping PWR or BWR assemblies. Shipments of MTR, DIDO fuel assemblies, TRIGA fuel elements, TRIGA fuel cluster rods, high burnup PWR or BWR rods, PWR MOX rods, TPBAR contents, PULSTAR fuel elements, spiral fuel assemblies, MOATA plate bundles, or irradiated hardware must use the ISO container.

CoC Page 31 of 31

19. Revision 59 of this certificate may be used until October 31, 2015.

REFERENCES

NAC International, Inc., application dated June 18, 2010.

NAC International, Inc., supplements dated February 3, March 2, and May 24, October 26, and December 5, 2012; January 14, February 14, July 19 (two supplements), October 18, December 31, 2013 and May XX, 2014.

Enclosure 6

SAR Page Changes and LOEP

No. 9225 for NAC-LWT Cask

NAC-LWT SAR, Revision LWT-14C

ANSTO OPAL Amendment

May 2014

Revision LWT-14C

NAC-LWT

Legal Weight Truck Cask System

SAFETY ANALYSIS REPORT

Volume 1 of 2

Docket No. 71-9225

NAC INTERNATIONAL

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315-40-110	Sheets 1 - 3	Rev 1	Weldment, 7 Cell Basket, Base Module, DIDO Fuel
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032236		Rev B	RERTR Primary Enclosure, General Atomics
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Table 1.2-4 Fuel Characteristics (Continued)

Parameter	Metallic Fuel	Metallic Fuel	Metallic Fuel	MTR HEU	MTR MEU	MTR LEU	TRIGA LEU Element	TRIGA HEU Element	TRIGA Cluster Rod
Maximum Number of Assemblies, Elements or Rods	15 rods (sound)	9 rods (failed)	3 rods (severely failed in filters)	42[1]	42	42[2]	140	140	560
Maximum Overall Weight, lbs	1805	1805	1805	30 (max)[3]	30 (max)[3]	30 (max)[3]	13.2 (max)[3]	8.82 (nom.) 13.2 (max)[3]	1.5[3]
Maximum Overall Length, in	120.5	120.5	120.5	25.4[4]	26.1[4]	26.1[4]	47.74[5]	47.74[5]	31.0
Maximum Active Fuel Length, in	120.0	120.0	120.0	24.8	25.6	25.6	15	15	22.5
Fuel Rod Cladding	Al	Al	Al	Al	Al	Al	Al or SS	Al or SS	Incoloy 800
Maximum Uranium, kg U	54.5	54.5	54.5	0.422 0.511	0.950	3.368[2]	0.824	0.196	0.0505 (HEU) 0.2894 (LEU)
Maximum Initial ^{235}U, wt %	Natural	Natural	Natural	94	94[6]	25	20	70	95 (HEU)/20 (LEU)
Maximum Burnup, MWd/MTU	1,600	1,600	1,600	Variable up to 660,000[7]	Variable up to 293,300	Variable up to 139,300	151,100 (80% ^{235}U)	460,000 (80% ^{235}U)	600,000 (HEU)/ 139,300 (LEU) (80% ^{235}U)
Maximum Unit Decay Heat, kW	0.036	0.036	0.036	Variable[8]	0.030[8]	0.030[8, 10]	0.0075	0.0075	0.001875
Maximum Cask Decay Heat, kW	0.54	0.54	0.54	1.26	1.26	1.26	1.05	1.05	1.05
Minimum Cool Time, yr	1	1	1	Variable[8]	Variable[8]	Variable[8]	Variable[9]	Variable[9]	Variable[9]

1 For NISTR fuel, 42 assemblies may be cut in half, producing 84 fuel-bearing pieces. Each fuel-bearing piece may contain up to 0.211 kgU.

2 MTR fuel elements having ^{235}U content >490 g (>23.5 g per plate) are limited to a total of 4 elements in a 7-element basket. Basket openings 1, 2 and 3 shall be blocked by cell block spacers to ensure that MTR elements are not loaded in these openings. Therefore, depending on the number of such 4-element baskets, the maximum number of elements per cask will be reduced accordingly.

3 Maximum weight of fuel element(s), spacer(s) and fuel can, as applicable, per basket module cell shall be 80 pounds.

4 For MTR fuel elements, which are cut to remove nonfuel-bearing hardware prior to transport, a nominal 0.28 inch of nonfuel or spacer hardware will remain above and below the active fuel region to allow for fuel handling operations. The HFBR element, with an element length of 57.24 inches, must be cut prior to shipment. For HEU MTR elements having >380 g ^{235}U but less than 460 g ^{235}U, a minimum of 2.0 cm (0.8 inch) of nonfuel hardware and/or spacers/plates shall be provided at the ends of the element.

5 Permissible fuel element length is limited to basket cavity length, which is a minimum 47.74 inches for the basket top module, 30.94 inches for the intermediate modules, and 32.64 inches for the bottom module.

6 Typical MEU enrichment is 45 wt% ^{235}U. Criticality analysis supports up to 94 wt% under the MEU fuel definition.

7 Maximum burnup is 660,000 MWd/MTU for 380g ^{235}U and 577,500 MWd/MTU for 460g ^{235}U.

8 Minimum cool times for MTR fuel, down to 90 days, shall be determined using the procedure presented in Section 7.1.5.

9 Minimum cool times for TRIGA fuel elements and fuel cluster rods, down to 90 days, are determined so that the maximum decay heat of any element to be shipped is ≤ 7.5 watts and any fuel cluster rod is ≤ 1.875 watts.

10 Up to five LEU MTR fuel assemblies with ≤ 40 W may be loaded per basket module with total heat load for the basket module ≤ 210 W. Fuel assembly selection shall be determined using the procedure presented in Section 7.1.5.

Table 1.2-4 Fuel Characteristics (Continued)

Parameter	DIDO HEU	DIDO MEU	DIDO LEU
Number of Fuel Cylinders per Assembly	4	4	4
Maximum Overall Weight (lb)[1]	15	15	15
Minimum Plate Thickness, in	0.051	0.051	0.051
Minimum Clad Thickness (Al), in	0.00984	0.00984	0.00984
Maximum ^{235}U per Element, g	190	190	190
Maximum Initial ^{235}U, wt %	94	94	94
Minimum Initial ^{235}U, wt %	90	40	19
Maximum Uranium, kg U	0.2111	0.4750	1.0000
Minimum Active Fuel Height, in	23.13	23.13	23.13
Minimum Element Height[2], in	24.21	24.21	24.21
Maximum Burnup, MWd/MTU	577,460	256,650	121,910
Maximum Unit Decay Heat[3], kW	0.025	0.025	0.025
Maximum Cask Decay Heat, kW	1.05	1.05	1.05
Minimum Cool Time[4], yr	Variable	Variable	Variable

1 Maximum weight of fuel element(s), spacer(s) and fuel can, as applicable, per basket module cell shall be 80 pounds.

2 Element height provides for spacing of fissile material. An optional spacer may be used to maintain spacing if the element is cut shorter than 24.21 inches.

3 Maximum unit decay heat of 0.025 kW allowed only in conjunction with spacers for top basket (see Section 7.1.4). The per element heat load is limited to 0.018 kW with no top basket spacer. For DIDO fuel elements loaded into a top ANSTO basket module, the maximum decay heat load is limited to 0.010 kW per element (with or without DFC).

4 Minimum cool times for DIDO fuel assemblies, down to 180 days, shall be determined using the procedure presented in Section 7.1.4.

May 2014

Revision LWT-14C

NAC-LWT

Legal Weight Truck Cask System

SAFETY ANALYSIS REPORT

Volume 2 of 2

Docket No. 71-9225

NAC INTERNATIONAL

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Table 5.1.1-2 Design Basis Fuel for Shielding Evaluation

Parameter	PWR	BWR	Metallic	MTR (HEU)	MTR (MEU)	MTR (LEU)	DIDO
Assembly Array	15 × 15	7 × 7	N/A	Parallel Plates	Parallel Plates	Parallel Plates	Fuel Tubes
Assembly or Element Weight (lbs)	1650	750	1805 (15 rods)	13.0 (max)	13.0 (max)	13.0 (max)	15.0 (max)
Assembly/Element/Rod Length (in)	162	176	120.5	25.23[5]	26.14[5]	26.14[5]	24.6
Active Fuel Length (in)	144	144	120.0	24.80	25.59	25.59	23.6
No. Rods per Assembly	204	49	N/A	N/A	N/A	N/A	N/A
No. of Plates per Element	N/A	N/A	N/A	23	23	23	4
Fuel Rod Diameter/Plate Thickness (in)	0.422	0.563	1.36	0.050	0.050	0.050	0.059
Clad Material	Zr-4	Zr-4	Al	Al	Al	Al	Al
Clad Thickness (in)	0.0243	0.032	0.080	0.0150	0.0150	0.0150	0.0167
Pellet Diameter/Meat Thickness (in)	0.3659	0.487	1.36	0.020	0.020	0.020	0.026
Fuel Material	UO_2	UO_2	U metal	U_3O_8-Al; U-Al; or U_3Si_2-Al	U_3O_8-Al; U-Al; or U_3Si_2-Al	U_3O_8-Al; U-Al; or U_3Si_2-Al	U_3O_8-Al; U-Al; or U_3Si_2-Al
Percent Theoretical Density	95	95	100	N/A	N/A	N/A	N/A
Enrichment (wt % ^{235}U)	3.7	4.0	Natural	90[8]	40[8]	19[8]	90 (HEU) 400 (MEU) 199 (LEU)
Maximum Average Burnup (MWd/MTU)	35,000	30,000	1,600	Variable up to 660,000[2,9]	Variable up to 293,300[2]	Variable up to 139,300[2]	Variable up to 577,460 (HEU) 256,650 (MEU) 121,910 (LEU)
Minimum Cool Time	2 Years	2 Years	1 Year	Variable down to 90 days[2]	Variable down to 90 days[2]	Variable down to 90 days[2]	Variable down to 180 days[10]
U Weight (kg/assembly)	475	198	N/A	N/A	N/A	N/A	N/A
U Weight (kg/element)	N/A	N/A	54.5	0.422 0.511	0.950	3.3684	0.2111 (HEU) 0.4750 (MEU) 1.0000 (LEU)
UO_2 Weight (kg/assembly)	538.9	224.3	N/A	N/A	N/A	N/A	N/A

Notes:

1. Up to 2 of the PWR rods may have a maximum average burnup of 65,000 MWd/MTU.
2. Variable cool time down to 90 days using the procedure in Section 7.1.4.
3. Design Basis normal condition source term is for ACPR fuel with 86,100 MWd/MTU (50% ^{235}U depletion) and accident condition source term is for FLIP-LEU-II with 151,100 MWd/MTU (80% ^{235}U depletion).
4. Detailed fuel data is presented in Tables 1.2-1 and 6.2.5-1. The values presented here are the physical values for the bounding source terms of the ACPR and FLIP-LEU-II fuel types.
5. For MTR fuel assemblies, which are cut to remove non-fuel bearing hardware prior to transport, a nominal 0.28 inch of nonfuel hardware will remain above and below the active fuel region to allow for fuel handling operations
6. Minimum cool time varies with burnup such that maximum decay heat is 1.875 watts/rod.
7. Varies with burnup – see Table 5.3.8-29.
8. For the shielding evaluation, lower values are conservatively assumed.
9. Maximum burnup of 660,000 MWd/MTU for 380 g ^{235}U and 577,500 MWd/MTU for 460 g ^{235}U.
10. Variable cool time down to 180 days using the procedure in Section 7.1.4.

Table 5.1.1-2 Design Basis Fuel for Shielding Evaluation (continued)

Parameter	PWR Rods	High B/U PWR Rods	High B/U BWR Rods	PWR MOX/UO_2 Rods	TRIGA[4]	TRIGA Fuel Cluster Rods	TPBARs
Assembly Array	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Assembly or Element Weight (lbs)	N/A	N/A	N/A	N/A	8.82 (nominal) 13.2 (max)		2.655
Assembly/Element/Rod Length (in)	162	162	176.1	162	45	31.0	153.035 (pre-irradiation)
Active Fuel Length (in)	144	150	150	153.5	15	22	N/A
No. Rods per Assembly per Shipment	25	25	25	16	1	1	300 Production or 55 Segmented
No. of Plates per Element	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Fuel Rod Diameter/Plate Thickness (in)	0.422	0.440	0.570 (7×7) 0.4961 (other)	0.440	1.478	0.542	0.381
Clad Material	Zr-4	Zr-4	Zr-2	Zirc Alloy	304SS	Incoloy 800	316 SS
Clad Thickness (in)	0.242	0.026	0.036 (7×7) 0.0343 (other)	0.026	0.02	0.016	0.0225
Pellet Diameter/Meat Thickness (in)	0.3659	0.3805	0.4900 (7×7) 0.4213 (other)	0.3805	1.435 (max)	0.510	N/A
Fuel Material	UO_2	UO_2	UO_2	UO_2 – PuO_2/ UO_2	U-ZrH	U-ZrH	N/A
Percent Theoretical Density	97	95	95	95	95	95	N/A
Enrichment (wt % ^{235}U)	5.0	5.0	5.0	5.0 (UO_2) 7.0 fissile Pu (MOX))	20	92 (HEU) 19 (LEU)	N/A
Maximum Average Burnup (MWd/MTHM)	60,000[1]	80,000	60,000 – 80,000	62,500	ACPR 86,100 (50% ^{235}U)[3] FLIP-LEU-II 151,100 (80% ^{235}U)[3]	Variable up to 600,000 (HEU) Variable up to 140,000 (LEU)	N/A
Minimum Cool Time	150 days	150 days	Varies with burnup[7]	90 days (Power Grade MOX – 120 days)	ACPR 231 days FLIP-LEU-II 908 days	Varies with burnup[6]	30 days for production TPBAR; 90 days for PIE TPBAR
U Weight (kg/assembly)	58.2	65.6	108.8 (7×7) 91.3 (other)	N/A	N/A	N/A	N/A
HM Weight (kg/element)	N/A	N/A	N/A	2.63[11]	ACPR 0.280 FLIP-LEU-II 0.824	0.0505 (HEU) 0.2894 (LEU)	N/A
UO_2 Weight (kg/assembly)	66.0	66.0	74.5	N/A	N/A	N/A	N/A

Notes:
1. Up to 2 of the PWR rods may have a maximum average burnup of 65,000 MWd/MTU.
2. Variable cool time down to 90 days using the procedure in Section 7.1.4.
3. Design Basis normal condition source term is for ACPR fuel with 86,100 MWd/MTU (50% ^{235}U depletion) and accident condition source term is for FLIP-LEU-II with 151,100 MWd/MTU (80% ^{235}U depletion).
4. Detailed fuel data is presented in Tables 1.2-1 and 6.2.5-1. The values presented here are the physical values for the bounding source terms of the ACPR and FLIP-LEU-II fuel types.
5. For MTR fuel assemblies, which are cut to remove nonfuel-bearing hardware prior to transport, a nominal 0.28 inch of nonfuel hardware will remain above and below the active fuel region to allow for fuel handling operations.
6. Minimum cool time varies with burnup such that maximum decay heat is 1.875 watts/rod.
7. Varies with burnup – see Table 5.3.8-29.
8. For the shielding evaluation, lower values are conservatively assumed.
9. Maximum burnup of 660,000 MWd/MTU for 380 g ^{235}U and 577,500 MWd/MTU for 460 g ^{235}U.
10. Variable cool time down to 180 days using the procedure in Section 7.1.4.
11. Heavy metal weight per rod.

case, which was bounding. The SAS2H results from these cases are used for the design basis photon and neutron source terms and are summarized in Table 5.3.4-2 and Table 5.3.4-3 for 380 grams ^{235}U and Table 5.3.4-4 and Table 5.3.4-5 for 460 grams ^{235}U. The material densities used in the analysis are summarized in Table 5.3.4-8. Minimum cool time curves for the various MTR fuel and loading configurations are shown in Section 7.1.5.

The 490-gram ^{235}U and 40 W per element configuration is evaluated identically to that applied to the lower and higher mass LEU element, MEU, and HEU elements. SAS2H cases are run between 1% and 80% with a minimum cool time of 90 days. At maximum depletion the element requires 424 days to decay to a heat load of 40 W per element. Dose rates are determined at the maximum depletion (equivalent burnup of 139,300 MWd/MTU) and a reduced cool time of 402 days for that statepoint (heat load marginally greater than 40 W). Gamma and neutron source terms at this statepoint are shown in Table 5.3.4-16 and Table 5.3.4-17. LEU 40 W radial cask and 2 meters from conveyance dose rates are illustrated in Figure 5.3.4-4 and Figure 5.3.4-5. Dose rates were plotted for the radial cask and 2 meters from conveyance surfaces as they present the limiting locations (i.e., nearest approach to regulatory limits) for NAC-LWT transport of MTR fuel. The limiting location determination was based on the HEU dose rates shown in Table 5.3.4-9 through Table 5.3.4-15. LEU 40 W dose rates are below or statistically equivalent to those of the preferentially loaded HEU fuel shown in Table 5.3.4-9 and Table 5.3.4-11. Note that this evaluation conservatively applies 40 W elements to all seven basket positions.

Minimum allowed cool time for MTR fuels is set to 90 days. Below 90 days the potential exists for high power core operations to produce significant amounts of short lived radionuclides (in particular ^{140}La with a 2-day half life and a 1.5 MeV gamma peak, parent nuclide is ^{140}Ba, a fission product with 13-day half life) with significant higher gamma penetration energies then those applied at the maximum depletion/burnup statepoint used in the evaluations discussed in the previous paragraphs. Restricting the minimum cool time to 90 days eliminates this concern. To verify acceptability, the following loading combinations were evaluated:

Fuel Type	^{235}U Mass (g)	Heat per Element (W)	Heat per Basket (W)
LEU	490	40	280
MEU	380	30	210
HEU	460	120	120[1]

Note 1: Only the center element was evaluated to demonstrate that maximum permitted burnup dose rates bound the minimum 90-day cool time dose rates.

Each fuel type was evaluated at 90 days at maximum depletion to reach the desired heat load. Results of a comparison between minimum cool time and maximum depletion dose rates (fixed heat load) are shown in Figures 5.3.4-6 through 5.3.4-8. LEU and HEU data produces maximum dose

rates at maximum depletion. MEU, while showing slightly higher dose at the low depletion point, is significantly bounded by the LEU and HEU cases and is, therefore, acceptable.

To provide justification that intermediate statepoints along the equal heat load burnup/cool time curve do not produce bounding dose rates, additional evaluations are presented for the LEU (490 g ^{235}U) element. Sources are generated at a 40 W level for all burnup/cool time combinations. The total neutron and gamma source (in units of MeV/s) are compared in Figure 5.3.4-9 and Figure 5.3.4-10, respectively. The neutron source increases exponentially with increasing burnup. The gamma sources peak at lower burnups where lower heat loads allow reduced cool times. At the reduced cool times shorter lived fission products contribute significantly to the gamma source. The gamma source at 80% burnup is greater than any other burnup greater than 30%. At any burnup less than 30%, the neutron source will result in negligible dose rates. Therefore, at burnups greater than 30%, the maximum burnup will produce maximum dose rates due to maximum gamma and neutron source. At burnups less than 30%, the minimum burnup will produce maximum dose rates due to maximum gamma source and negligible neutron source.

MTR elements may contain a small amount of cadmium (maximum 100 grams Cd) in the form of nonfuel hardware. Table 5.3.4-6 and Table 5.3.4-7 contain comparisons of the cadmium light element gamma source compared to the U-Al fuel material gamma source. The light element source is produced during the SAS2H depletion analysis and applies 100% of the element flux levels. Included for comparison are HEU (460 gram) and LEU (640 gram) fuel types at the maximum allowed burnup (i.e., maximum activation) and cool times required to meet 30 watts (uniform heat load limit per element). Also shown are conservative comparisons of the design basis 30-watt fuel source to a 90-day-cooled Cd source. As shown in the comparison tables, the cadmium source is not significant to NAC-LWT cask shielding evaluations. The hardware gamma source of the cadmium represents less than 0.1% of the fuel gamma source at the required minimum cool time and less than 2% at the conservative 90-day-cooled Cd source. As the majority of the Cd source is at energy lines less than 0.5 MeV and does not penetrate the NAC-LWT cask shields, the actual effect on dose rates is even smaller than that indicated by the difference in total source magnitude.

Based on the MTR source term calculation, the (alpha, n) reactions in ^{27}Al and ^{28}Si are included in the MTR neutron source term. The (alpha, n) reactions in ^{27}Al and ^{28}Si increase the neutron source term by a factor of ~2.9. Consequently, a factor of 2.9 is applied to the MTR neutron source terms.

The SAS4 (Tang) sequence is used to calculate the dose rates at all points of interest. In this sequence, a 1D adjoint XSDRNPM model generates biasing parameters for a 3D MORSE Monte Carlo model of the NAC-LWT cask with the MTR fuel. SAS4 requires model symmetry about the active fuel midplane (midplane of the six basket modules in this case). A 3D Monte Carlo model is developed for the upper half of the cask. This model bounds the results for a lower half model as the cask has more shielding in the axial direction at the bottom end. The upper half

model is shown in Figure 5.3.4-2. The model assumes that the fuel is at the highest point in the basket module, that the fuel is loaded in the same way axially in all of the modules, and it ignores the presence of the impact limiters. The neutron shield material is modeled as a water/glycol mixture and does not contain boron. No lead slump is included in the NAC-LWT MTR shielding model. NAC procedures dictate that the lead is allowed to cool from the lowest point with molten lead from the top filling gaps formed during solidification. Therefore, no gap is expected to occur and further accident analyses detailing potential shifting of the lead gap are not necessary. Detectors are placed at three radial locations of interest. These locations are: 1) cask surface; 2) one meter from the cask surface; and 3) at two meters from the edge of the cask conveyance.

5.3.4.1 Shielding Evaluation for MTR Fuel

This section presents the shielding analyses for normal conditions of transport, illustrates compliance with 10 CFR Part 71. In normal transport, the dose rate limits are:

- The dose rate on the surface of the package is less than 200 mrem/hr. Localized dose rates up to 1000 mrem/hr are allowed if it is shown that the dose rate on the surface of the ISO enclosure (ISO container is 20 ft long by 8 ft wide) is less than 200 mrem/hr.

  The transport cask is centered within the 8 foot width of the ISO by the cask support structure. Conveyance vertical planes are therefore at a radial distance of 121.96 cm from the cask centerline. The transport cask is centered within the ISO length. The cask length with impact limiters is ~232 inches leaving minimal free space.

- At 2 meters from the edge of the transport vehicle the dose rate is limited to 10 mrem/hr. Detectors are placed at radial distances of 321.96 cm, which is one half the ISO width plus 2 meters.
- The truck cab (defined as a point 5 meters from the NAC-LWT lid) dose rate is limited to 2 mrem/hr.

The dose rates for the bounding loading configuration (Configuration 1) are shown in Table 5.3.4-9, Table 5.3.4-10 and Table 5.3.4-11 for the cask surface, plane of conveyance, and at 2 meters from the edge of the conveyance, respectively. These dose rates are well below the regulatory limits. The dose rates at 1 meter from the cask surface are presented in Table 5.3.4-12, where the maximum dose rate defines the Transport Index (TI) for the cask.

The axial surface and the 5 meter (back of tractor cab) dose rates are shown in Table 5.3.4-13 and Table 5.3.4-14. Shielding provided by the impact limiter is conservatively neglected. The axial dose rates at the bottom of the cask are conservatively assumed to be equal to the dose rates reported at the top.

