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March 3, 2010

U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852-2738

Attention: Document Control Desk

Subject: Second Supplement to Request for Amendment to Revise the Model No. NAC-LWT Package U.S. Nuclear Regulatory Commission (NRC) Certificate of Compliance (CoC) No. 9225 to Include the General Atomic TRIGA Fuel as Authorized Content

Docket 71-9225

References:

1. USNRC CoC No. 9225, Revision 53, Model No. NAC-LWT Package, Dated February 4, 2010
2. NAC-LWT Safety Analysis Report (SAR), Revision 40, NAC International, January 2010
3. Request for Amendment to Revise the Model No. NAC-LWT Package U.S. Nuclear Regulatory Commission (NRC) Certificate of Compliance (CoC) No. 9225 to Include the General Atomic TRIGA Fuel as Authorized Content, NAC International, February 9, 2010
4. Supplement to Request for Amendment to Revise the Model No. NAC-LWT Package U.S. Nuclear Regulatory Commission (NRC) Certificate of Compliance (CoC) No. 9225 to Include the General Atomic TRIGA Fuel as Authorized Content, NAC International, February 23, 2010

NAC International (NAC) hereby submits a second supplement to Reference 3 consisting of clarification changes to Chapter 6 information as requested in a telephone conference on March 1, 2010. The changes consist of

- Evaluation of the array of damaged packages and calculation of Criticality Safety Index
- Input file for the criticality evaluation for the array of packages
- Addition of a figure illustrating the configuration for the top and bottom baskets for the TRIGA fuel rods having enrichment $\geq 93\%$
- Addition of a figure illustrating the configuration for the entire package with TRIGA fuel rods having enrichment $\geq 93\%$

ED20100026

NMSS01

This submittal includes one copy of this transmittal letter and Revision LWT-10C changed pages to the Reference 2 SAR. The changed pages incorporate the requested supplemental information to the amendment to the CoC. Consistent with NAC administrative practice, this proposed SAR revision is numbered to uniquely identify the applicable changed pages. Revision bars mark the SAR text changes on the Revision LWT-10C pages. Due to text flow, a large number of Revision LWT-10C pages are included with no changes indicated. Also, some Revision LWT-10A pages are included as unchanged backing pages. The included List of Effective Pages identifies the current revision level of all pages in the Reference 2 SAR.

In accordance with NAC's administrative practices, upon final acceptance of this application, the Revision LWT-10C changed pages will be reformatted and incorporated into the next revision of the NAC-LWT SAR.

In this supplement to the amendment request, the proposed changes are limited to Chapter 6.

Approval of the amendment to Reference 1 is requested by March 15, 2010, to support shipping schedules planned for summer of 2010.

If you have any comments or questions, please contact me on my direct line at 678-328-1274.

Sincerely,

Anthony L. Patko
Director, Licensing
Engineering

Enclosure

March 2010

Revision LWT-10C

NAC-LWT

Legal Weight Truck Cask System

SAFETY ANALYSIS REPORT

Volume 1 of 2

Docket No. 71-9225

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NAC-LWT

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SAFETY ANALYSIS REPORT

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Chapter 6

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Note: See separate Section 6.6 for Appendices to this chapter, along with the List of Figures for the Appendices.

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second section evaluates severely damaged TRIGA fuel, including debris, in sealed and screened cans. The third section contains the evaluations for a screened can containing TRIGA elements with potential clad damage, but meeting structural requirements for transport. The fourth section evaluates increases in the range of enrichment and fissile material mass of TRIGA fuel elements in intact, screened, and sealed canister configurations. The fifth section contains the evaluation of a mixed shipment of TRIGA fuel elements and TRIGA cluster rods. Unless otherwise indicated, all models represent the accident condition cask (i.e., no neutron shield) in a finite cask array of eight casks. The array of eight casks is placed in a close-pack triangular pitch configuration as shown in Figure 6.4.5-9. As demonstrated in the analysis results sections, neutronic coupling between casks in an array, with void between casks, maximizes reactivity. Placing the casks in a tight pitch array, therefore, represents the most reactive configuration. The CSI based on the eight-cask accident array is 12.5 (N=4, CSI=50/N). Under normal conditions, with the neutron shield in place, the system is evaluated for an infinite array of casks (reflective boundary condition on a cuboid surrounding the cask) producing a CSI of 0.

While the analyses evaluate both screened and sealed cans, shipment is only permitted in the sealed canister configuration.

6.4.5.6.1 Intact Fuel Elements (No Can)

Basic TRIGA fuel element characteristics affecting system reactivity are itemized in the following paragraphs, with a qualitative description as to their effect on system reactivity.

Following the qualitative description are the result discussions of the KENO-Va calculations for the individual parameters.

Enrichment

TRIGA fuel elements are constructed at two basic enrichment levels (20 wt % and 70 wt % ^{235}U).

Fissile Material Mass

Maximum fissile material mass for each enrichment/fuel clad material combination is assigned to the models. Maximum fissile material mass will result in maximum system reactivity.

Zirconium