Dose rates on the external surface of the package are limited to 1000 mrem/hr, as specified by 10 CFR 71.47 (b)(1). MTR fuel transport meets subsection (i), (ii), and (iii) by placing the NRC-LWT into an ISO container with the cask secured to the ISO container by a transport frame. There is no loading and unloading of the contents between beginning and end of transportation. Per Table 5.3.4-9 and Table 5.3.4-13, both radial and axial dose rates are significantly below this limit.

A vehicle outer surface dose rate limit of 2 mSv/h (200 mrem/hr) is stated in 10 CFR 71.47(b)(2). The dose rate limit is applicable to the top and underside of the vehicle.

- Table 5.3.4-10 contains dose rates at a radial distance of 48 inches from the centerline of the cask, which represents the vertical walls of the ISO container. Dose rates calculated are below 50 mrem/hr and demonstrate compliance with the regulation.
- In the cask axial direction (ends of the ISO container), Table 5.3.4-13 demonstrates that maximum dose rates on the cask lid are only slightly above this limit and drop by over an order of magnitude at a distance of 1 meter. The table values were calculated without consideration of either spacing and material of the impact limiter, or spacing and material of the ISO container. The data is considered sufficient to demonstrate that at the outer surface of the vehicle (the outer surface of the ISO container for this requirement), dose rates will be less than 200 mrem/hr.
- The NAC-LWT is located on a transport frame within the ISO container cavity. The transport frame secures the cask slightly below the ISO container centerline. The reference dimension offset is ~43 inches from the lower surface of an 8 foot (reference dimension) ISO container height. Table 5.3.4-10 results demonstrate top side dose rates are below dose rate limits. Thus, the package is acceptable with respect to top side dose rates.
- While the lower surface of the ISO container is ~5 inches (reference dimension) closer to the cask centerline than the detectors applied in the analysis, the cask/ISO container combination is located on a truck bed during typical transport operations. The truck bed will provide additional spacing to vehicle underside locations. The ISO container material and the truck bed provide shielding to the underside of the vehicle. The ISO container and the truck bed material will more than offset the minor dimensional differences in detector location making Table 5.3.4-10 results bounding for the vehicle underside dose rates. Therefore, the dose rate limits are met on the underside of the vehicle.

Dose rates at any point 2 meters (80 in) from the outer lateral surfaces of the vehicle (excluding the top and underside of the vehicle) are limited to 0.1 mSv/h (10 mrem/hr) as specified by 10 CFR 71.47(b)(3). Table 5.3.4-11 demonstrates that this limit is met at 2 meters from the radial surface of the cask/ISO container. Table 5.3.4-13 states the maximum dose rate at 1 meter from

the cask lid surface is < 11 mrem/hr. While the calculated dose rate at 1 meter from the lid is slightly in excess of the 10 mrem/hr limit, geometric attenuation would produce dose rates well below 10 mrem/hr at 2 meters from the vehicle (over a factor of 10 drop occurs between surface and 1 meter). Therefore, regulatory limits will be met without crediting either the impact limiter or the ISO container spacing and materials. As described in 10 CFR 71.47(b)(4), the 2 mrem/hr normally occupied position criteria is met per Table 5.3.4-14.

This evaluation shows that the NAC-LWT cask, with up to 42 MTR fuel assemblies, meets the shielding requirements of 10 CFR 71, 49 CFR 173, and IAEA Transportation Safety Standards (TS-R-1).

5.3.4.2 Accident Conditions of Transport

This section presents the accident condition shielding analyses. Under accident conditions, the NRC limits the package dose rate to 1000 mrem/hr at 1 meter off the package surface. The only accident condition examined in this section is the loss of the LWT liquid neutron shield.

This analysis examines Configuration 1 consistent with the limiting configuration analysis for normal conditions of transport presented in Section 5.3.4. The accident condition source terms are identical to the normal condition source terms. The accident condition results are presented in Table 5.3.4-15. Only radial results are presented for the normal condition. Axial surface dose analysis was based on the loss of the impact limiters and produced results at the lid surface significantly below the 1000 mrem/hr accident condition limit at 1 meter.

Figure 5.3.4-1 MTR Fuel Evaluated Configurations

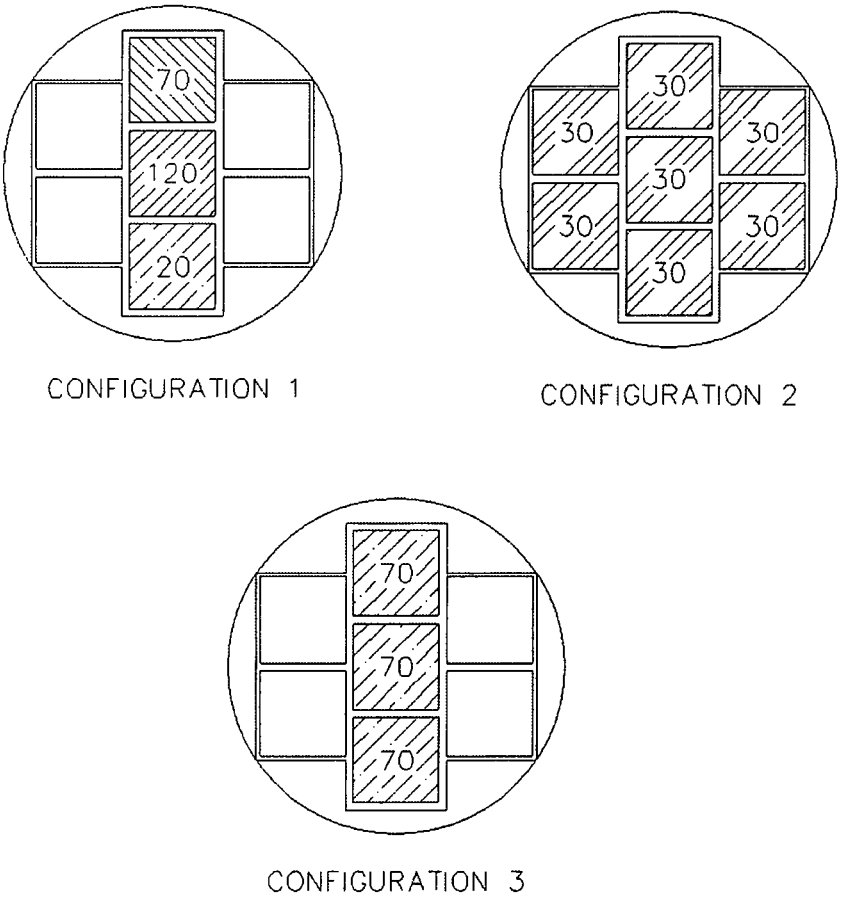


Figure 5.3.4-2 SAS4 Shielding Model for the MTR Fuel Basket in the NAC-LWT (Upper Half)

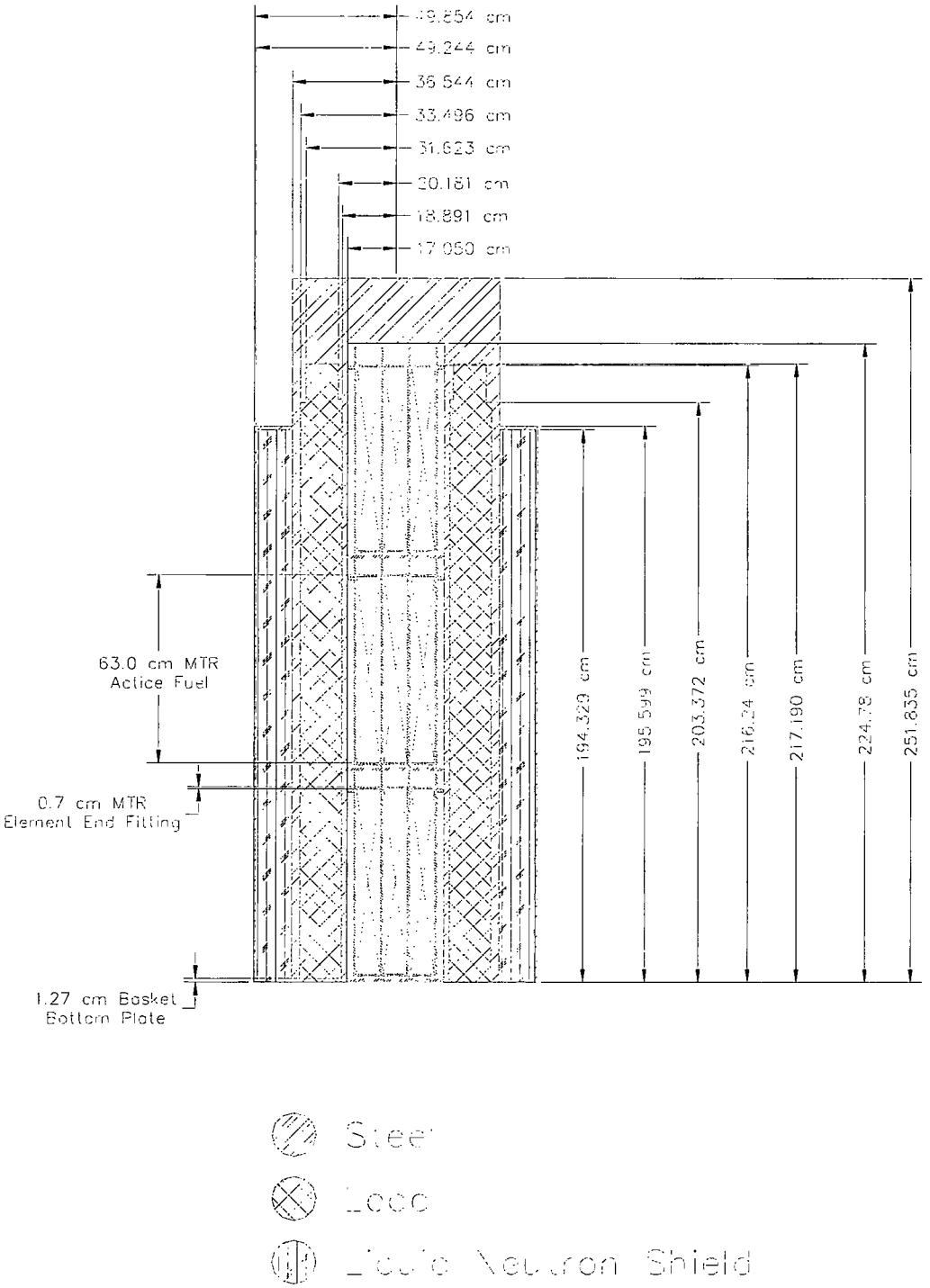
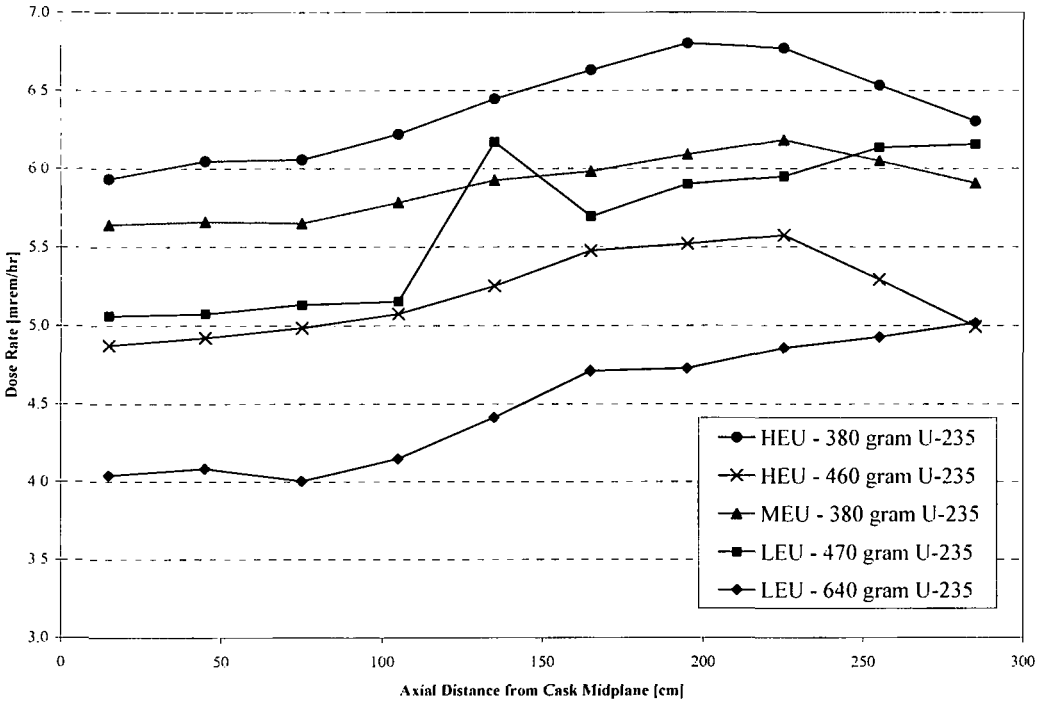


Figure 5.3.4-3 Dose Rates 2 Meters from Transport Vehicle (30 W Uniform Loading)



Note: The 40 W per element LEU and preferential loaded HEU patterns are not shown in this figure as the figure is designed to demonstrate fuel material enrichment and mass impact on dose rate at a fixed heat load.

Figure 5.3.4-4 Dose Rate Profile at Radial Surface of LWT Cask – Normal Conditions – LEU Fuel at 80% Burnup and 40W Uniform Loading

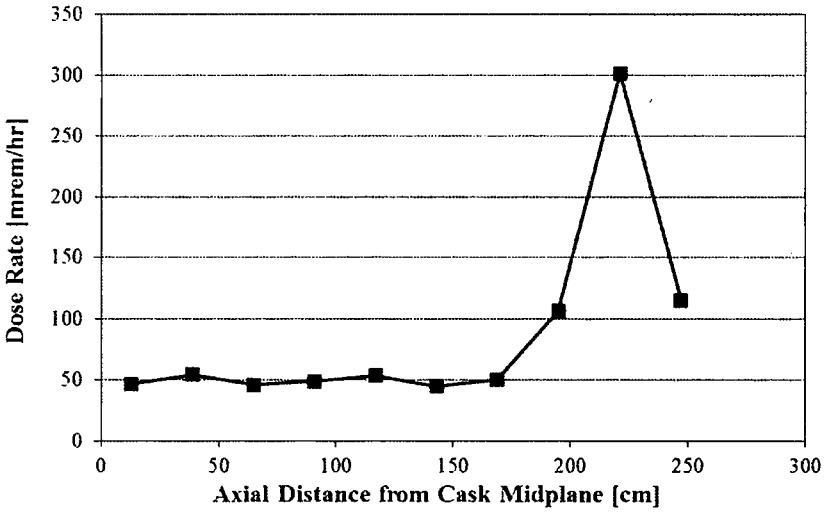


Figure 5.3.4-5 Dose Rate Profile at 2m from Conveyance Radial Surface of LWT Cask – Normal Conditions – LEU Fuel at 80% Burnup and 40W Uniform Loading

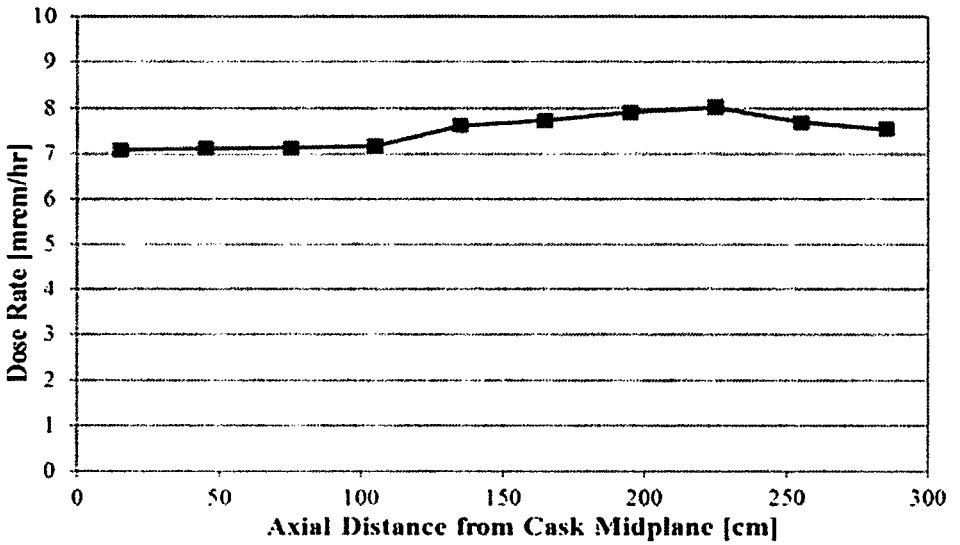


Figure 5.3.4-6 MTR LEU Low Burnup Dose Rate Profile Comparison

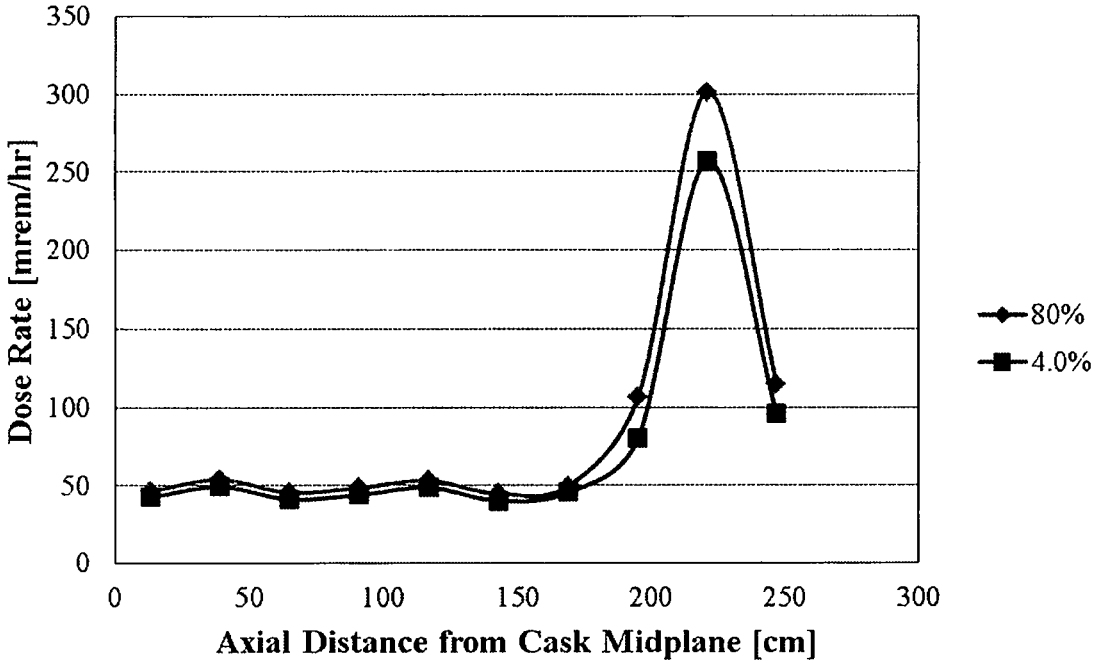


Figure 5.3.4-7 MTR MEU Low Burnup Dose Rate Profile Comparison

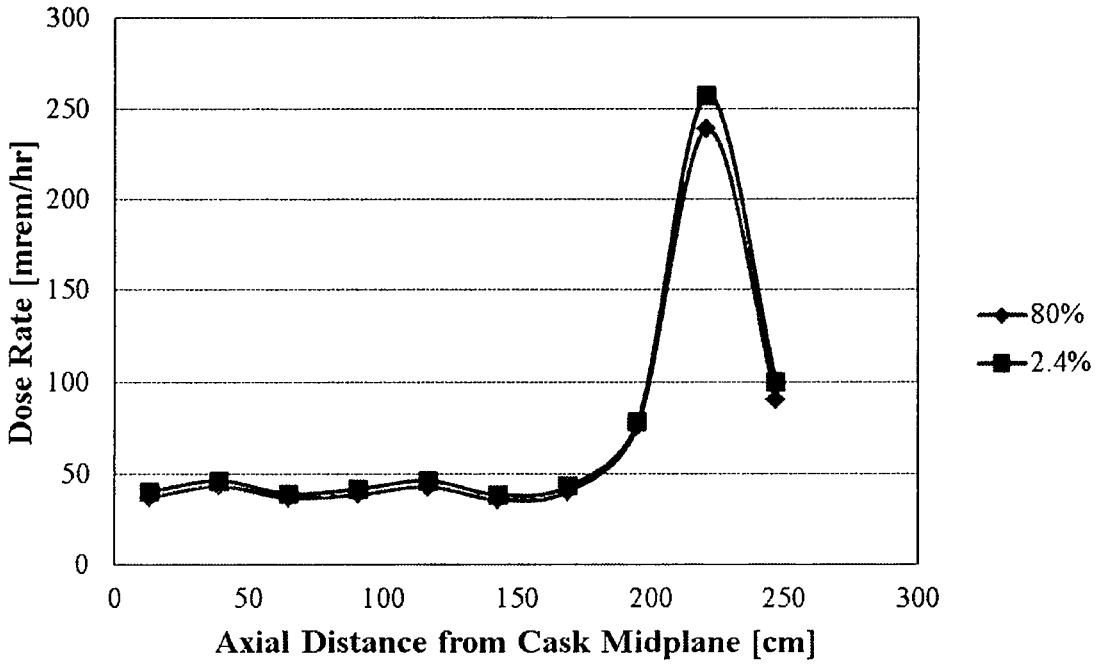


Figure 5.3.4-8 MTR HEU Low Burnup Dose Rate Profile Comparison

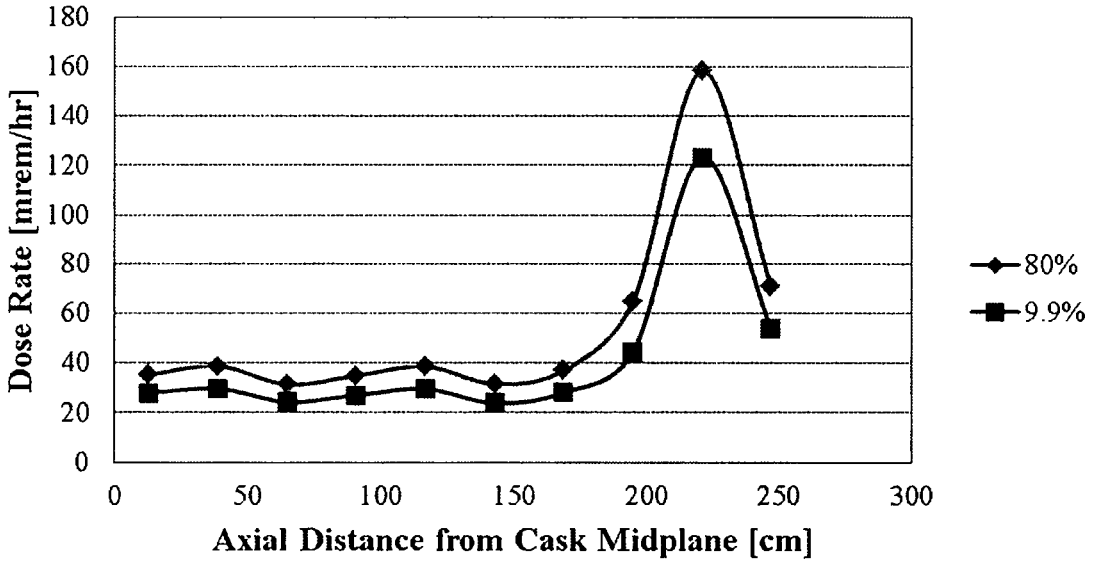


Figure 5.3.4-9 Assembly Total Neutron Source at Various Burnups – 490 grams ^{235}U LEU Fuel with 40 W Heat Load

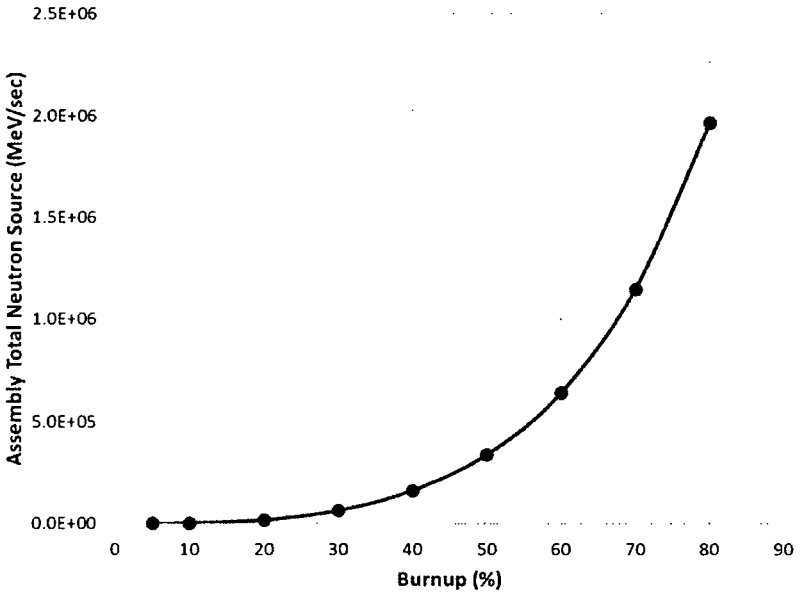


Figure 5.3.4-10 Assembly Total Gamma Source at Various Burnups – 490 grams ^{235}U LEU Fuel with 40 W Heat Load

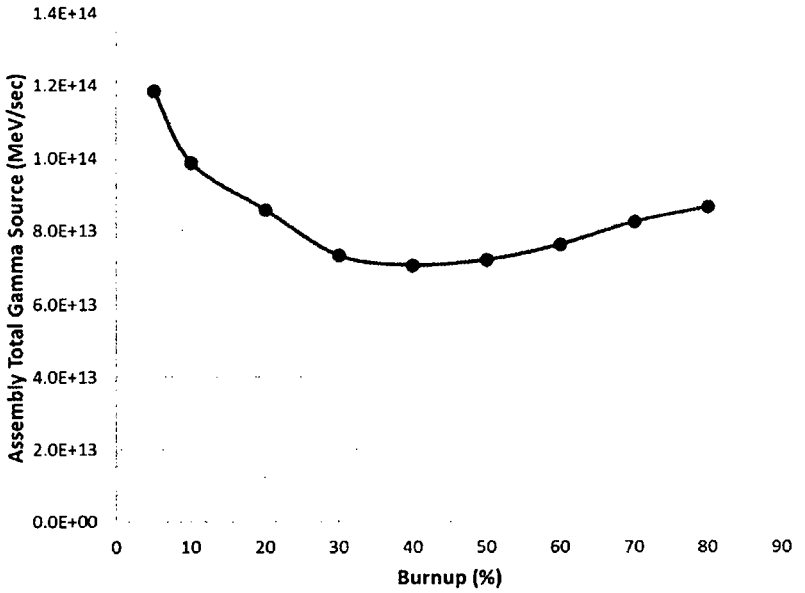


Table 5.3.4-1 Design Basis MTR Fuel Assembly Characteristics

Fuel Parameters	Units	HEU	MEU	LEU
Element Width	[cm]	7.6	7.6	7.6
Element Depth	[cm]	8.0	8.0	8.0
Side Plate Thickness	[cm]	0.475	0.475	0.475
Side Plate Depth	[cm]	7.5	7.5	7.5
Number of Plates		23	23	23
Plate Thickness	[cm]	0.127	0.127	0.127
Active Fuel Length	[cm]	63	65	65
Active Fuel Width	[cm]	6.35	6.35	6.35
Active Fuel Thickness	[cm]	0.051	0.051	0.051
Cut End Length	[cm]	0.7	0.7	0.7
Fuel Composition		U-Al	U-Al	U-Al
Wt % ^{235}U		90	40	19
Maximum ^{235}U per Fuel Assembly	[g]	380[1]	380	470[2]
Wt % U in Fuel Composition		30	50	75

[1] HEU fuel was also analyzed at 460 grams of ^{235}U per fuel element.
[2] LEU fuel was also analyzed at 490 and 640 grams of ^{235}U per fuel element. The 490-gram ^{235}U patten is evaluated to a higher heat load of 40 W per element.

Table 5.3.4-2 MTR Fuel Element Gamma Source Terms by Thermal Output – 380 grams ^{235}U

Burnup 660,000 MWd/MTU			MTR Assembly Thermal Output			
			20 Watts	30 Watts	70 Watts	120 Watts
Group	E_{hi} (Mev)	E_{low} (Mev)	2162 Days (g/sec)	1413 Days (g/sec)	581 Days (g/sec)	330 Days (g/sec)
1	10.00	8.00	1.63E+03	1.81E+03	2.08E+03	2.21E+03
2	8.00	6.50	7.69E+03	8.52E+03	9.79E+03	1.04E+04
3	6.50	5.00	3.92E+04	4.35E+04	4.99E+04	5.30E+04
4	5.00	4.00	9.77E+04	1.08E+05	1.24E+05	1.32E+05
5	4.00	3.00	3.30E+07	1.32E+08	6.24E+08	9.96E+08
6	3.00	2.50	2.81E+08	1.17E+09	5.84E+09	9.56E+09
7	2.50	2.00	2.45E+10	1.47E+11	1.09E+12	2.00E+12
8	2.00	1.66	6.34E+09	2.33E+10	1.32E+11	2.34E+11
9	1.66	1.33	5.93E+11	1.19E+12	3.01E+12	4.20E+12
10	1.33	1.00	1.87E+12	2.75E+12	5.21E+12	6.81E+12
11	1.00	0.80	8.36E+12	1.61E+13	3.47E+13	4.42E+13
12	0.80	0.60	4.21E+13	6.14E+13	1.14E+14	2.15E+14
13	0.60	0.40	1.70E+13	3.41E+13	7.83E+13	1.04E+14
14	0.40	0.30	9.18E+11	1.71E+12	7.11E+12	1.23E+13
15	0.30	0.20	1.42E+12	2.47E+12	9.38E+12	1.62E+13
16	0.20	0.10	5.22E+12	9.84E+12	4.12E+13	7.19E+13
17	0.10	0.05	6.33E+12	1.09E+13	4.07E+13	7.00E+13
18	0.05	0.01	2.19E+13	3.60E+13	1.26E+14	2.15E+14
Total	--	--	1.06E+14	1.77E+14	4.60E+14	7.61E+14

Table 5.3.4-3 MTR Fuel Element Neutron Source Terms by Thermal Output – 380 grams ^{235}U

Burnup 660,000 MWd/MTU			MTR Assembly Thermal Output			
			20 Watts	30 Watts	70 Watts	120 Watts
Group	E_{hi} (Mev)	E_{low} (Mev)	2162 Days (n/sec)	1413 Days (n/sec)	581 Days (n/sec)	330Days (n/sec)
1	2.00E+01	6.43E+00	5.42E+04	6.06E+04	7.06E+04	7.52E+04
2	6.43E+00	3.00E+00	6.26E+05	6.98E+05	8.12E+05	8.67E+05
3	3.00E+00	1.85E+00	7.11E+05	7.90E+05	9.14E+05	9.74E+05
4	1.85E+00	1.40E+00	3.92E+05	4.37E+05	5.07E+05	5.39E+05
5	1.40E+00	9.00E-01	5.25E+05	5.86E+05	6.81E+05	7.24E+05
6	9.00E-01	4.00E-01	5.69E+05	6.36E+05	7.40E+05	7.87E+05
7	4.00E-01	1.00E-01	1.11E+05	1.24E+05	1.45E+05	1.54E+05
8	1.00E-01	1.70E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9	1.70E-02	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
10	3.00E-03	5.50E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11	5.50E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12	1.00E-04	3.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
13	3.00E-05	1.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14	1.00E-05	3.05E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
15	3.05E-06	1.77E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
16	1.77E-06	1.30E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	1.30E-06	1.13E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	1.13E-06	1.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
19	1.00E-06	8.00E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	8.00E-07	4.00E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
21	4.00E-07	3.25E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
22	3.25E-07	2.25E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
23	2.25E-07	1.00E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
24	1.00E-07	5.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25	5.00E-08	3.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
26	3.00E-08	1.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
27	1.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	--	--	2.99E+06	3.33E+06	3.87E+06	4.12E+06

Table 5.3.4-4 MTR Fuel Element Gamma Source Terms by Thermal Output – 460 grams ^{235}U

Burnup 577,500 MWd/MTU			MTR Assembly Thermal Output			
			20 Watts	30 Watts	70 Watts	120 Watts
Group	E_{hi} (Mev)	E_{low} (Mev)	2247 Days (g/sec)	1467 Days (g/sec)	602 Days (g/sec)	341 Days (g/sec)
1	10.00	8.00	1.07E+03	1.16E+03	1.31E+03	1.40E+03
2	8.00	6.50	5.02E+03	5.48E+03	6.18E+03	6.59E+03
3	6.50	5.00	2.56E+04	2.80E+04	3.15E+04	3.36E+04
4	5.00	4.00	6.38E+04	6.97E+04	7.86E+04	8.38E+04
5	4.00	3.00	2.70E+07	1.15E+08	5.77E+08	9.39E+08
6	3.00	2.50	2.33E+08	1.02E+09	5.47E+09	9.13E+09
7	2.50	2.00	2.08E+10	1.34E+11	1.08E+12	2.03E+12
8	2.00	1.66	5.73E+09	2.12E+10	1.27E+11	2.30E+11
9	1.66	1.33	5.49E+11	1.12E+12	2.93E+12	4.14E+12
10	1.33	1.00	1.86E+12	2.73E+12	5.18E+12	6.81E+12
11	1.00	0.80	7.73E+12	1.52E+13	3.37E+13	4.34E+13
12	0.80	0.60	4.20E+13	6.08E+13	1.12E+14	2.09E+14
13	0.60	0.40	1.56E+13	3.21E+13	7.58E+13	1.02E+14
14	0.40	0.30	9.39E+11	1.68E+12	7.05E+12	1.24E+13
15	0.30	0.20	1.46E+12	2.44E+12	9.31E+12	1.63E+13
16	0.20	0.10	5.34E+12	9.69E+12	4.10E+13	7.28E+13
17	0.10	0.05	6.58E+12	1.09E+13	4.07E+13	7.09E+13
18	0.05	0.01	2.26E+13	3.60E+13	1.26E+14	2.17E+14
Total	--	--	1.05E+14	1.73E+14	4.55E+14	7.56E+14

Table 5.3.4-5 MTR Fuel Element Neutron Source Terms by Thermal Output – 460 grams ^{235}U

Burnup 577,500 MWd/MTU			MTR Assembly Thermal Output			
			20 Watts	30 Watts	70 Watts	120 Watts
Group	E_{hi} (Mev)	E_{low} (Mev)	2247 Days (n/sec)	1467 Days (n/sec)	602 Days (n/sec)	341 Days (n/sec)
1	2.00E+01	6.43E+00	3.49E+04	3.83E+04	4.33E+04	4.61E+04
2	6.43E+00	3.00E+00	4.12E+05	4.50E+05	5.09E+05	5.46E+05
3	3.00E+00	1.85E+00	4.83E+05	5.24E+05	5.89E+05	6.29E+05
4	1.85E+00	1.40E+00	2.59E+05	2.83E+05	3.19E+05	3.38E+05
5	1.40E+00	9.00E-01	3.42E+05	3.74E+05	4.22E+05	4.48E+05
6	9.00E-01	4.00E-01	3.68E+05	4.03E+05	4.55E+05	4.84E+05
7	4.00E-01	1.00E-01	7.19E+04	7.87E+04	8.90E+04	9.47E+04
8	1.00E-01	1.70E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9	1.70E-02	3.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
10	3.00E-03	5.50E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
11	5.50E-04	1.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
12	1.00E-04	3.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
13	3.00E-05	1.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
14	1.00E-05	3.05E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
15	3.05E-06	1.77E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
16	1.77E-06	1.30E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
17	1.30E-06	1.13E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
18	1.13E-06	1.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
19	1.00E-06	8.00E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
20	8.00E-07	4.00E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
21	4.00E-07	3.25E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
22	3.25E-07	2.25E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
23	2.25E-07	1.00E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
24	1.00E-07	5.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
25	5.00E-08	3.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
26	3.00E-08	1.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
27	1.00E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	--	--	1.97E+06	2.15E+06	2.43E+06	2.59E+06

Table 5.3.4-6 LEU MTR Hardware Source to Fuel Source Comparison

Group	E_{hi} (Mev)	E_{low} (Mev)	834 days Fuel (γ/sec)	Cd at 834 days 100 g Cd (γ/sec)	Cd Source % of Fuel Gamma	Cd at 90 days 100 g Cd (γ/sec)	Cd Source % of Fuel Gamma
1	10.00	8.00	6.30E+02	0.00E+00	0.0%	0.00E+00	0.0%
2	8.00	6.50	2.97E+03	0.00E+00	0.0%	0.00E+00	0.0%
3	6.50	5.00	1.51E+04	0.00E+00	0.0%	0.00E+00	0.0%
4	5.00	4.00	3.78E+04	0.00E+00	0.0%	0.00E+00	0.0%
5	4.00	3.00	2.57E+08	4.49E-16	0.0%	1.80E-15	0.0%
6	3.00	2.50	2.16E+09	3.23E+00	0.0%	2.55E+01	0.0%
7	2.50	2.00	1.72E+11	1.19E+03	0.0%	9.38E+03	0.0%
8	2.00	1.66	3.60E+10	5.80E+04	0.0%	5.04E+05	0.0%
9	1.66	1.33	8.12E+11	7.57E+07	0.0%	6.35E+08	0.1%
10	1.33	1.00	2.68E+12	8.65E+05	0.0%	2.07E+09	0.1%
11	1.00	0.80	9.90E+12	2.11E+08	0.0%	5.66E+09	0.1%
12	0.80	0.60	6.14E+13	2.87E+08	0.0%	3.49E+09	0.0%
13	0.60	0.40	2.21E+13	2.13E+07	0.0%	3.12E+09	0.0%
14	0.40	0.30	2.36E+12	2.19E+08	0.0%	3.55E+09	0.2%
15	0.30	0.20	3.34E+12	8.06E+08	0.0%	5.78E+09	0.2%
16	0.20	0.10	1.27E+13	4.57E+09	0.0%	2.32E+10	0.2%
17	0.10	0.05	1.45E+13	1.17E+10	0.1%	3.88E+10	0.3%
18	0.05	0.01	4.76E+13	5.52E+10	0.1%	1.65E+11	0.3%
Total	--	--	1.78E+14	7.31E+10	0.0%	2.51E+11	0.1%

Table 5.3.4-7 HEU MTR Hardware Source to Fuel Comparison

Group	E_{hi} (Mev)	E_{low} (Mev)	1467 days Fuel (γ/sec)	Cd at 1467days 100 g Cd (γ/sec)	Cd Source % of Fuel Gamma	Cd at 90 days 100 g Cd (γ/sec)	Cd Source % of Fuel Gamma
1	10.00	8.00	1.16E+03	0.00E+00	0.0%	0.00E+00	0.0%
2	8.00	6.50	5.48E+03	0.00E+00	0.0%	0.00E+00	0.0%
3	6.50	5.00	2.80E+04	0.00E+00	0.0%	0.00E+00	0.0%
4	5.00	4.00	6.97E+04	0.00E+00	0.0%	0.00E+00	0.0%
5	4.00	3.00	1.15E+08	8.77E-15	0.0%	1.14E-13	0.0%
6	3.00	2.50	1.02E+09	2.69E+00	0.0%	1.23E+02	0.0%
7	2.50	2.00	1.34E+11	9.89E+02	0.0%	4.52E+04	0.0%
8	2.00	1.66	2.12E+10	4.82E+04	0.0%	2.49E+06	0.0%
9	1.66	1.33	1.12E+12	6.30E+07	0.0%	3.66E+09	0.3%
10	1.33	1.00	2.73E+12	7.02E+05	0.0%	4.30E+10	1.6%
11	1.00	0.80	1.52E+13	1.75E+08	0.0%	9.22E+10	0.6%
12	0.80	0.60	6.08E+13	2.38E+08	0.0%	2.76E+10	0.0%
13	0.60	0.40	3.21E+13	4.54E+07	0.0%	5.33E+10	0.2%
14	0.40	0.30	1.68E+12	5.87E+08	0.0%	6.72E+10	4.0%
15	0.30	0.20	2.44E+12	2.16E+09	0.1%	1.01E+11	4.2%
16	0.20	0.10	9.69E+12	1.23E+10	0.1%	3.51E+11	3.6%
17	0.10	0.05	1.09E+13	3.01E+10	0.3%	5.20E+11	4.8%
18	0.05	0.01	3.60E+13	1.33E+11	0.4%	1.75E+12	4.9%
Total	--	--	1.73E+14	1.79E+11	0.1%	3.01E+12	1.7%

Table 5.3.4-8 Material Densities for MTR Fuel Shielding Analysis

Material	Element	Density [atom/barn-cm]
HEU Fuel (380 g ^{235}U)	AL	2.470E-02
	U-235	2.548E-04
	U-238	2.795E-05
HEU Fuel (460 g ^{235}U)	AL	2.590E-02
	U-235	3.075E-04
	U-238	3.373E-05
MEU Fuel	AL	2.432E-02
	U-235	2.460E-04
	U-238	3.643E-04
LEU Fuel	AL	2.361E-02
	U-235	3.051E-04
	U-238	1.284E-03
End Fitting	AL	2.634E-02
H_2O/Glycol	H	5.988E-02
	C	1.070E-02
	O	2.459E-02
Stainless Steel	CR	1.743E-02
	MN	1.736E-03
	FE	5.936E-02
	NI	7.721E-03
Lead	PB	3.297E-02

Note: Fuel plate meat/core material is modeled as Uranium in an Aluminum matrix material. Uranium may also be in an oxide (U_3O_8) or silicide (U_xS_2) form. Neither oxygen nor silicon has a significant neutron absorption cross section or produce activation products significant to the shielding analysis. Oxygen or silicon represents a minor component of the overall fuel matrix composition.

Table 5.3.4-9 LWT Cask Surface Total Dose Rates (Normal Conditions of Transport)

Band [cm]	LWT Cask Surface Radial Dose Rates (mrem/hr)							
	Gamma	FSD (%)	Neutron	FSD (%)	N-Gamma	FSD (%)	Total	FSD (%)
247	98.87	1.1	18.62	0.6	0.19	3.3	117.69	0.9
221	234.17	1.1	59.67	0.3	0.48	1.7	294.31	0.9
195	86.34	0.5	43.38	0.4	1.38	0.7	131.10	0.4
169	54.75	0.4	5.06	0.7	2.58	0.5	62.39	0.4
143	45.55	0.5	4.75	0.7	2.75	0.5	53.04	0.4
117	57.19	0.5	5.31	0.6	2.91	0.4	65.42	0.4
91	52.97	0.5	5.13	0.6	2.90	0.5	61.00	0.4
65	46.75	0.5	4.85	0.6	2.89	0.4	54.48	0.4
39	58.61	0.5	5.40	0.7	3.00	0.4	67.01	0.4
13	53.69	0.5	5.22	0.6	3.03	0.5	61.94	0.4

Maximum dose rate for 460 gram ^{235}U element is 267.1 mrem/hr at the 221 cm band.

Table 5.3.4-10 LWT Cask Plane of Conveyance Dose Rates (Normal Conditions of Transport)

Band [cm]	Conveyance Dose Rates (mrem/hr)							
	Gamma	FSD (%)	Neutron	FSD (%)	N-Gamma	FSD (%)	Total	FSD (%)
266	30.64	1.1	6.20	0.5	0.18	1.0	37.01	0.9
238	39.27	1.0	8.17	0.5	0.25	0.8	47.69	0.8
210	35.26	0.9	8.48	0.4	0.37	0.6	44.11	0.8
182	26.66	0.6	6.29	0.5	0.50	0.5	33.45	0.5
154	22.13	0.5	3.77	0.6	0.62	0.5	26.52	0.4
126	20.53	0.5	2.47	0.7	0.71	0.4	23.70	0.4
98	20.27	0.4	1.96	0.6	0.78	0.4	23.01	0.4
70	19.92	0.4	1.76	0.6	0.82	0.4	22.50	0.3
42	20.05	0.4	1.72	0.7	0.84	0.4	22.61	0.4
14	20.24	0.4	1.69	0.5	0.86	0.4	22.78	0.4

Maximum dose rate for 460 gram ^{235}U element is 43.8 mrem/hr at the 238 cm band.

Table 5.3.4-11 LWT Cask 2 Meter Off The Plane of Conveyance Dose Rates (Normal Conditions of Transport)

Band	2 Meters off the Vertical Plane of Conveyance Dose Rates (mrem/hr)							
[cm]	Gamma	FSD (%)	Neutron	FSD (%)	N-Gamma	FSD (%)	Total	FSD (%)
285	7.00	2.0	1.14	2.0	0.10	2.1	8.23	1.7
255	7.55	2.0	1.19	1.9	0.11	2.1	8.86	1.8
225	8.47	2.4	1.19	1.8	0.12	2.0	9.79	2.1
195	8.02	1.6	1.20	1.9	0.14	1.7	9.36	1.4
165	8.60	1.8	1.12	1.8	0.15	1.7	9.87	1.5
135	8.42	1.3	1.11	1.8	0.16	1.7	9.69	1.1
105	8.55	1.2	1.01	1.9	0.17	2.1	9.74	1.1
75	8.59	1.1	0.97	2.1	0.18	1.6	9.73	1.0
45	8.85	1.7	0.94	2.0	0.18	1.6	9.98	1.5
15	8.80	1.2	0.89	2.0	0.19	1.7	9.88	1.1

Maximum dose rate for 460 gram ^{235}U element is 9.36 mrem/hr at the 195 cm band.

Table 5.3.4-12 LWT Cask 1 Meter From the Cask Surface Dose Rates (Normal Conditions of Transport)

Band	1 Meter off the Cask Dose Rates							
[cm]	Gamma	FSD (%)	Neutron	FSD (%)	N-Gamma	FSD (%)	Total	FSD (%)
285	17.95	1.0	3.86	0.6	0.14	0.9	21.96	0.8
255	25.73	1.1	4.98	0.5	0.20	0.8	30.90	0.9
225	25.83	1.0	5.58	0.4	0.27	0.6	31.68	0.8
195	23.06	0.8	5.03	0.5	0.35	0.6	28.45	0.7
165	19.06	0.6	3.69	0.5	0.44	0.5	23.18	0.5
135	17.24	0.5	2.54	0.6	0.51	0.4	20.29	0.4
105	16.68	0.4	1.90	0.6	0.57	0.4	19.16	0.4
75	16.44	0.4	1.60	0.6	0.61	0.4	18.65	0.4
45	16.33	0.4	1.47	0.7	0.63	0.4	18.42	0.4
15	16.38	0.4	1.40	0.5	0.65	0.4	18.43	0.3

Maximum dose rate for 460 gram ^{235}U element is 29.5 mrem/hr at the 225 cm band.

Table 5.3.4-13 Axial Surface Dose Rates at Cask Lid (Normal Conditions of Transport)

Band	Cask Lid Dose Rates (mrem/hr) Directly Above the MTR Elements					
[cm]	Gamma	FSD (%)	Neutron	FSD (%)	Total	FSD (%)
28.5	16.19	0.8	16.82	7.2	33.01	3.7
25.5	25.34	0.9	19.95	7.9	45.53	3.5
22.5	35.61	0.8	24.84	5.8	60.55	2.4
19.5	48.48	0.8	29.90	6.5	78.43	2.5
16.5	63.02	0.8	41.88	24.9	105.20	9.9
13.5	80.35	0.9	38.04	7.9	118.46	2.6
10.5	103.64	0.9	44.71	14.1	148.35	4.3
7.5	126.16	0.9	51.17	10.1	177.41	3.0
4.5	147.50	1.2	41.19	10.5	188.70	2.5
1.5	158.66	2.5	52.57	26.1	211.23	6.8

Notes:

a.) Maximum dose rate for 460 gram ^{235}U element is 174.1 mrem/hr at the 1.5 cm band.

b.) Maximum dose rate for 380 gram ^{235}U element is 10.9 mrem/hr at 1 meter from the cask lid surface.

Table 5.3.4-14 LWT Cask Dose Rates 5 Meters from the Cask Lid (Back of Tractor Cab) for Normal Conditions of Transport

Band [cm]	5 Meter Dose Rates (mrem/hr)					
	Gamma	FSD (%)	Neutron	FSD (%)	Total	FSD (%)
84.38	0.47	1.6	0.12	13.9	0.59	3.1
73.13	0.49	1.6	0.11	12.4	0.61	2.6
61.88	0.49	1.8	0.12	16.3	0.61	3.5
50.63	0.51	2.1	0.13	19.0	0.65	4.2
39.38	0.53	2.4	0.12	18.8	0.65	3.9
28.13	0.54	3.0	0.10	23.1	0.64	4.4
16.88	0.55	3.6	0.07	28.2	0.62	4.6
5.63	0.54	5.8	0.14	51.6	0.68	11.5

Maximum dose rate for 460 gram ^{235}U element is 0.62 mrem/hr at the 28.13 cm band.

Table 5.3.4-15 LWT Cask Dose Rates – 1 Meter from the Cask Surface (Hypothetical Accident Conditions)

Band [cm]	1 Meter Accident Dose Rates (mrem/hr)					
	Gamma	FSD (%)	Neutron	FSD (%)	Total	FSD (%)
285	21.38	5.2	9.78	0.4	31.18	3.5
255	33.72	13.5	13.90	0.3	47.63	9.6
225	31.01	3.0	19.15	0.3	50.19	1.9
195	30.50	2.9	24.55	0.2	55.08	1.6
165	29.36	3.5	29.32	0.2	58.71	1.7
135	29.51	3.0	33.11	0.2	62.66	1.4
105	28.68	3.4	35.67	0.2	64.38	1.5
75	29.52	4.3	37.51	0.2	67.07	1.9
45	28.49	2.2	38.59	0.2	67.12	0.9
15	27.74	1.2	39.24	0.2	67.02	0.5

Maximum dose rate for 460 gram ^{235}U element is 54.5 mrem/hr at the 15 cm band.

Table 5.3.4-16 LEU MTR Fuel Element Gamma Source Term - 40 W - 490g ^{235}U- 80% Burnup

Group	E_{hi} (Mev)	E_{low} (Mev)	402 Days (γ/sec)
1	10.00	8.00	4.666E+02
2	8.00	6.50	2.199E+03
3	6.50	5.00	1.122E+04
4	5.00	4.00	2.797E+04
5	4.00	3.00	5.259E+08
6	3.00	2.50	4.538E+09
7	2.50	2.00	4.817E+11
8	2.00	1.66	7.979E+10
9	1.66	1.33	1.139E+12
10	1.33	1.00	2.862E+12
11	1.00	0.80	1.183E+13
12	0.80	0.60	6.811E+13
13	0.60	0.40	2.915E+13
14	0.40	0.30	4.091E+12
15	0.30	0.20	5.466E+12
16	0.20	0.10	2.217E+13
17	0.10	0.05	2.339E+13
18	0.05	0.01	7.351E+13
Total	--	--	2.423E+14

Table 5.3.4-17 LEU MTR Fuel Element Neutron Source Term - 40 W - 490g ^{235}U- 80% Burnup

Group	E_{hi} (Mev)	E_{low} (Mev)	402 Days (n/sec)
1	2.00 E+01	6.43 E+00	1.462E+04
2	6.43 E+00	3.00 E+00	1.878E+05
3	3.00 E+00	1.85 E+00	2.095E+05
4	1.85 E+00	1.40 E+00	1.067E+05
5	1.40 E+00	9.00 E-01	1.408E+05
6	9.00 E-01	4.00 E-01	1.529E+05
7	4.00 E-01	1.00 E-01	2.999E+04
8	1.00 E-01	1.70 E-02	--
9	1.70 E-02	3.00 E-03	--
10	3.00 E-03	5.50 E-04	--
11	5.50 E-04	1.00 E-04	--
12	1.00 E-04	3.00 E-05	--
13	3.00 E-05	1.00 E-05	--
14	1.00 E-05	3.05 E-06	--
15	3.05 E-06	1.77 E-06	--
16	1.77 E-06	1.30 E-06	--
17	1.30 E-06	1.13 E-06	--
18	1.13 E-06	1.00 E-06	--
19	1.00 E-06	8.00 E-07	--
20	8.00 E-07	4.00 E-07	--
21	4.00 E-07	3.25 E-07	--
22	3.25 E-07	2.25 E-07	--
23	2.25 E-07	1.00 E-07	--
24	1.00 E-07	5.00 E-08	--
25	5.00 E-08	3.00 E-08	--
26	3.00 E-08	1.00 E-08	--
27	1.00 E-08	0.00 E+00	--
Total	--	--	8.423E+05

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release brakes and remove the chocks when required to complete uprighting operations. If an ISO container is used, it may be removed from the trailer and secured in the unloading area.

3. Remove the personnel barrier or the roof and roof cross-members from the ISO container.

   Note: Verify that the package nameplate displays the correct package identification number in accordance with the CoC.

4. Perform a Health Physics survey of the cask and adjacent surfaces of the trailer.

   Note: A receiving survey of the cask and transporter must be performed as soon as practicable after arrival at the site to assure compliance with 10 CFR 20, 10 CFR71.87(i) and 10 CFR 71.47, and to assure timely reporting of any reportable noncompliance.

5. Remove the top and bottom impact limiters.
6. Remove the cask tie-down strap.
7. Using the lifting yoke with the guides removed, engage the lifting trunnions. Raise the cask to vertical by rotating the cask rotation sockets on the rear cask supports, moving the crane and/or trailer as required to keep the lift yoke engaged to the trunnions and the cask engaged in the rear supports. When the cask is fully vertical, lift the cask from the supports and remove it from the trailer/container.
8. Place the cask onto the dry loading station/stand. Disengage the lifting yoke and move clear.
9. Visually inspect the neutron shield tank fill, drain and level inspection plugs for signs of neutron shield fluid leakage. If leakage is detected or suspected, verify shield tank fluid level and correct, as required.
10. Remove the vent and drain valve port covers. Prior to reinstallation of the port covers, carefully inspect the O-ring seals and, if the O-rings show any damage, replace them with approved spares. Ensure that the replacement O-rings are properly installed and seated. Visually inspect the valved quick-disconnect nipples and replace them, if necessary.

    Note: For Alternate B port covers, replace the metallic O-ring with an approved spare prior to reinstallation.

11. Remove closure lid bolts. Attach the lid lift slings to the closure lid. Remove the closure lid and set it on a support that is suitable for radiological control and for maintaining the cleanliness of the closure lid. Prior to reinstallation of the lid, carefully inspect the Teflon O-ring seal in the underside of the closure lid and, if it shows any damage, replace it. Remove the metallic O-ring and replace it with an approved spare. Ensure that the replacement O-rings are properly installed and seated. Inspect the lid bolts and replace any that are damaged.
12. Visually inspect the inner cavity for foreign material or damage. Install or verify presence of a proper drain tube including drain tube alignment ring, as required.

13. Install the required dry transfer system components on the top of the cask.
14. Position the shielded transfer cask system components for fuel loading, as appropriate.
15. Identify the fuel to be loaded into each fuel basket module. Fuel elements loaded into each basket and/or module shall comply with the approved content conditions specified in Condition 5.(b)(1) and 5.(b)(2) of CoC No. 9225. Specific guidance on fuel selection, use of loading diagrams and preferential loading procedures is provided in Section 7.1.5. Perform an independent verification of the loading diagrams and fuel loading operations per Section 7.1.5.3. MTR plate canister loading shall be in accordance with Section 7.1.4.1 and ANSTO DFC loading shall be in accordance with Section 7.1.4.2.

    Note: If a basket module is to be loaded with a LEU MTR fuel element having ^{235}U content >490 g (>23.5 g ^{235}U per plate), cell block spacers, as shown on Drawing 315-40-085, shall be installed in basket module cell positions 1, 2 and 3 to prevent inadvertent loading of more than four LEU MTR fuel elements.

    Note: For the loading of HEU MTR fuel elements having ^{235}U content >380 g, a minimum of 2.0 cm of nonfuel hardware and /or spacer plates shall be provided at both ends of the fuel element to meet criticality control analysis requirements.
16. Load the shielded transfer cask and basket module with the selected fuel contents.
17. Place the shielded transfer cask containing a loaded fuel basket module onto the dry transfer system components positioned on the top of the cask.
18. Lower the loaded basket module from the transfer cask into the shipping cask.
19. Repeat the loading and transfer of loaded basket modules until the approved cask loading plan is completed.
20. Install the closure lid onto the cask using the dry transfer system. Visually verify that the lid is properly seated.
21. Remove the dry transfer system components from the top of the cask.
22. Install and tighten the 12 closure bolts to 260 ± 20 ft-lb in three passes, using the sequence stamped on the lid.
23. Connect a gas supply line to the vent valve and the drain line to the drain valve.
24. Open the air, nitrogen or helium gas supply valve and pressurize the cask cavity (< 30 psig) to force any residual water out the drain line. Continue to supply pressurized gas to the cask for a minimum of five minutes after the last residual free water discharges from the drain. Remove the drain and gas supply lines and attach a vacuum drying system (VDS) to the vent.
25. Evacuate the cask cavity to less than or equal to 10 torr (13 mbar) and continue vacuum pumping for a minimum of 15 minutes.
26. At the end of the vacuum pumping period, isolate the cask cavity from the vacuum pump and stop the vacuum pump. Monitor the cask cavity pressure for a minimum of 10 minutes. If the pressure rise is less than 5 torr (6.7 mbar), the cavity is verified as dry of

6. Position loaded ANSTO module onto the ANSTO basket assembly or the ANSTO-DIDO combination basket assembly.

7.1.5 MTR General and Preferential Loading Procedures

Up to 42 LEU, MEU, and HEU MTR fuel elements may be loaded into the NAC-LWT MTR Fuel Basket, i.e., 7 fuel elements per basket module × 6 basket modules per fuel basket, except for LEU MTR fuel elements with greater than 490 g ^{235}U (or greater than 23.5 g ^{235}U per plate), which are limited to 4 elements per basket module as detailed in the following paragraphs. Each MTR basket module has 7 fuel element positions. The MTR basket module loading diagram presented in Figure 7.1-1 has a center position (Position 1), two exterior positions (Positions 2 and 3) that are in line with the center position, and four exterior positions (Positions 4, 5, 6, and 7) that are adjacent to the center row positions. The basket module's fuel element locations are specifically identified to ensure loading of each location with the appropriate fuel element. Ensuring MTR fuel loadings are performed in strict accordance with the procedures presented herein will ensure that the MTR fuel content conditions of the CoC are met and that the analyses presented in this SAR are bounding.

MTR fuel elements are selected for loading into specific fuel element locations based on the decay heat of each individual fuel element at the time of loading. Figure 7.1-2 through Figure 7.1-5 and Figure 7.1-12 through Figure 7.1-13 are provided to assist in determining the acceptability of a MTR fuel element for loading in a 30 W uniform loading pattern depending on enrichment (i.e., LEU, MEU or HEU) or ^{235}U content (i.e. 380 or 460 grams). For determining the acceptability of higher heat load HEU fuel elements, Figure 7.1-6 and Figure 7.1-7 are provided for 380 and 460 grams of ^{235}U, respectively. For determining the acceptability of higher heat load LEU fuel elements, Figure 7.1-13 is provided for 490 grams of ^{235}U. Curves are provided in this figure at 10, 20, 30, and 40 W maximum heat load for maximum flexibility in the preferentially loaded basket. The use of the fuel element cool time versus fuel burnup figures are described in Section 7.1.5.4. LEU MTR fuel elements with a ^{235}U content greater than 23.5 grams per plate (490 g ^{235}U per element), but not exceeding 32 grams ^{235}U per plate (640 g ^{235}U per element), are restricted to baskets containing a maximum of four fuel elements (or an equivalent number of fuel plates per opening). The four elements per basket module is in effect even if only one LEU MTR assembly exceeds 23.5 grams ^{235}U per plate (490 g ^{235}U per element). Specific basket locations and restrictions for the high load LEU elements are described in Section 7.1.5.1.

The procedural steps and sequence to ensure the MTR fuel loading and content condition limits are met are: 1) determine ^{235}U content weight per element; 2) determine fuel element decay heat load per Section 7.1.5.4; 3) determine basket module loading position for each element and

overall basket loading pattern; and 4) individual basket module loading and assembly of the fuel basket in the NAC-LWT. Each of these steps shall be independently verified.

Attention to the overall cask loading pattern allows the decay heat load of the cask to be maintained as uniform, as is practical, and within CoC total heat load limits. Loading diagrams for each individual module and the complete cask assembly shall be developed and used during the basket module and cask loading operations. After the decay heat load of each of the MTR fuel elements to be loaded and transported is calculated or determined and verified, the loading and content considerations of Sections 7.1.5.1 through 7.1.5.3 shall be met or complied with to establish the final acceptable loading pattern and sequence.

7.1.5.1 General Loading Requirements

1. The maximum decay heat load per MTR fuel basket module shall not exceed 210 W and the maximum decay heat load per cask (package) shall not exceed 1.26 kW. A MTR fuel element with a decay heat greater than 120 W shall not be loaded. The minimum allowed cool time for an MTR element/plate shall be 90 days.
2. LEU, MEU and HEU MTR fuel elements with decay heat not exceeding 30 W per element may be loaded in any basket module fuel element location in any combination.
3. HEU MTR fuel elements with decay heats exceeding 30 W shall be preferentially loaded in a basket module in decreasing decay heat order according to the loading diagram in Figure 7.1-1, with the highest heat load element loaded in fuel location one. Fuel elements with heat loads of up to 120 W shall only be loaded in the center fuel element location of any MTR fuel basket module. The decay heat of the fuel element in either of the two fuel element locations (i.e., number 2 or 3), in line with the center fuel element location of a MTR fuel basket module, shall not exceed 70 W.
4. LEU MTR fuel elements (or canistered fuel plates) with a ^{235}U content greater than 23.5 g per plate (>490 g ^{235}U per element), and not exceeding 32 g per plate (≤ 640 g ^{235}U per element), shall only be loaded into basket positions 4, 5, 6 and 7 shown in Figure 7.1-1. In order to ensure that baskets containing the high fissile mass LEU MTR elements (>23.5 g ^{235}U per plate , >490 g ^{235}U per element) will not be loaded with fuel elements (or fuel plates) in basket opening positions 1, 2 and 3, a cell block spacer shall be installed in each of these three basket openings. The cell block spacer, as shown on Drawing 315-40-085, is of sufficient height and diameter to ensure that LEU MTR fuel elements are prevented from being placed in these openings. The capacity limitation of a maximum of four MTR fuel elements per module is in effect even if a single LEU MTR fuel elements (or canistered fuel plates) having >23.5 g ^{235}U per plate (> 490 g ^{235}U per element) is to be loaded.
5. LEU MTR fuel elements with decay heats exceeding 30 W shall be preferentially loaded in a basket module in decreasing decay heat order according to the loading diagram in Figure 7.1-1. The total decay heat load of any individual basket with 40 W preferentially loaded assemblies is 210 W.
6. An MTR plate canister may be loaded into any fuel basket module fuel element location. The contents of each plate canister shall be limited to the number of fuel plates, dimensions and masses of an equivalent intact MTR fuel element.

7. MTR fuel elements with corrosion and/or mechanically damaged cladding may be loaded, provided that the total surface area of through-clad corrosion and/or mechanical damage does not exceed 5% of the elements cross-sectional area.

7.1.5.2 Determination of Basket Module Loading Pattern

1. Perform an evaluation of the full inventory of fuel elements to be loaded into the NAC-LWT cask(s) and develop an overall loading plan that minimizes overall dose rates to minimize general population dose and operator dose. The loading of LEU MTR fuel elements with greater than 23.5 g ^{235}U per plate (> 490 g ^{235}U per element) shall be governed by the loading restrictions in item 4 of Section 7.1.5.1, and cell block spacers shall be placed in basket loading positions 1, 2 and 3 to prevent inadvertent loading of more than four high fissile mass LEU MTR elements.
2. Select up to seven MTR fuel elements to be loaded in a basket module meeting the general loading requirements of Section 7.1.5.1. Identify if spacers or spacer plates are required to properly position the MTR elements axially in the basket module.
3. Rank the fuel elements in order of decreasing decay heat load from 1 to 7. (i.e., the assembly with the highest decay heat is designated number 1.)
4. Generate loading diagrams for each basket module based on Figure 7.1-1, by placing the numbered assemblies in the matching numbered basket module positions, except that fuel elements ranked 4,5,6 or 7 may be loaded in any of the outer (i.e., 4-7) basket module positions.
5. Repeat steps 1 through 4 for all of the basket modules to be loaded.
6. Independently verify the basket module loading diagrams.
7. The loading diagrams shall be used to direct the loading of the basket modules per Section 7.1.5.3.

Once the basket module loading charts are complete, they are used to direct the loading of the basket modules.

7.1.5.3 Basket Loading Procedure

1. Locate the MTR fuel element to be loaded into the basket module per the loading diagram prepared for that module type (i.e., base, intermediate or top).
2. Independently verify the element identification.
3. Load the element into the predetermined fuel basket module fuel element location using the loading diagram. Ensure spacers are installed in positions 1, 2 and 3 of any basket module containing a high fissile mass LEU MTR element (greater than 23.5 g ^{235}U per plate, greater than 490 g ^{235}U per element).
4. Independently verify that the fuel element and spacer loading in the basket module complies with the loading diagram.
5. Repeat steps 1 through 4 until all identified fuel elements have been loaded into basket modules in compliance with the loading diagrams.

7.1.5.4 Estimating Assembly Decay Heat

When the decay heat of a fuel element is not known, the assembly burnup (MWd/MTU) and cooling time (years) can be used to define the allowable basket module positions using Figure 7.1-2 through Figure 7.1-7 and Figure 7.1-12 through Figure 7.1-13, depending on fuel enrichment (i.e., LEU, MEU or HEU) or ^{235}U content.

When using the load curves, placing the data point above a curve results in the fuel element being acceptable for loading at the heat load for which the curve was generated. Fuel elements with characteristics locating the point below the curve results in the fuel element not being acceptable for loading at the heat load for which the curve was generated. Uncertainties associated with burnup/depletion assignment for use with the load curves must be taken into account. Should an element be near the minimum load time determined by the load curves, or maximum burnup applicable to the curve, uncertainties in reading the curves must be taken into account.

HEU MTR fuel elements may be loaded with heat loads greater than 30 W. HEU elements exceeding 30 W shall be preferentially loaded, and Figure 7.1-6 and Figure 7.1-7 identify the appropriate cooling times and burnup limits for 120 W, 70 W and 20 W HEU elements, having a ^{235}U mass of up to 380 grams and a ^{235}U mass of up to 460 grams, respectively. The following steps are used to develop the appropriate loading patterns.

1. Locate the point on Figure 7.1-6 or Figure 7.1-7 for the fuel element burnup and cooling time, and ^{235}U content.
2. If the located point is above the 20 W line, there are no restrictions on fuel element placement in the basket module.
3. If the located point is between the 20 W and 70 W lines, the element is loaded as a 70 W element.
4. If the located point is between the 70 W and 120 W lines, the element is loaded as a 120 W element.
5. If the located point is below the 120 W line, the element shall not be loaded in the NAC-LWT cask.
6. The maximum total decay heat load for a preferentially loaded basket module shall not exceed 210 W and 1.26 kW for a loaded NAC-LWT cask.
7. Each shipper shall ensure that the Certificate of Compliance maximum decay heat load limits of 210 W per basket module and 1.26 kW per cask are not exceeded.

LEU MTR fuel elements may be loaded with heat loads greater than 30 W. LEU elements exceeding 30 W but not exceeding 40 W shall be preferentially loaded, and Figure 7.1-13 identifies the appropriate cooling times and burnup limits for 40 W, 30 W, 20 W and 10 W LEU elements, having a ^{235}U mass of up to 490 grams (up to 23.5 ^{235}U gram per plate). The following steps are used to develop the appropriate loading patterns.

1. Locate the point on Figure 7.1-13 for the fuel element burnup and cooling time.

2. If the located point is above the 10 W line, there are no restrictions on fuel element placement in the basket module.
3. If the located point is between the 10 W and 20 W lines, the element is loaded as a 20 W element. If the located point is above the 20 W line and beyond the 10 W line (i.e., element has a higher depletion than plotted for the 10 W line) the element is loaded as a 20 W element.
4. If the located point is between the 20 W and 30 W lines, the element is loaded as a 30 W element.
5. If the located point is between the 30 W and 40 W lines, the element is loaded as a 40 W element.
6. If the located point is below the 40 W line, the element shall not be loaded in the NAC-LWT cask.
7. The maximum total decay heat load for a LEU preferentially loaded basket module shall not exceed 210 W and 1.26 kW for a loaded NAC-LWT cask.
8. Each shipper shall ensure that the Certificate of Compliance maximum decay heat load limits of 210 W per basket module and 1.26 kW per cask are not exceeded.

Figure 7.1-1 MTR Fuel Basket Module Loading Pattern (Top View)

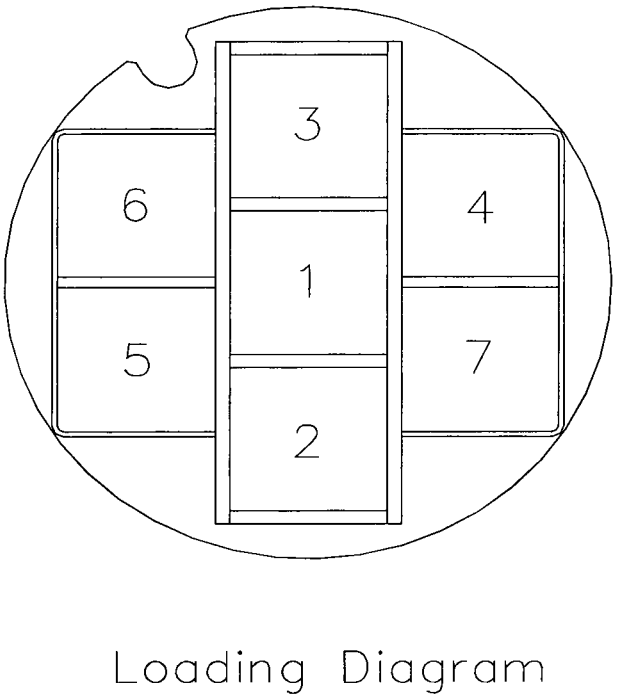


Figure 7.1-2 LEU MTR Fuel Basket Loading Guidelines for 30 W Uniform Loading – Maximum 470 grams ^{235}U

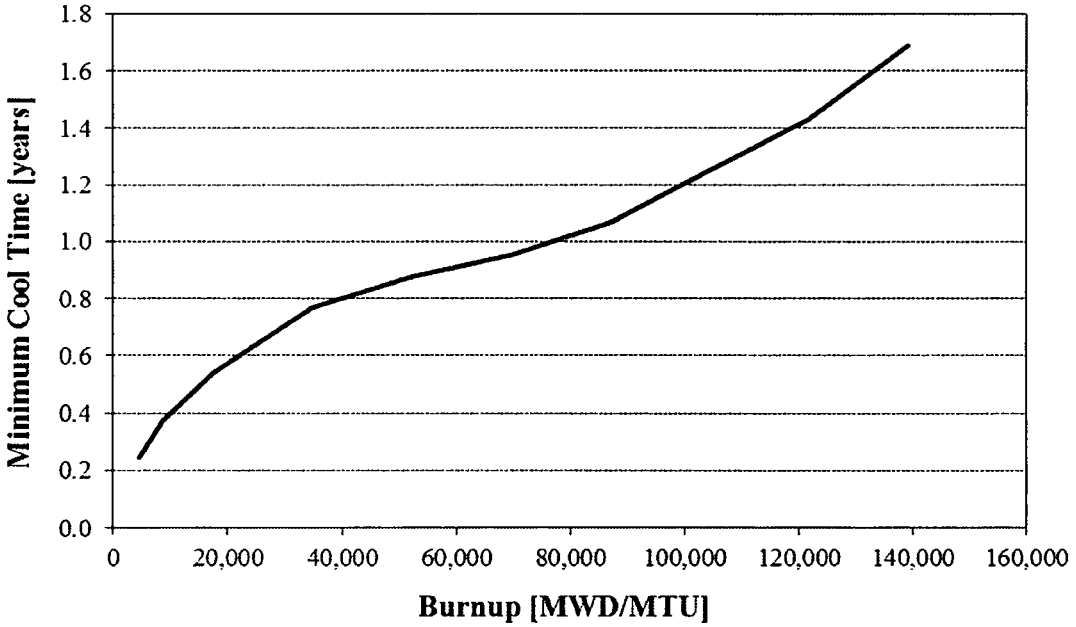


Figure 7.1-3 MEU MTR Fuel Basket Loading Guidelines for 30 W Uniform Loading

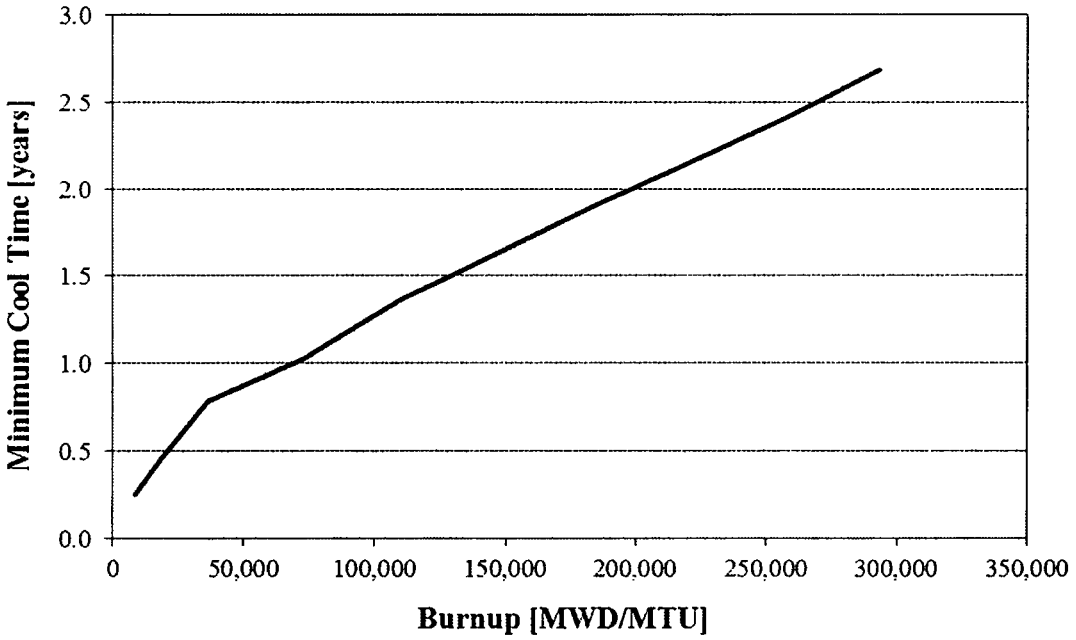


Figure 7.1-4 HEU MTR Fuel Basket Loading Guidelines for 30 W Uniform Loading – Maximum 380 grams ^{235}U

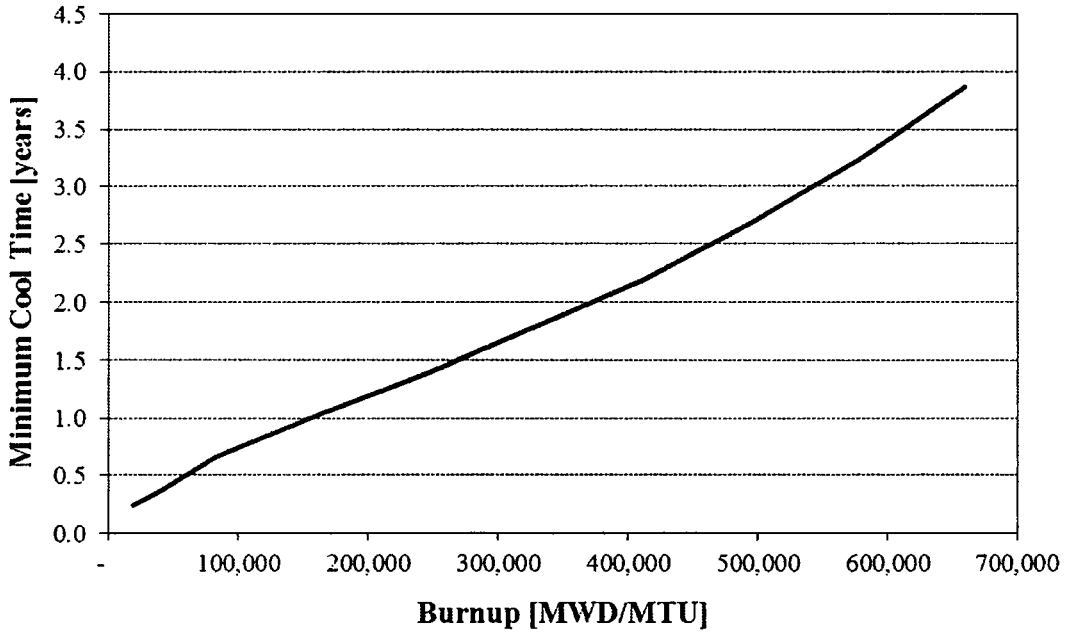


Figure 7.1-5 HEU MTR Fuel Basket Loading Guidelines for 30 W Uniform Loading – Maximum 460 grams ^{235}U

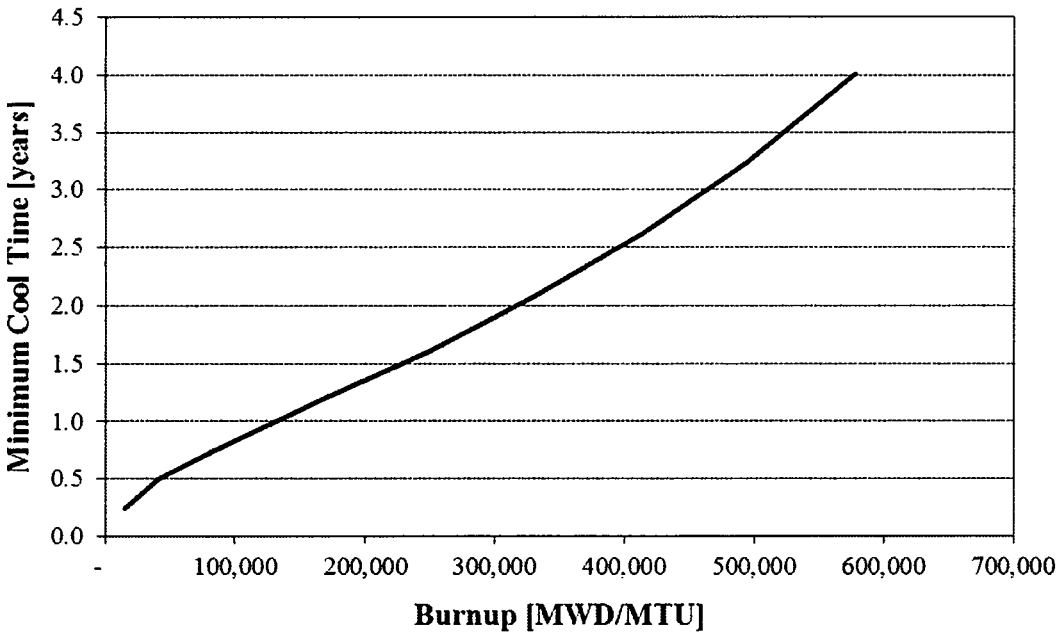


Figure 7.1-6 HEU MTR Fuel Basket Loading Guidelines for Preferential Loading – Maximum 380 grams ^{235}U

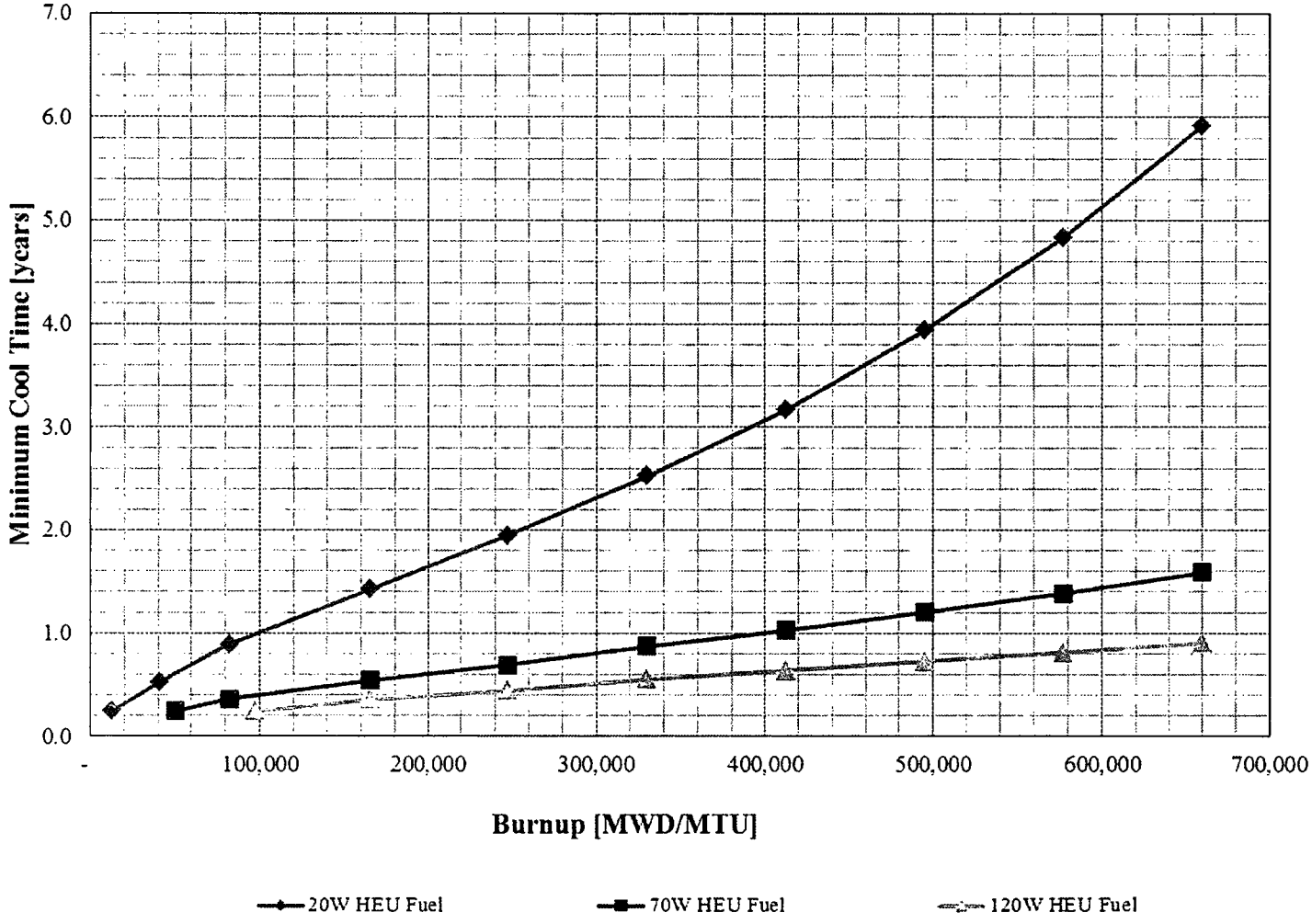


Figure 7.1-7 HEU MTR Fuel Basket Loading Guidelines for Preferential Loading – Maximum 460 grams ^{235}U

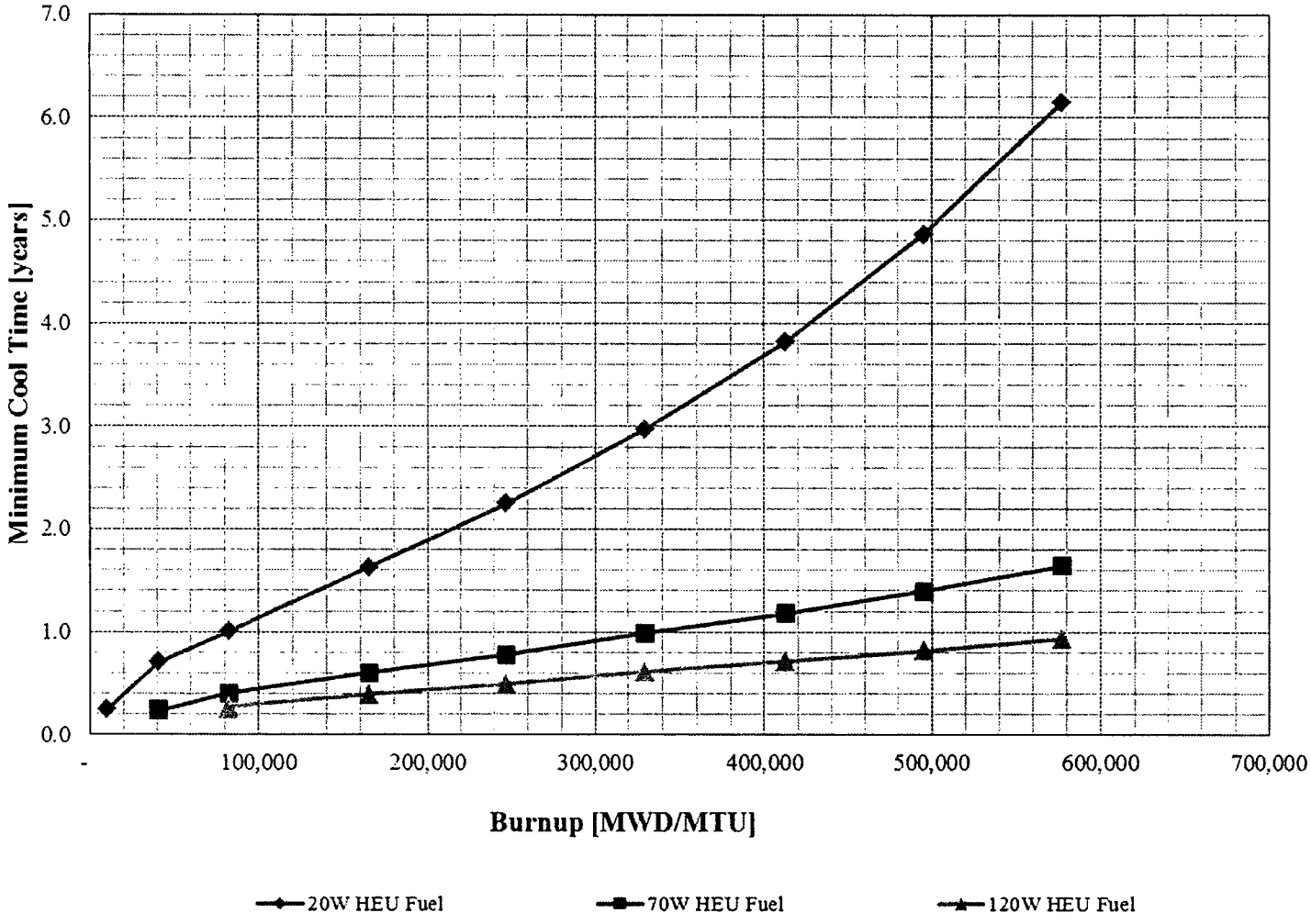


Figure 7.1-8 DIDO LEU Cooling Time vs. Fuel Burnup Basket Module Loading Guidelines for Uniform Loading

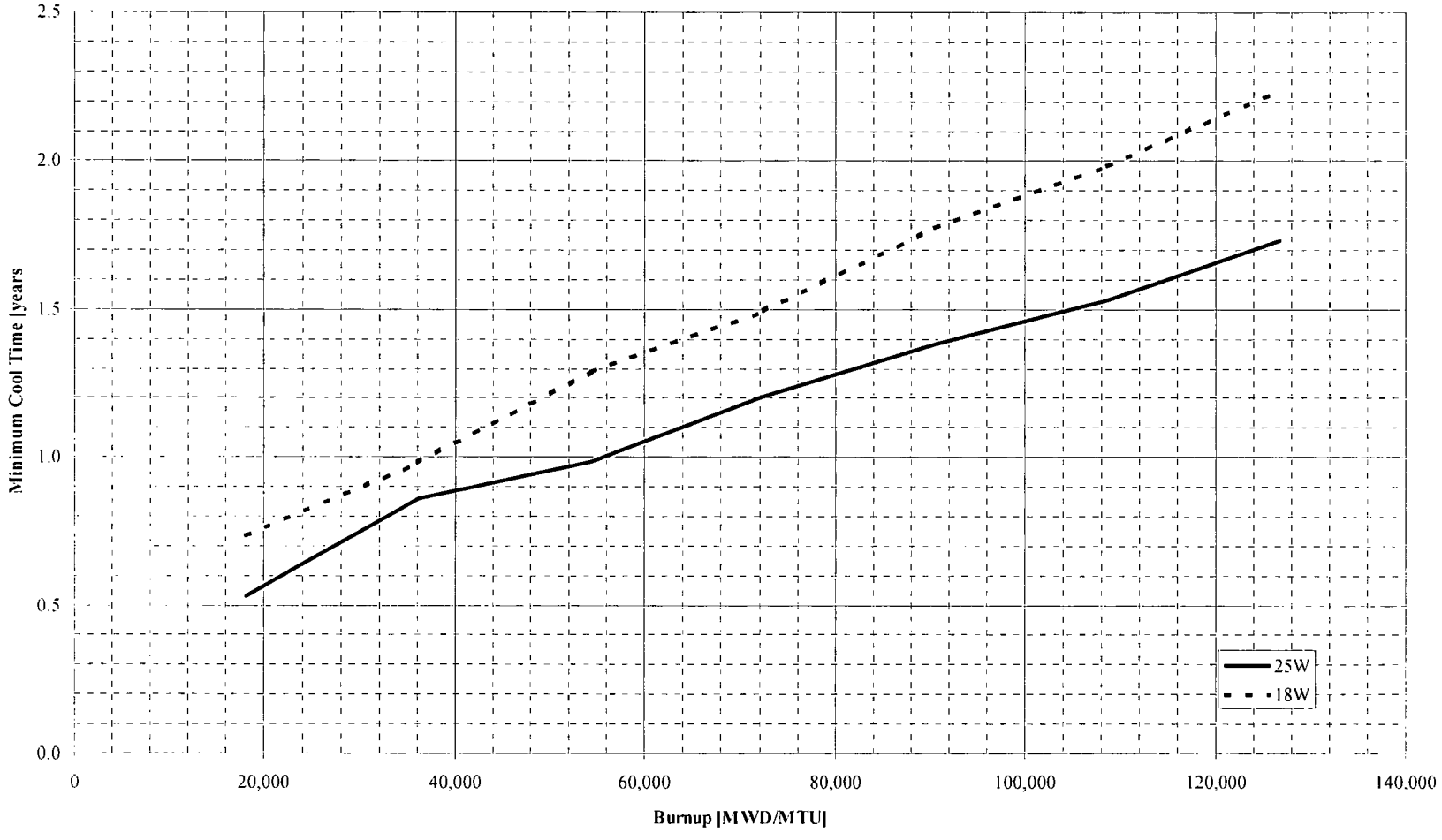


Figure 7.1-9 DIDO MEU Cooling Time vs. Fuel Burnup Basket Module Loading Guidelines for Uniform Loading

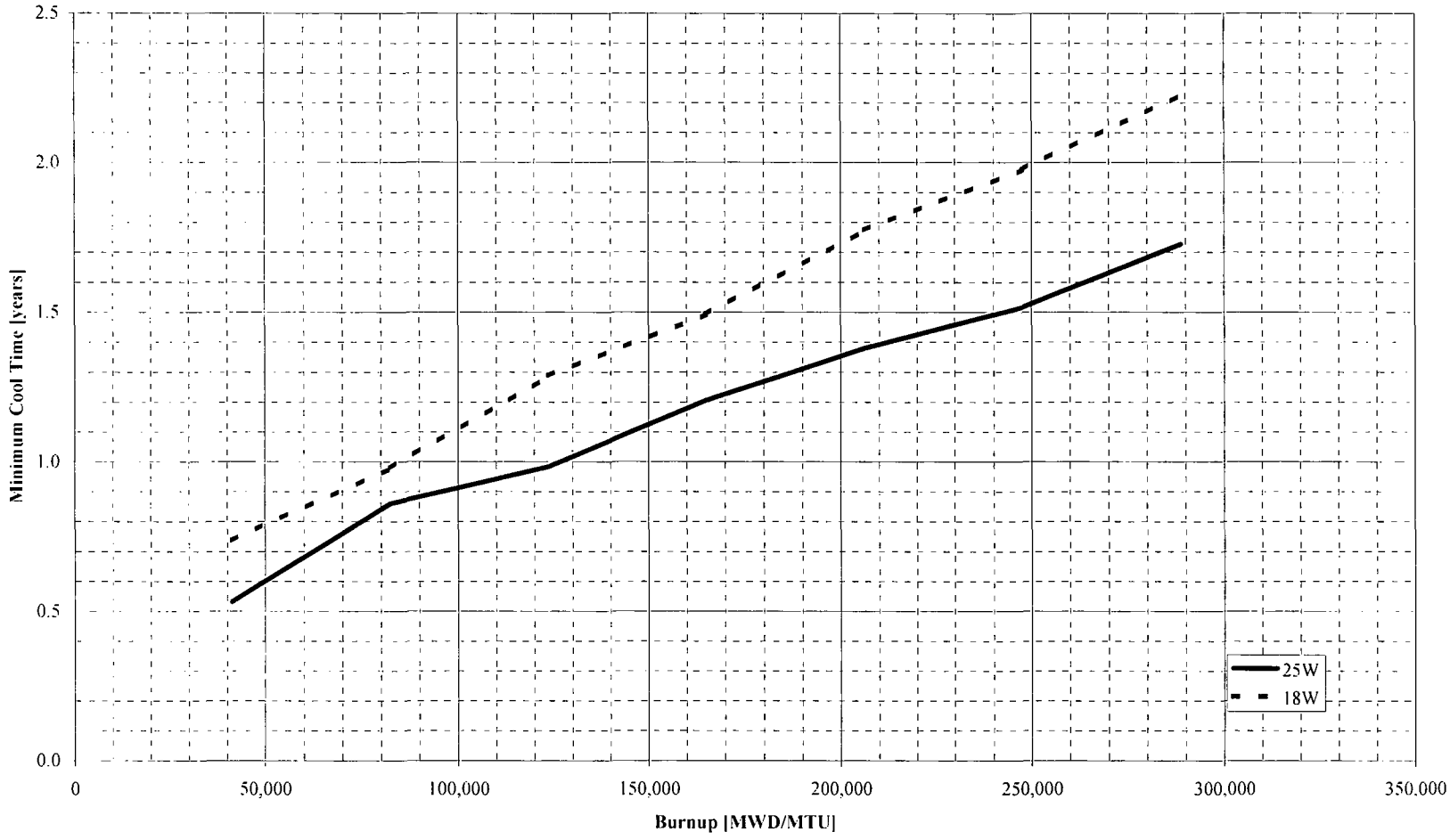


Figure 7.1-10 DIDO HEU Cooling Time vs. Fuel Burnup Basket Module Loading Guidelines for Uniform Loading

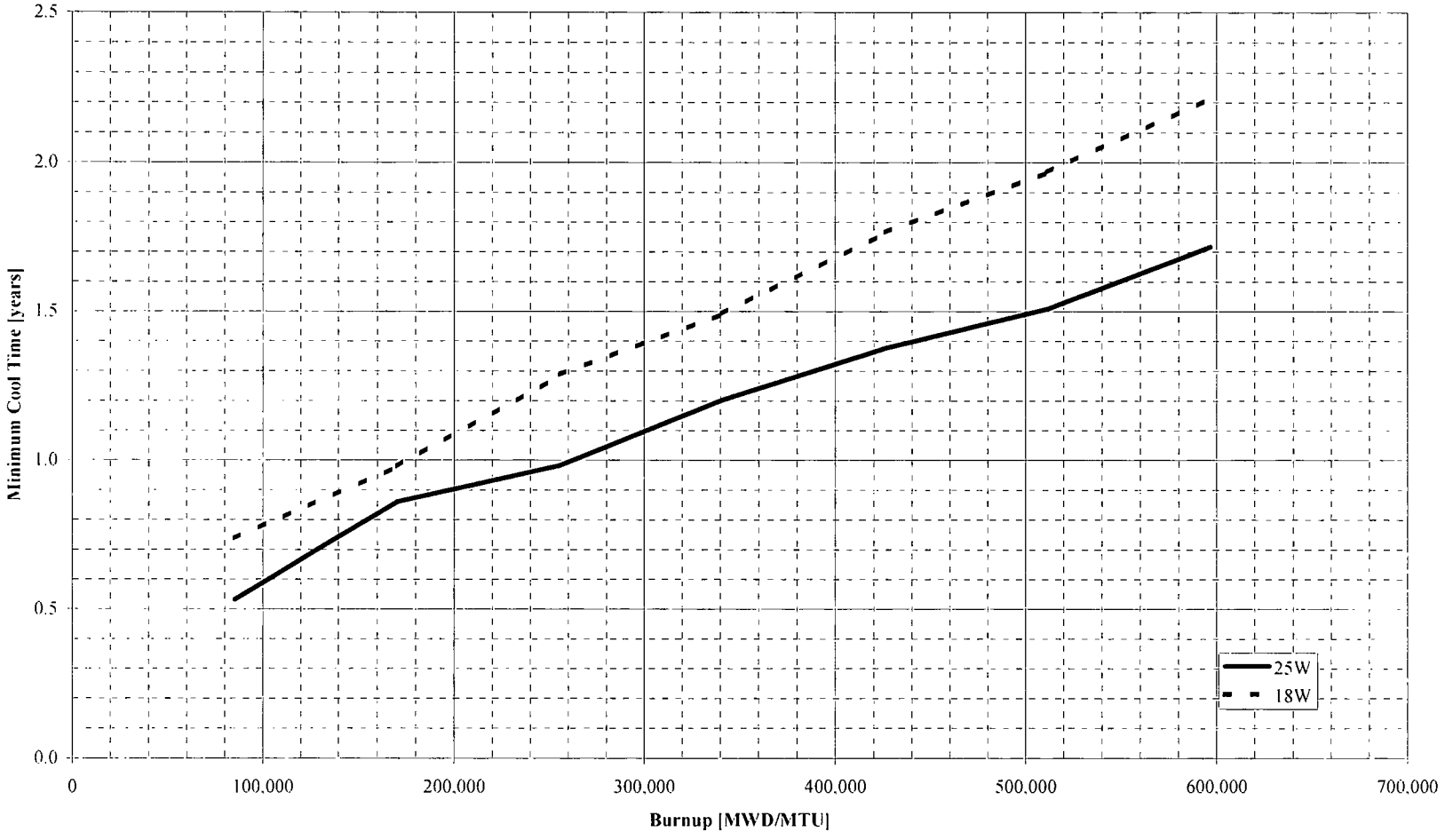


Figure 7.1-11 Bounding DIDO Element Minimum Cool Time vs. wt % ^{235}U Depletion

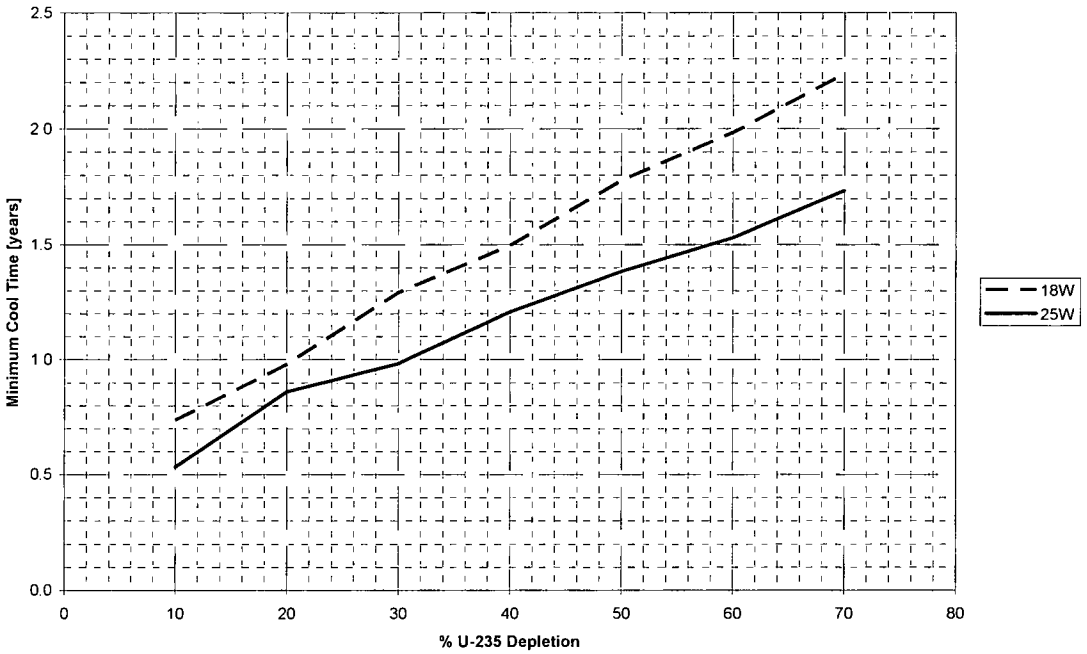


Figure 7.1-12 LEU MTR Fuel Basket Loading Guidelines for 30 W Uniform Loading - Maximum 640 grams ^{235}U

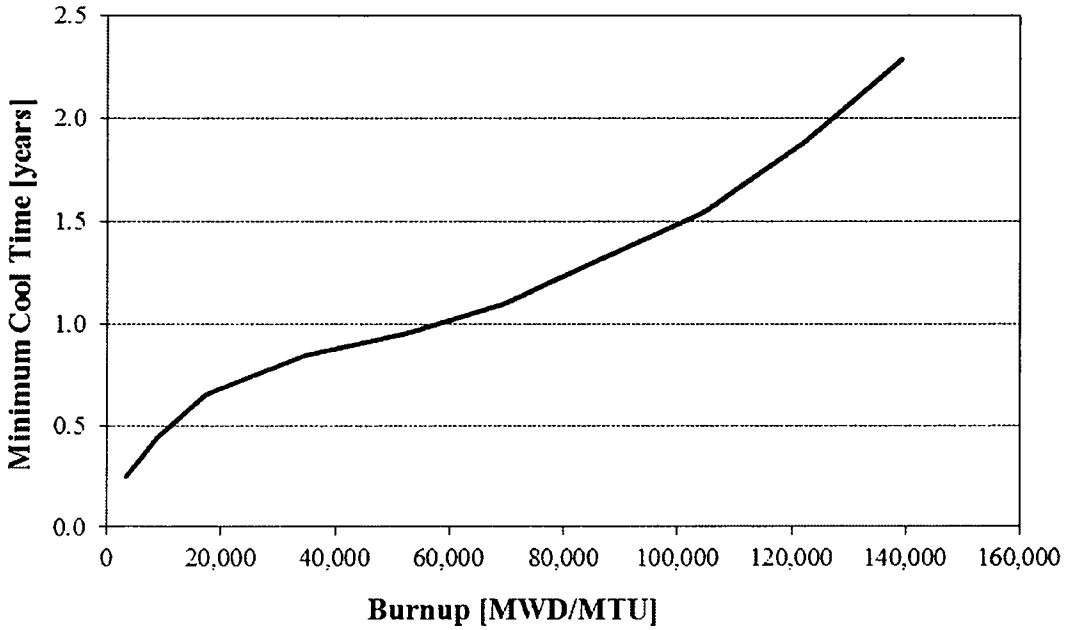
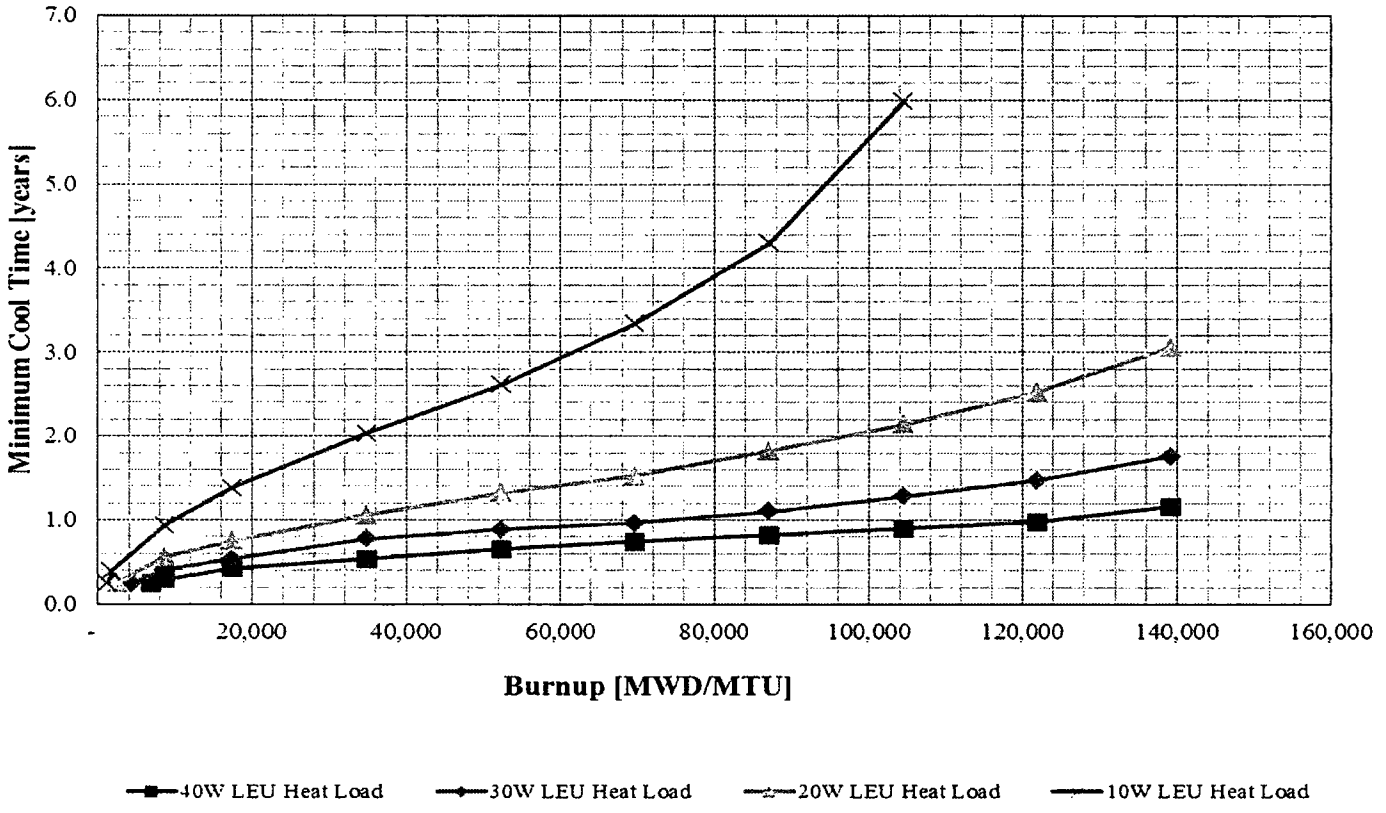


Figure 7.1-13 LEU MTR Fuel Basket Loading Guidelines for 40 W Preferential Loading - Maximum 490 grams ^{235}U



Note: Maximum burnup allowed is 139.3 GWd/MTU and minimum cool time is 90 days.

7.1.6 Procedure for Dry Loading of TRIGA Fuel Basket Modules and GA IFM Modules into the NAC-LWT Cask

This procedure presents the steps for dry loading, using a transfer cask, of the nonpoisoned or poisoned TRIGA fuel basket modules into the NAC-LWT. For transport, five TRIGA fuel basket modules, consisting of a top module, a base module, and three intermediate modules must be loaded into the NAC-LWT. An alternative loading option is available for the poisoned TRIGA basket modules. This configuration, Configuration 2, consists of 1 base module and 4 intermediate modules. A spacer attached to the underside of the NAC-LWT lid is used with Configuration 2. Each basket module consists of seven cells, a center cell, and six peripheral cells. The center cell of the nonpoisoned basket design is blocked and cannot be loaded. Each unblocked cell may contain up to four TRIGA fuel elements, or up to 16 TRIGA fuel cluster rods within a fuel rod insert placed into the cell prior to loading. The maximum decay heat load of any TRIGA fuel element is 7.5 watts, while the maximum decay heat load of a TRIGA fuel cluster rod is 1.875 watts. An alternative loading option is available for the General Atomics (GA) Irradiated Fuel Material (IFM) Fuel Handling Units (FHU). This configuration consists of one GA IFM top module and one GA IFM spacer. The GA IFM top module, based on the TRIGA basket design, has two canister storage tubes that hold the GA IFM FHU.

TRIGA fuel elements may be transported directly in the basket module cell, or in a sealed damaged fuel can (DFC). TRIGA fuel cluster rods may be transported within the fuel rod insert in a basket cell, or a sealed DFC. The sealed DFCs fit in a module cell. The sealed DFC holds up to two equivalent TRIGA elements as damaged fuel or fuel debris, or up to six equivalent TRIGA fuel cluster rods as damaged rods or fuel debris. Damaged TRIGA fuel and fuel debris are contained in sealed DFCs.

When loading TRIGA fuel elements directly into the basket cells of a TRIGA basket module, the fuel elements may be loaded with either 4 elements per cell, or one element per cell, without shoring. If a basket cell is loaded with 2 or 3 intact elements, dummy rods will be inserted as necessary to fill the remaining space in the cell.

Each nonpoisoned basket module may contain up to 24 TRIGA fuel elements for a total of 120 elements, up to 96 TRIGA fuel cluster rods for a total of 480 rods per basket assembly, or a mixed loading in separate cells of the basket module of TRIGA fuel elements and TRIGA fuel cluster rods.

For the loading of the following TRIGA fuel elements, a maximum of three intact fuel elements are authorized for loading in each cell of a nonpoisoned top or bottom basket module. A dummy TRIGA spacer tube, as shown on Drawing No. 315-40-085, shall be inserted into the open

position prior to fuel element loading to ensure that the maximum number of three TRIGA fuel elements is not exceeded:

- TRIGA Stainless Steel (SS) LEU fuel elements having > 169 g ^{235}U < 275 g ^{235}U; or
- TRIGA SS HEU fuel elements having > 138 g ^{235}U < 175 g ^{235}U

The licensee's approved fuel loading plan shall ensure compliance with all fuel loading restrictions.

Each poisoned basket module may contain up to 28 TRIGA fuel elements for a total of 140 elements, or up to 112 TRIGA fuel cluster rods for a total of 560 rods per basket assembly.

Damaged TRIGA fuel elements and cluster rods and fuel debris are required to be loaded into sealed DFCs. The sealed DFCs are provided in two lengths. The short sealed DFC may be used in the base or top basket module. The long sealed DFC may be used in only the top module. The sealed DFCs are vacuum dried prior to loading into a TRIGA fuel basket (see sealed DFC loading procedure in Section 7.1.7).

There are two separate GA IFM FHU designs. One FHU is designed to hold research reactor fuel and the other is designed to hold High-Temperature Gas-Cooled Reactor fuel pellets. Each FHU consists of a sealed inner canister within a sealed outer canister. Each FHU contains irradiated fuel materials as described in Chapter 1. When loading the GA IFM FHUs, each individual sealed FHU will be loaded separately into a single GA IFM basket. This single basket containing two GA IFM FHUs and a spacer will comprise the entire cask load. Loading of the GA IFM basket into the NAC-LWT cask will utilize the TRIGA dry configuration loading procedure that is described in the following paragraphs.

TRIGA fuel elements that can be loaded into the cask are limited to a maximum decay heat of 7.5 watts per element, as discussed in Section 1.2.3. The decay heat load of the element must be calculated, and verified to be equal to or less than 7.5 watts per element prior to loading. TRIGA fuel cluster rods that can be loaded into the cask are limited to a maximum decay heat of 1.875 watts per element, as discussed in Section 1.2.3 (by reference to Table 5.1.1). The decay heat load of the fuel cluster rod must be calculated, and verified to be equal to or less than 1.875 watts per element prior to loading.

The procedure for loading the package with TRIGA fuel in a dry configuration is as follows:

1. Perform a receipt inspection of the empty cask and trailer/ISO container, inspecting for transport damage.
2. Position the trailer in the designated cask unloading area. Set the trailer brakes and chock the wheels to prevent unintended movement. If site-specific conditions exist that require the trailer to move to allow the cask to be uprighted on its rotation

trunnions, release brakes and remove the chocks when required to complete uprighting operations. If an ISO container is used, it may be removed from the trailer and secured in the unloading area.

3. Remove the personnel barrier or the roof and roof cross-members from the ISO container.

   Note: Verify that the package nameplate displays the correct package identification number in accordance with the CoC.

4. Perform a Health Physics survey of the cask and adjacent surfaces of the trailer.

   Note: A receiving survey of the cask and transporter must be performed as soon as practicable after arrival at the site to assure compliance with 10 CFR 20, 10 CFR 71.87(i) and 10 CFR 71.47, and to assure timely reporting of any reportable noncompliance.

5. Remove the top and bottom impact limiters.
6. Remove the cask tie-down strap.
7. Using the lifting yoke with the guides removed, engage the lifting trunnions. Raise the cask to vertical by rotating the cask rotation sockets on the rear cask supports, moving the crane and/or trailer as required to keep the lift yoke engaged to the trunnions and the cask engaged in the rear supports. When the cask is fully vertical, lift the cask from the supports and remove it from the trailer/container.
8. Place the cask onto the dry loading station. Disengage the lifting yoke and move clear.
9. Visually inspect the neutron shield tank fill, drain and level inspection plugs for signs of neutron shield fluid leakage. If leakage is detected or suspected, verify shield tank fluid level and correct, as required.
10. Remove the vent and drain valve port covers. Prior to reinstallation of the port covers, carefully inspect the O-rings and, if the O-rings show any damage, replace them with approved spares. Ensure that the replacement O-rings are properly installed and seated. Visually inspect the valve quick-disconnect nipples and replace them, if necessary.

    Note: For Alternate B port covers, replace the metallic O-ring with an approved spare prior to reinstallation.

11. Remove closure lid bolts. Attach the lid lift slings to the closure lid. Remove the closure lid and set it on a support that is suitable for radiological control and for maintaining the cleanliness of the closure lid. Prior to reinstallation of the lid, carefully inspect the Teflon O-ring seal in the underside of the closure lid and, if it shows any damage, replace it. Remove the metallic O-ring and replace it with an approved spare. Ensure that the replacement O-rings are properly installed and seated. Inspect the lid bolts and replace any that are damaged.
12. Visually inspect the inner cavity for foreign material or damage. Install, or verify the presence of the proper drain tube and drain alignment ring.
13. Install the required dry transfer system components on the top of the cask.
14. Position the shielded transfer cask system components for fuel loading, as appropriate.

15. Identify the TRIGA fuel basket modules to be loaded. Modular baskets consisting of one base unit, three intermediate units, and one top unit, may be loaded into the cask cavity. The base unit must be the first unit loaded and the top unit must be the last unit loaded. The intermediate modules may be loaded in any of the other loading operations. If the poisoned basket Configuration 2 is used, ensure that the TRIGA spacer is bolted and torqued to 40 ft-lbs to the underside of the NAC-LWT lid. If TRIGA fuel cluster rods are to be transported, ensure that fuel rod inserts are placed into each cell location that will contain fuel cluster rods. For the GA IFM basket load, install the GA IFM spacer, shown on NAC drawing 315-40-123, prior to inserting the loaded GA IFM top module.

    Notes:
    a. When utilizing nonpoisoned TRIGA baskets, visually verify that the center blocking plate is welded in place on each basket module.
    b. When utilizing poisoned TRIGA baskets, visually inspect each cell of each basket module for foreign material or damage and verify the presence of the neutron poison material (borated stainless steel plates) as shown on NAC Drawings 315-40-080, -081, and -082.
    c. When utilizing the GA IFM top module, follow the TRIGA loading procedure below, noting that this is a single basket load.

16. Identify the TRIGA fuel elements and TRIGA fuel cluster rods to be loaded into each fuel basket module. Fuel elements and rods to be loaded into each basket module shall comply with the applicable approved content conditions specified in Condition 5.(b)(1) and 5.(b)(2) of CoC No. 9225.

    If a top or bottom basket module cell is to be loaded with a TRIGA LEU SS fuel element having > 169 g ^{235}U, or a TRIGA HEU SS fuel element > 138 g ^{235}U, a dummy TRIGA spacer tube, as shown on NAC Drawing 315-40-085, shall be preinstalled in the module cell prior to fuel loading to prevent inadvertent loading of more than three high ^{235}U content TRIGA fuel elements per cell. High ^{235}U content TRIGA fuel elements are further restricted to loading in the top and bottom basket modules of a nonpoisoned basket only.

17. Perform an independent verification that the TRIGA fuel elements, fuel cluster rods and dummy TRIGA spacer tubes loaded in the basket module comply with the approved loading plan and the CoC content conditions including fuel parameters, heat load, enrichment, minimum cooling period, etc.
18. Load a TRIGA fuel basket module into the shielded transfer cask.
19. Place the shielded transfer cask containing the loaded basket module onto the dry transfer system components positioned on the top of the cask.
20. Lower the fuel basket from the shielded transfer cask into the shipping cask.
21. Repeat the loading and transfer of loaded basket modules until the approved cask loading plan is completed.
22. Install the closure lid onto the cask. Visually verify that the lid is properly seated.
23. Remove the dry transfer system components from the top of the cask.
24. Install and tighten the 12 closure bolts to 260 ± 20 ft-lbs in three passes, using the torque sequence stamped on the closure lid.

25. Connect a gas supply line to the vent valve and the drain line to the drain valve.
26. Open the air, nitrogen or helium gas supply valve and pressurize the cask cavity (< 30 psig) to force any residual water out the drain line. Continue to supply pressurized gas to the cask for a minimum of five minutes after the last residual free water discharges from the drain. Remove the drain and gas supply lines and attach a vacuum drying system (VDS) to the vent.
27. Evacuate the cask cavity to less than or equal to 10 torr (13 mbar) and continue vacuum pumping for a minimum of 15 minutes.
28. At the end of the vacuum pumping period, isolate the cask cavity from the vacuum pump and stop the vacuum pump. Monitor the cask cavity pressure for a minimum of ten minutes. If the pressure rise is less than 5 torr (6.7 mbar), the cavity is verified as dry of free water. If pressure rise is >5 torr (6.7 mbar), repeat vacuum drying until the dryness verification results are satisfactory.
29. Backfill the cask cavity with helium to 0 psig (1 atmosphere, absolute), +1, -0 psi and disconnect the VDS from the vent valve.
30. Perform a helium leakage test of the closure lid containment O-ring using a Helium Mass Spectrometer Leak Detector (He MSLD) in accordance with the procedural requirements of Section 8.1.3.1, Steps 3 through 10.
31. Install the vent and drain alternate port covers and torque the bolts to 100 ±10 inch-pounds.
32. If an alternate port cover containment O-ring seal was replaced, perform a helium leakage test on the affected port cover using a He MSLD in accordance with the requirements of 8.1.3.2.2.
33. If the alternate port cover containment seal was inspected and accepted for reuse, perform a gas pressure drop leakage test on the affected port cover as follows.
    a. Install a pressure test fixture to the port cover test port including a calibrated pressure gauge with a minimum sensitivity of 0.25 psi.
    b. Pressurize the port cover seal annulus to 15 psig, +1, -0 psi.
    c. Isolate the gas supply and observe the pressure gauge for a minimum of five minutes.
    d. The acceptance criterion for the test is no measurable drop in pressure during the minimum test time. An acceptable test assures that the minimum assembly verification leakage test sensitivity is achieved.

    Note: Alternate B port covers, if used, shall have a helium maintenance leakage rate test performed to confirm a leaktight containment closure. Install the Alternate B port cover and perform the maintenance leakage rate test per the requirements of Section 8.1.3.3.2.
34. Decontaminate the cask surfaces. Survey the cask for surface contamination and radiation dose rates.

    Note: Ensure compliance with 10 CFR 71.87(i) and 10 CFR 71.47.
35. Engage the cask lifting yoke to the lifting trunnions.
36. Lift the cask and position the cask rotation sockets in the rear rotation trunnions of the rear support structure. Carefully lower the cask to the horizontal transport orientation

resting on the front saddle by moving the crane and/or the trailer as required to maintain cask engagement to the rear supports.

37. Disengage the lifting yoke from the lifting trunnions and remove it from the area. Install the cask tie-down strap. Install the top and bottom impact limiters. Install a TID to an attachment point on the top impact limiter.
38. Install ISO container bracing and lid, or personnel barrier.
39. Complete radiation and contamination surveys of the external surfaces of the package and record the data. Ensure removable contamination and radiation dose rate survey results comply with the limits specified in 10 CFR 71.87(i) and (j).
40. 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.
41. 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.
42. Apply appropriate placards to the transport vehicle in accordance with 49 CFR 172, Subpart F.
43. Complete the shipping documents and provide the carrier with instructions regarding the requirements for maintaining an exclusive use shipment.

7.1.7 Procedure for Loading TRIGA Damaged Fuel or Fuel Debris into a TRIGA Sealed Damaged Fuel Can (DFC)

1. Examine the sealed damaged fuel can (DFC) body and inspect for damage. Verify that the lid sealing surface is clean and free of defects. Visually verify that the drain plug seal is installed and the drain plug is partially threaded into the drain plug adapter to allow for draining.
2. Lower the DFC into the pool and position it for fuel loading.
3. Load the damaged TRIGA fuel cluster rods or fuel debris into the DFC. Verify that no more than the equivalent of 2 design base fuel elements, or 6 fuel cluster rods, as damaged fuel or fuel debris are loaded into the sealed DFC as specified in the CoC. Visually verify that there is no debris in the lid sealing surface and thread areas.
4. Examine the DFC lid and inspect for damage. Visually verify that the sealing surface is clean and free of defects. Lubricate the lid bolts, install the lid seal and verify that the lid valve is in the open position and the valve lock set screw is retracted.
5. Attach the testing hose to the lid test connection and ensure that the fitting is properly seated.
6. Install the lid and torque the lid bolts to 150 ± 10 inch-pound.

   Note: Torque any two diametrically opposed bolts first, then torque the remaining two bolts. Complete the torque sequence by verifying the torque of all four bolts in a clockwise direction.

7. Pressurize the sealed DFC with air or helium to 5-15 psig to remove the water. Continue the purge for at least 5 minutes after bubbles appear from the base of the DFC.
8. Access and torque the DFC drain plug to 50 ± 10 inch-pound.
9. Evacuate the DFC to a pressure below 10 torr (13 mbar) and continue vacuum pumping for 10 minutes.
10. Stop and isolate the vacuum pump and monitor the DFC vacuum pressure for a minimum of 10 minutes. If the pressure rise is <5 torr (6.7 mbar) in 10 minutes, the DFC is verified as dry of free water. If the pressure rise is >5 torr (6.7 mbar) in 10 minutes or less, the DFC is not considered dry of free water. Repeat vacuum drying and pressure rise testing until the dryness verification results are satisfactory.
11. Backfill the DFC with helium to a pressure of 1 atmosphere (0 psig), +1, -0 psi.
12. Shut and lock the lid diaphragm valve. The DFC is now sealed, dried and backfilled.
13. Disconnect the testing hose from the lid test connection.
14. The sealed DFC is now ready for loading into a TRIGA basket module.

7.1.8 Procedure for Wet Loading of PWR/BWR Fuel Rods or TPBARs into the PWR/BWR Transport Canister

For the shipment of PWR and BWR fuel rods and nonfuel-bearing components (e.g., PWR guide tubes or BWR water rods), the PWR/BWR transport canister has three configurations: sealed canister, screened canister, and free-flow canister. All three canister configurations may be used to contain either intact or damaged fuel rods, or a combination of both damaged and intact fuel rods. The loaded transport canisters are loaded into the NAC-LWT cask containing a LWT PWR basket assembly with an appropriate bottom weldment spacer. For transport canisters containing any damaged fuel rod contents, a can and an insert spacer are required to be installed and bolted to the underside of the closure lid to limit the axial movement of the canister. The use of the can and insert spacer requires the use of the PWR basket assembly fitted with the Alternate B spacer. Transport canisters containing intact rods may be placed in any of the three types of PWR basket assemblies. For the transport of a mixed loading of PWR or BWR fuel rods with nonfuel-bearing components, a modified 5×5 insert with 21 fuel rod locations and a larger tube position for the larger diameter nonfuel-bearing component (up to a nominal diameter of 1.3 inches) is required to be used with the PWR/BWR transport canister.

For the shipment of TPBARs, only the screened or free flow PWR/BWR Rod Transport Canister containing the 5 × 5 rod insert may be used.

Upon completion of loading the transport canister, the canister and the insert spacer are loaded, either together or individually, into the basket assembly in a manner similar to loading a PWR assembly.

1. If the transport canister is to be shipped in a sealed configuration, verify the five drain plugs are installed and torqued to 50 ± 2 foot-pound. If the transport canister is to be shipped in the free flow configuration, verify the five drain plugs are not installed. If the transport canister is to be shipped in the screened configuration, verify the screened plugs are installed and torqued to 50 ± 2 foot-pound in the bottom of the canister.
2. Lower the transport canister (and insert) into the fuel pool for loading.
3. Load the spent fuel rods into the transport canister in accordance with site-specific procedures. Separate failed fuel rod capsules may be used to contain either intact or damaged fuel rods within the canister. The capsules are intended to limit dispersal of radioactive material to the canister internals. Visually upon completion of loading, verify that there is no debris on the lid sealing surface and threaded areas.
4. Using the appropriate lid (sealed, screened or free-flow), examine and inspect for damage. Visually verify that the sealing surface is clean and free of defects. Lubricate the lid bolts.
5. Install the lid and torque the lid bolts to 35 ± 5 inch-pound.

   Note: Torque any two diametrically opposed bolts first, then torque the remaining six bolts. Complete the torque sequence by verifying the torque of all eight bolts in a clockwise direction.
6. If the transport canister is being shipped in either the screened or free-flow configuration, it is now ready for shipment. To ship PWR and BWR rods and nonfuel-bearing components, the transport canister shall be loaded into the NAC-LWT cask in accordance with Section 7.1.1, Procedures for Wet Loading of LWR Fuel Assemblies and Canistered LWR Fuel Rods. To ship TPBARs, the transport canister shall be loaded in accordance with Section 7.1.9, Procedure for Wet Loading of TPBAR Consolidation Canister or PWR/BWR Rod Transport Canister into the NAC-LWT Cask. If the transport canister is being shipped in the sealed configuration, complete steps 7-14 of this section.
7. Connect vent and drain lines to the respective quick-disconnect fittings on the sealed transport canister lid. The drain hose discharge should be directed to the plant drain system for radiological wastewater or another appropriate collection point.
8. Pressurize and purge the transport canister using helium. (Caution do not exceed 25 psig. while dewatering the transport canister.) Secure the purge once no fluid is observed exiting the discharge for at least 10 minutes.
9. Connect the vent line to a suitable vacuum pump. Maintain connection of drain line to the can, but isolate the line to allow vacuum drying of the sealed failed fuel can.
10. Evacuate the can to a pressure below 10 torr (13 mbar) and continue vacuum pumping for 10 minutes.
11. Stop and isolate the vacuum pump and monitor the cask cavity vacuum pressure for a minimum of 10 minutes. If the pressure rise is less than 5 torr (6.7 mbar), the cavity is verified as dry of free water. If the pressure rise is >5 torr (6.7 mbar), repeat vacuum drying until the dryness verification results are satisfactory.
12. Backfill the transport canister cavity with helium to 1 atmosphere (absolute), +1, -0 psi.

13. Disconnect the vent and drain lines from the transport canister.
14. The sealed transport canister is now ready for shipment and may be loaded into the NAC-LWT cask in accordance with Section 7.1.1.

7.1.9 Procedure for Wet Loading of TPBAR Consolidation Canister or PWR/BWR Rod Transport Canister into the NAC-LWT Cask

This section describes the procedures for loading the NAC-LWT with a TPBAR consolidation canister or with a screened or free flow PWR/BWR Rod Transport Canister. The consolidation canister can contain up to 300 TPBARs, two of which may be prefailed. Dunnage (i.e., spacer grids, stainless steel tubes, etc.) may be used in consolidation canisters containing fewer than 300 TPBARs. The total weight and volume of the contents (i.e., dunnage and reduced number of TPBARs) must be less than, or equal to, the weight and volume of the full load of 300 TPBARs.

The PWR/BWR Rod Transport Canister may contain up to 25 TPBARs.

Appropriate radiological controls and procedures addressing tritium shall be utilized by the licensee, including appropriate personnel monitoring for tritium exposure.

NAC-LWT casks to be used to transport the TPBAR consolidation canisters shall be configured as shown on Drawing No. 315-40-128, including Alternate B port covers. NAC-LWT casks to be used to transport a PWR/BWR Rod Transport Canister shall be configured as shown on Drawing No. 315-40-104, Assembly 95, including Alternate B port covers.

1. Perform a receiving survey of the empty cask and inspect for damage. Verify, by cask serial number, that the cask is approved for TPBAR shipment.
2. Position a trailer in the designated cask unloading area. Set the trailer brakes and chock the wheels to prevent unintended movement. If site-specific conditions exist that require the trailer to move to allow the cask to be uprighted on its rotation trunnions, release brakes and remove the chocks when required to complete uprighting operations. If an ISO is used, it may be removed from the trailer and secured in the unloading area.
3. Remove the roof from the ISO container and open the front and rear ISO doors. Remove roof cross-members, if installed.

   Note: Verify that the package nameplate displays the package identification number, USA/9225/B(M)-96, as required by the CoC for TPBAR contents.
4. Perform a Health Physics survey of the cask and adjacent surfaces of the trailer.

   Note: A receiving survey of the cask and transporter must be performed as soon as practical after arrival at the site to assure compliance with 10 CFR 71.87(i) and 10 CFR 71.47, and to assure timely reporting of any reportable noncompliance.
5. Remove the top and bottom impact limiters.
6. Remove the cask tie-down strap.
7. Using the lifting yoke with the guides removed, engage the lifting trunnions. Raise the cask to vertical by rotating the cask rotation sockets on the rear cask supports,

moving the crane and/or trailer as required to keep the lift yoke engaged to the trunnions and the cask engaged in the rear supports. When the cask is fully vertical, lift the cask from the supports and remove it from the trailer/container.

8. Place the cask in the decontamination pit or other designated area. Disengage the lifting yoke. Clean cask surfaces of road dirt as required for entry into the spent fuel pool.
9. Visually inspect the neutron shield tank fill, drain and level inspection plugs for signs of neutron shield fluid leakage. If leakage is detected, verify shield tank fluid level and correct, as required.
10. Remove the Alternate B vent and drain valve port covers. Prior to reinstallation of the port covers, replace the metallic O-ring seal with an approved spare and inspect the Viton® O-ring seal for each port cover. If the Viton® O-ring shows any damage, replace it. Ensure that the replacement O-rings are properly installed and seated. Store the port covers to protect the seal surfaces. Visually inspect the valved quick-disconnect nipples and replace them, if necessary.
11. Remove closure lid bolts. Attach the lid lift slings to the closure lid. Remove the closure lid and set it on a support that is suitable for radiological control and for maintaining the cleanliness of the closure lid. Prior to reinstallation of the lid, carefully inspect the Teflon O-ring seal in the underside of the closure lid. If the O-ring shows any damage, replace it. Remove the metallic O-ring and replace it with an approved spare. Ensure that the replacement O-rings are properly installed and seated. Inspect the lid bolts and replace any that are damaged. Ensure that the TPBAR spacer is installed on the bottom of the cask lid for consolidation canister transports and not damaged when the lid is set down.
12. Visually inspect the inner cavity for foreign material or damage. Install or verify the presence of the standard drain tube and the TPBAR basket assembly (Drawing No. 315-40-10, Assembly 96 or Assembly 95) for loading of the consolidation canister; or the standard drain tube, TPBAR basket assembly (Drawing No. 315-40-10, Assembly 95), and the PWR Insert (Drawing No. 315-40-105, Assembly 99) for the loading of the PWR/BWR Rod Transport Canister containing TPBARs.

    Note: The PWR inset may be installed during the placement of the loaded PWR/BWR Rod Transport Canister into the NAC-LWT cask.

13 Fill the cask cavity with clean water. Install lift yoke arm guides and remote actuation components on the cask lifting yoke.
14. Engage the cask lifting yoke with the cask lifting trunnions and pick up the cask. Carefully lower the cask to the bottom of the cask loading area while spraying the cask down with clean water.
15. Disengage the lifting yoke from the cask and remove the yoke from the pool.
16. Identify the TPBAR consolidation canister or the PWR/BWR Rod Transport Canister containing TPBARs to be loaded.
17. Pick up the consolidation canister or the PWR/BWR Rod Transport Canister using the required grapple system.
18. Position the container over the cask and then carefully lower it into the cask to avoid damage to the cask sealing surfaces. Orient the consolidation canister bail so that it is

aligned with the drain tube location. Confirm that the container is fully seated, then release and raise the grapple to the full up position.

19. Position the cask lifting yoke over the cask closure lid. Attach the slings to the closure lid and cask lifting yoke. Lower the yoke over the cask.
20. Position the closure lid over the cask and slowly lower it into place. For the consolidation canister, ensure the bail is properly aligned to the TPBAR spacer on the bottom of the lid. Use the cask and lid match marks as guides to properly align the lid. Visually confirm that the closure lid is seated.
21. Lower the cask handling yoke to slack the closure lid cables. Engage the lift yoke to the lifting trunnions and begin lifting.

    Note: Visually verify the yoke engagement before lifting the cask.
22. Raise the cask until the lid is slightly above the surface of the pool. At the option of the licensee/user, a number of closure lid bolts (4 to 12) may be installed hand tight.
23. Raise the cask clear of the pool, rinsing the yoke and cask with clean water.
24. Transfer the cask to the decontamination pit or other work area. Remove the yoke and lid lift slings.
25. Install and tighten the 12 closure lid bolts to 260 ± 20 ft-lb in three passes, using the torque sequence stamped on the closure lid.
26. At the option of the licensee/user, a 25 to 50 gallon clean water flush of the cask cavity may be performed by connecting a valved clean water line to the drain valve and a valved drain line to the vent valve. After the cavity flushing is completed, if performed, disconnect the water supply and drain lines.
27. Connect a gas supply line to the vent valve and the drain line to the drain valve.
28. Open the air, nitrogen or helium gas supply valve and pressurize the cask cavity (<30 psig) to force out the water. Continue to supply pressurized gas to the cask for a minimum of five minutes after the last residual free water discharges from the drain line. Remove the drain and gas supply lines and attach a vacuum drying system (VDS) to the cask vent valve.
29. Evacuate the cask cavity to a vacuum pressure of less than 10 torr (13 mbar) and continue vacuum pumping for a minimum of 15 minutes.
30. At the end of the vacuum pumping period, isolate the cask cavity from the vacuum pump and stop the pump. Monitor the cask cavity pressure for a minimum of ten (10) minutes. If the pressure rise is less than 5 torr (6.7 mbar), the cavity is verified as dry of free water. If the pressure rise >5 torr (6.7 mbar), repeat vacuum drying until the dryness verification results are satisfactory.
31. Backfill the cask cavity with helium to 0 psig (1 atmosphere, absolute), +1, -0 psi. Disconnect the VDS.
32. Perform the helium leakage test of the closure lid containment O-ring using a Helium Mass Spectrometer Leak Detector (He MSLD) in accordance with the requirements of Section 8.1.3.1, Steps 3 through 10.
33. Install and helium leakage test the Alternate B vent and drain port covers to leaktight criteria in accordance with Section 8.1.3.3.2.

34. Decontaminate the cask. Survey the cask for surface contamination and radiation dose rates.

    Note: Ensure compliance with 10 CFR 71.87(i) and 10 CFR 71.47.
35. Remove lift yoke arm guides. Engage the cask lifting yoke to the lifting trunnions.
36. Lift the cask and position the cask rotation sockets in the rear rotation trunnions of the rear support structure. Carefully lower the cask to the horizontal transport orientation resting on the front saddle by moving the crane and/or trailer, as required, to maintain cask engagement to the rear supports.
37. Disengage the cask lifting yoke from the cask lifting trunnions and remove it from the area.
38. Install the cask tie-down strap. Install the top and bottom impact limiters.
39. Install a TID to an attachment point of the top impact limiter.
40. Install roof cross-members, close ISO container doors, and replace ISO container roof.
41. Complete radiation and contamination surveys of the external surfaces of the package and record the data. Ensure removable contamination and radiation dose rate survey results comply with the limits specified in 10 CFR 71.87(i) and (j).
42. 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.
43. 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.
44. Apply appropriate placards to the transport vehicle in accordance with 49 CFR 172, Subpart F.
45. Complete the shipping documents and provide the carrier with instructions regarding the requirements for maintaining an exclusive use shipment.

7.1.10 Procedure for the Dry Loading of PULSTAR Fuel Into the NAC-LWT Cask

This section describes the procedures for loading the NAC-LWT cask with intact PULSTAR fuel assemblies, intact PULSTAR fuel rods in fuel rod inserts, and intact or damaged PULSTAR fuel assemblies, fuel rods, fuel debris, and nonfuel components of PULSTAR fuel assemblies in either sealed or screened PULSTAR cans. Up to 28 PULSTAR fuel assemblies, rod inserts, and sealed or screened cans can be loaded in the 28 MTR (four module × seven cells/module) basket assembly. The 28 MTR basket assembly consists of a base module, two intermediate modules, and a top module.

Damaged PULSTAR fuel assemblies, damaged fuel rods, fuel debris, and nonfuel components of fuel assemblies are required to be loaded in either a sealed failed fuel or screened PULSTAR can. Intact PULSTAR fuel rods may be loaded into either one of the cans at the option of the

licensee. The PULSTAR cans are limited to being loaded in any cell in either the top or the base module. The top and base basket modules can also contain intact PULSTAR fuel assemblies and fuel rod inserts containing intact PULSTAR fuel rods.

The NAC-LWT cask will be loaded dry, utilizing a transfer cask for loading each of the four basket modules. The basket modules will be preloaded with the PULSTAR fuel contents. The damaged fuel cans will be preloaded, closed, drained and dried, if applicable, prior to loading in either the top or base basket module. The PULSTAR cans shall be loaded and prepared for transport in accordance with the applicable steps of Section 7.1.7.

The NAC-LWT dry PULSTAR fuel loading and preparation for transport procedures are as follows.

1. Perform a receipt inspection of the empty cask and trailer/ISO container, inspecting for transport damage.
2. Position the trailer in the designated cask unloading area. Set the trailer brakes and chock the wheels to prevent unintended movement. If site-specific conditions exist that require the trailer to move to allow the cask to be uprighted on its rotation trunnions, release brakes and remove the chocks when required to complete uprighting operations. If an ISO container is used, it may be removed from the trailer and secured in the unloading area.
3. Remove the lid/top of the ISO container and remove any bracing.

   Note: Verify that the package nameplate displays the correct package identification number in accordance with the CoC.
4. Perform a Health Physics survey of the cask and adjacent surfaces of the trailer.

   Note: A receiving survey of the cask and transporter must be performed as soon as practical after arrival at the site to assure compliance with 10 CFR 71.87(i) and 10 CFR 71.47, and to assure timely reporting of any reportable noncompliance.
5. Remove the top and bottom impact limiters.
6. Remove the cask tie-down strap.
7. Using the lifting yoke with the guides removed, engage the lifting trunnions. Raise the cask to vertical by rotating the cask rotation sockets on the rear cask supports, moving the crane and/or trailer as required to keep the lift yoke engaged to the trunnions and the cask engaged in the rear supports. When the cask is fully vertical, lift the cask from the supports and remove it from the trailer/container.
8. Place the cask into the dry loading station.
9. Disengage the lift yoke.
10. Visually inspect the neutron shield tank fill, drain and level inspection plugs for signs of neutron shield fluid leakage. If leakage is detected or suspected, verify shield tank fluid level and correct, as required.

11. Remove the vent and drain port covers. Prior to reinstallation of the port covers, carefully inspect the port cover O-ring seals and, if the O-rings show any damage, replace them with approved spares. Ensure that the replacement O-rings are properly installed and seated. Visually inspect the vent and drain quick-disconnect nipples and replace them, if necessary.

    Note: For Alternate B port covers, replace the metallic O-ring with an approved spare prior to reinstallation.

12. Remove closure lid bolts. Attach the lid lift slings to the closure lid. Remove the closure lid and set it on a support that is suitable for radiological control and for maintaining the cleanliness of the closure lid. Prior to reinstallation of the lid, carefully inspect the Teflon O-ring seal in the underside of the closure lid. If the O-ring shows any damage, replace it. Remove the metallic O-ring and replace it with an approved spare. Ensure that the replacement O-rings are properly installed and seated. Inspect the lid bolts and replace any that are damaged.
13. Visually inspect the cask cavity for foreign material or damage. Clean as necessary. Install or verify the presence of a correct drain tube assembly including alignment ring.
14. Install the required dry transfer system components to the top of the cask.
15. Position the shielded transfer cask components for basket module loading, as appropriate.
16. Identify the PULSTAR fuel assemblies, fuel rod holders, and fuel cans to be loaded, and verify that the PULSTAR fuel contents comply with the authorized content, heat load and quantity conditions of the CoC. Four basket modules (e.g., one base module, two intermediate modules, and a top module) constitute the 28 MTR basket assembly. Spacers will be used as provided to position the PULSTAR fuel contents, as required.
17. Each module is capable of containing up to seven intact fuel assemblies, fuel rod inserts or a PULSTAR fuel can. Fuel cans are restricted to being loaded into the top and base modules, where the cans may be loaded with intact fuel assemblies or fuel rod holders without loading preference. There are no limitations on loading location for intact fuel assemblies or fuel rod holders in any of the four basket modules.

    The base module is loaded into the cask first, followed by the two intermediate modules and the top module is loaded last.
18. Load the shielded transfer cask with the loaded base basket module.
19. Place the shielded transfer cask containing the base module unit onto the dry transfer system components positioned on the top of the cask.
20. Lower the fuel basket from the transfer cask into the NAC-LWT cask cavity.
21. Repeat the loading and transfer of loaded basket modules until the approved cask loading plan is completed.
22. Install the closure lid onto the cask using the dry transfer system. Visually verify that the lid is properly seated.
23. Remove the dry transfer cask system components from the top of the cask.

24. Install and torque the 12 closure lid bolts to 260 ± 20 ft-lb in three passes using the torquing sequence stamped on the lid.
25. Connect a gas supply line to the vent valve and a drain line to the drain valve.
26. Open the nitrogen or helium gas supply valve and pressurize the cask cavity (< 30 psig) to force any residual water out the drain line. Continue to supply pressurized gas to the cask for a minimum of five minutes after the last residual free water discharges form the drain. Remove the drain and gas supply lines and attach a vacuum drying system (VDS) to the vent.
27. Evacuate the cask cavity to less than or equal to 10 torr (13 mbar) and continue vacuum pumping for a minimum of 15 minutes.
28. At the end of the vacuum pumping period, isolate the cask cavity from the vacuum pump and stop the vacuum pump, and monitor the cask cavity pressure for a minimum of 10 minutes. If the pressure rise is less than 5 torr (6.7 torr), the cavity is verified dry of free water. If the pressure rise is >5 torr (6.7 mbar), continue vacuum drying until the dryness verification is completed satisfactorily.
29. Backfill the cask cavity with helium to 0 psig (1 atmosphere, absolute), +1, -0 psi. Disconnect the VDS from the vent valve.
30. Perform the helium leakage test of the closure lid containment O-ring using a Helium Mass Spectrometer Leak Detector (He MSLD) in accordance with the requirements of Section 8.1.3.1, Steps 3 through 10.
31. Install the vent and drain alternate port covers and torque the bolts to 100 ±10 inch-pounds.
32. If an alternate port cover containment O-ring seal was replaced, perform a helium leakage test on the affected port cover using a He MSLD in accordance with the requirements of Section 8.1.3.2.2.
33. If the alternate port cover containment seal was inspected and accepted for reuse, perform an air pressure drop leakage test on the affected port cover as follows.
    a. Install a pressure test fixture to the port cover test port, including a calibrated pressure gauge with a minimum sensitivity of 0.25 psi.
    b. Pressurize the port cover seal annulus to 15 psig, +1, -0 psi.
    c. Isolate the gas supply and observe the pressure gauge for a minimum of five minutes.
    d. The acceptance criterion for the test is no measurable drop in pressure during the minimum test time. An acceptable test assures that the minimum assembly verification leakage test sensitivity is achieved.

    Note: Alternate B port covers, if used, require the satisfactory completion of a helium maintenance leakage rate test for each loaded transport. Install the Alternate B port cover and perform the maintenance leakage rate test per the requirements of 8.1.3.3.2.

34. Decontaminate the cask. Survey the cask for surface contamination and radiation dose rates.

    Note: Ensure compliance with 10 CFR 71.87(i) and 10 CFR 71.47.

35. Engage the cask lifting yoke to the lifting trunnions.
36. Lift the cask and position the cask rotation sockets in the rear rotation trunnions of the rear support structure. Carefully lower the cask to the horizontal transport orientation resting on the front saddle by moving the crane and/or the trailer as required to maintain cask engagement to the rear supports.
37. Disengage the lifting yoke from the lifting trunnions and remove it from the area.
38. Install the cask tie-down strap. Install the top and bottom impact limiters.
39. Install a TID to an attachment point on the top impact limiter.
40. Install ISO container bracing and lid.
41. Complete radiation and contamination surveys of the external surfaces of the package and record the data. Ensure removable contamination and radiation dose rate survey results comply with the limits specified in 10 CFR 71.87(i) and (j).
42. 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.
43. Determine the appropriate Criticality Safety Index (CSI) assigned to the package contents in accordance with the Certificate of Compliance, and indicate the correct CSI on the Fissile Material label applied to the package per 49 CFR 172, Subpart E.
44. Apply appropriate placards to the transport vehicle in accordance with 49 CFR 172, Subpart F.
45. Complete the shipping documents and provide the carrier with instructions regarding the requirements for maintaining an exclusive use shipment.

7.1.11 Procedure for Dry Loading of TPBAR Waste Container

This section describes the procedure for the loading of a TPBAR Waste Container into a NAC-LWT cask in a dry loading facility. Appropriate radiological controls and procedures addressing tritium shall be utilized by the licensee, including appropriate monitoring for tritium exposure.

NAC-LWT casks to be used for the transport of TPBARs shall be configured as shown on Drawing No. 315-40-128, including Alternate B port covers.

1. Perform a receiving survey of the ISO and trailer, and inspect for damage.
2. Position the trailer in the designated cask unloading area. Set the trailer brakes and chock the wheels to prevent unintended movement. If site-specific conditions exist that require the trailer to move to allow the cask to be uprighted on its rotation trunnions, release the

brakes and remove the chocks when required to complete the uprighting operations. If necessary, the ISO container may be removed from the trailer and secured in the unloading area.

3. Licensees shall receive and survey the package for radiation and removable contamination (for both gross beta-gamma and tritium) per 10 CFR 20 and 49 CFR 173. Record the survey results. If radiation or contamination levels exceed the limits of 49 CFR 173.441 or 173.443, respectively, the licensee shall notify the shipper and ensure the appropriate notifications are completed.
4. Remove the roof from the ISO container and open the front and rear ISO doors. Remove the ISO roof cross members, if installed.
5. Remove the top and bottom impact limiters.
6. Remove the cask tie-down strap. Complete the radiation and contamination surveys of the package as additional surfaces become accessible. Clean the cask surfaces as required for entry into the dry loading facility.
7. Using the cask lifting yoke with lift yoke arm guides removed, engage the lifting trunnions of the front end of the cask. Raise the cask to a vertical position on the rear cask supports, moving the crane and/or trailer, as required, to keep the cask engaged in the rear cask supports and the crane cable vertical. When the cask is vertical, block the trailer wheels and lift the cask from the container.
8. Place the cask in a transfer cart or a loading fixture. Disengage the lifting yoke.
9. Remove the Alternate B vent and drain valve port covers. Replace the metallic seal with an approved spare and inspect the Viton® O-ring seal on each cover. If the Viton® O-ring shows any damage, replace it. Ensure the replacement O-rings are properly installed and seated. Store the port cover to protect the seal surfaces. Visually inspect the vent and drain valved quick-disconnect nipples and replace, if necessary.
10. Loosen and remove all closure lid bolts.
11. Attach the lid removal fixture to the closure lid.
12. Use a transfer cart or loading fixture and move the cask into the loading position.
13. Remove the closure lid and set it on a support that is suitable for radiological control and for maintaining the cleanliness of the closure lid. Carefully inspect the Teflon O-ring seal in the underside of the closure lid. If the O-ring shows any damage, replace it. Remove the metallic O-ring and replace it with an approved spare. Ensure the replacement O-rings are properly installed and seated. Inspect the lid bolts and replace any that are damaged. Verify that the TPBAR spacer is installed on the bottom of the cask lid and not damaged when the lid is set down.
14. Install the seal surface protector in the lid cavity, if required.
15. Load the TPBAR Waste Container into the TPBAR basket positioned in the cask cavity using the required grapple or handling system. Verify the contents of the Waste Container comply with the CoC content conditions.

16. Remove the cask seal surface protector, if used, and install the cask closure lid.
17. Use the transfer cart or loading fixture and remove the cask from the loading area.
18. Inspect, install and tighten all 12 closure lid bolts to 260 ± 20 ft-lbs in three passes using the torque sequence indicated on the closure lid.
19. Connect a vacuum pump to the cask vent valve.
20. Perform the helium mass spectrometer maintenance leakage rate test on the cask lid to leaktight criteria in accordance with the requirements of Section 8.1.3.1, Steps 3 through 10.
21. Following successful completion of the helium backfill and helium leak testing of the lid seal, monitor the cavity volume for tritium and record the results.

    Note: Tritium monitoring system shall have a minimum sensitivity of 5×10^{-3} micro curies/cc.
22. Install Alternate B port covers on the vent and drain openings and torque each port cover bolt to 285 ± 15 in-lbs. Perform a helium leakage rate test on each port cover to leaktight criteria in accordance with Section 8.1.3.3.2.
23. Decontaminate the cask. Survey the cask surface for gross beta-gamma and tritium removable contamination levels, and radiation dose rates.

    Note: Removable contamination levels and radiation levels shall comply with 49 CFR 173.443 and 173.441, respectively.
24. Using the cask lifting yoke with the guide arms removed, lift and position the cask in the rear cask supports on the ISO/trailer. Engage the trunnion pockets in the bottom end of the cask with the rotation trunnions. Lower the cask to rest on the front tiedown saddle, moving the crane, and/or trailer, as required, to keep the crane cables vertical. Disengage the cask lifting yoke from the cask lifting trunnions and set it aside.
25. Install and attach the cask tiedown strap. Install the cask top and bottom impact limiters.
26. Install a TID to an attachment point on the top impact limiter.
27. Install roof cross members, close ISO container doors, and replace ISO container roof.
28. Complete a Health Physics survey on the external surface of the package and record the results. Complete dose rate measurements at the cask surface, at 1 meter from the cask surface, and at 2 meters from the vertical plane of the side of the transport vehicle. The maximum dose rate at 1 meter from the cask is the transport index (TI). Ensure compliance with 10 CFR 71.87(i) and observe the following criteria.

    - If the dose rate is less than 2 mSv/h (200 mrem/hr) at all accessible points on the external surface of the cask, and the TI is less than 10, the package must meet the requirements of 10 CFR 71.47 (a).
    - If the dose rate is greater than 2 mSv/h (200 mrem/hr), but is less than 10 mSv/h (1000 mrem/hr) at any point on the external surface of the package, or the TI is

greater than 10, the package must be shipped as "exclusive use" and meet the requirements of 10 CFR 71.47 (b), (c) and (d). If the dose rate and shipping requirements of 10 CFR 71.47 (b), (1), (2), (3) and (4) cannot be met, the package cannot be shipped.

Note: 10 CFR 71.47 (c) and (d) require the shipper to provide the carrier with written instructions for maintenance of the exclusive use shipment. The instructions must be included with the shipping paper information. The instructions must be sufficient so that, when followed, they cause the carrier to avoid actions that unnecessarily delay delivery or unnecessarily result in increased radiation levels or radiation exposures to transport workers or members of the general public.

- If the dose rate is > 10 mSv/h (1000 mrem/hr) at any point on the external surface of the cask, the cask exceeds the limits of 10 CFR 71.47 and cannot be shipped.

29. Complete the shipping document, carrier instructions (if required), and apply appropriate placards and labels.

7.1.12 Procedure for Wet Loading PWR MOX Fuel Rods in a Transport Canister Into the NAC-LWT Cask

PWR MOX fuel rods (or combinations of PWR MOX and UO_2 PWR fuel rods) are required to be loaded into a screened or free flow PWR/BWR Rod Transport Canister prior to loading into the NAC-LWT cask for transport. Although a maximum quantity of 16 MOX fuel rods may be shipped, it is required that the 5 × 5 rod insert be used to position the rods in the transport canister (i.e., the 4 × 4 insert is not authorized for use for the transport of MOX fuel rods).

In order to satisfy the increased potential for release of significant quantities of radioactive materials, and as recommended by NUREG-1617, Supplement 1, the NAC-LWT cask assembly specified for the transport of PWR MOX fuel rods contained in a transport canister provides a leaktight containment boundary.

The screened or free flow transport canister with a 5 × 5 rod insert will be loaded with up to 16 PWR MOX fuel rods (or a combination of up to 16 PWR MOX and UO_2 PWR fuel rods). In addition to the 16 PWR MOX fuel rods, up to 9 zirconium alloy-based burnable poison rods (BPRs) may be loaded into the unused insert openings.

NAC-LWT casks to be used for the transport of MOX fuel rods shall be configured as shown on Drawing No. 315-40-104, Assembly 97.

1. Perform a receiving survey of the empty cask and inspect for damage.
2. Position a trailer in the designated cask unloading area. Set the trailer brakes and chock the wheels to prevent unintended movement. If site-specific conditions exist

that require the trailer to move to allow the cask to be uprighted on its rotation trunnions, release brakes and remove the chocks when required to complete uprighting operations. If an ISO is used, it may be removed from the trailer and secured in the unloading area.

3. Remove the roof from the ISO container and open the front and rear ISO doors. Remove roof cross-members, if installed.

   Note: Verify that the package nameplate displays the package identification number, USA/9225/B(U)F-96, as required by the CoC for PWR MOX fuel rods.

4. Perform a Health Physics survey of the cask and adjacent surfaces of the trailer.

   Note: A receiving survey of the cask and transporter must be performed as soon as practical after arrival at the site to assure compliance with 10 CFR 71.87(i) and 10 CFR 71.47, and to assure timely reporting of any reportable noncompliance.

5. Remove the top and bottom impact limiters.

6. Remove the cask tie-down strap.

7. Using the lifting yoke with the guides removed, engage the lifting trunnions. Raise the cask to vertical by rotating the cask rotation sockets on the rear cask supports, moving the crane and/or trailer as required to maintain the lift yoke engaged to the trunnions and the cask engaged in the rear supports. When the cask is fully vertical, lift the cask from the supports and remove it from the trailer/container.

8. Place the cask in the decontamination pit or other designated area. Disengage the lifting yoke. Clean cask surfaces of road dirt, as required, for entry into the spent fuel pool.

9. Visually inspect the neutron shield tank fill, drain and level inspection plugs for signs of neutron shield fluid leakage. If leakage is detected, verify shield tank fluid level and correct, as required.

10. Remove the vent and drain valve port covers. Prior to reinstallation of the port covers, carefully inspect the valve port cover O-ring seals and, if the O-rings show any damage, replace them with approved spares. Ensure that the replacement O-rings are properly installed and seated. Visually inspect the valved quick-disconnect nipples and replace them, if necessary.

    Note: For Alternate B port covers, replace the metallic O-ring with an approved spare prior to reinstallation.

11. Remove closure lid bolts. Attach the lid lift slings to the closure lid. Remove the closure lid and set it on a support that is suitable for radiological control and for maintaining the cleanliness of the closure lid. Prior to reinstallation of the lid, carefully inspect the Teflon O-ring seal in the underside of the closure lid. If the O-ring shows any damage, replace it. Remove the metallic O-ring and replace it with an approved spare. Ensure that the replacement O-ring(s) is properly installed and

seated. Inspect the lid bolts and replace any that are damaged. Ensure that the Rod Transport Canister spacer is not damaged when the lid is set down.

12. Visually inspect the inner cavity for foreign material or damage. Install or verify the presence of the drain tube and the PWR basket assembly.

13 Fill the cask cavity with clean water. Install lift yoke arm guides and remote actuation components on the cask lifting yoke.

14. Engage the cask lifting yoke with the cask lifting trunnions and pick up the cask. Carefully lower the cask to the bottom of the cask loading area while spraying the cask down with clean water.

15. Disengage the lifting yoke from the cask and remove the yoke from the pool.

16. Identify the PWR/BWR Rod Transport Canister to be loaded and verify that a 5 × 5 rod insert is located in the canister.

17. Identify the PWR MOX fuel rods (and standard PWR rods and BPRs, as applicable) to be loaded into the PWR/BWR Rod Transport Canister. Verify that the fuel rods and BPRs comply with the content type, form, heat load, minimum cooling time and quantity conditions of the NAC-LWT CoC. Load the screened or free flow PWR/BWR transport canister with up to 16 PWR MOX fuel rods, a combination of MOX and standard PWR rods, and up to 9 BPRs in the open tube locations in the 5 × 5 insert. Perform an independent verification of the fuel rod selection and loading process.

18. Install the transport canister lid and torque the lid bolts to 35 ± 5 inch-pounds.

19. Position the loaded PWR/BWR Rod Transport Canister over the cask and then carefully lower it into the cask to avoid damage to the cask sealing surfaces. Note that the transport canister may be loaded into the cask with the PWR basket insert.

20. Position the cask lifting yoke over the cask closure lid. Attach the slings to the closure lid and cask lifting yoke. Lower the yoke over the cask.

21. Position the closure lid over the cask and verify that the appropriate lid spacer is installed per the approved PWR MOX fuel rod transport arrangement in Drawing 315-40-104, Section 1.4. Lower the closure lid into the lid recess using the lid match marks as guides to align the lid. Visually confirm that the closure lid is flush with the top of the cask and properly seated.

22. Lower the cask handling yoke to slack the closure lid cables. Engage the lift yoke to the lifting trunnions and begin lifting the cask.

    Note: Visually verify the yoke engagement before lifting the cask.

23. Raise the cask until the lid is slightly above the surface of the pool. At the option of the licensee/user, a number of closure lid bolts (4 to 12) may be installed hand tight.

24. Raise the cask clear of the pool, rinsing the yoke and cask with clean water and transfer the cask to the decontamination pit or other work area. Remove the yoke and lid lift slings.

25. Install and tighten the 12 closure lid bolts to 260 ± 20 ft-lb in three passes, using the torque sequence stamped on the closure lid.

26. At the option of the licensee/user, a 25 to 50 gallon clean water flush of the cask cavity may be performed by connecting a valved clean water line to the drain valve and a valved drain line to the vent valve. After the cavity flushing is completed, if performed, disconnect the water supply and drain lines.

27. Connect a nitrogen or helium gas supply line to the vent valve and the drain line to the drain valve.

28. Open the nitrogen or helium gas supply valve and pressurize the cask cavity (<30 psig) to force out the water. Continue to supply pressurized helium to the cask for a minimum of five minutes after the last residual free water discharges from the drain line. Remove the drain and gas supply lines and attach a vacuum drying system (VDS) to the cask vent valve.

29. Evacuate the cask cavity to a vacuum pressure of less than 10 torr (13 mbar) and continue vacuum pumping for a minimum of 15 minutes.

30. At the end of the vacuum pumping period, isolate the cask cavity from the vacuum pump and stop the pump. Monitor the cask cavity pressure for a minimum of 10 minutes. If the pressure rise is less than 5 torr (6.7 mbar), the cavity is verified as dry of free water. If the pressure rise is greater than 5 torr (6.7 mbar), repeat vacuum drying until the dryness verification results are satisfactory.

31. Backfill the cask cavity with helium to 0 psig (1 atmosphere, absolute), +2, -0 psi. Disconnect the VDS.

32. Perform the helium leakage test of the closure lid containment O-ring using a Helium Mass Spectrometer Leak Detector (He MSLD) in accordance with the requirements of Section 8.1.3.1, Steps 6 through 10.

33. Install the vent and drain port covers and torque the bolts to 100 ± 10 inch-pounds.

34. If an alternate port cover containment O-ring seal was replaced, perform a helium leakage test on the affected port cover using a He MSLD in accordance with the requirements of Section 8.1.3.2.2.

35. If the alternate port cover containment seal was inspected and accepted for reuse, perform a gas pressure drop leakage test on the affected port cover as follows.

    a. Install a pressure test fixture to the port cover test port, including a calibrated pressure gauge with a minimum sensitivity of 0.25 psi.

    b. Pressurize the port cover seal annulus to 15 psig, +1, -0 psi.

    c. Isolate the gas supply and observe the pressure gauge for a minimum of five minutes.

    d. The acceptance criterion for the test is no measurable drop in pressure during the minimum test time. An acceptable test assures that the minimum assembly verification leakage test sensitivity is achieved.

Note: Alternate B port covers, if used, require the satisfactory completion of a helium maintenance leakage rate test to confirm a leaktight seal condition for each loaded transport. Install the Alternate B port cover and perform the maintenance leakage rate test per the requirements of Section 8.1.3.3.2.

36. Decontaminate the cask. Survey the cask for surface contamination and radiation dose rates.

    Note: Ensure compliance with 10 CFR 71.87(i) and 10 CFR 71.47.

37. Remove lift yoke arm guides. Engage the cask lifting yoke to the lifting trunnions.

38. Lift the cask and position the cask rotation sockets in the rear rotation trunnions of the rear support structure. Carefully lower the cask to the horizontal transport orientation resting on the front saddle by moving the crane and/or trailer, as required, to maintain cask engagement to the rear supports.

39. Disengage the cask lifting yoke from the cask lifting trunnions and remove it from the area.

40. Install the cask tie-down strap. Install the top and bottom impact limiters.

41. Install a TID to an attachment point on the top impact limiter.

42. Install roof cross-members, close ISO container doors, and replace ISO container roof.

43. Complete radiation and contamination surveys of the external surfaces of the package and record the data. Ensure removable contamination and radiation dose rate survey results comply with the limits specified in 10 CFR 71.87(i) and (j).

44 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.

45. 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.

46. Apply appropriate placards to the transport vehicle in accordance with 49 CFR 172, Subpart F.

47. Complete the shipping documents and provide the carrier with instructions regarding the requirements for maintaining an exclusive use shipment.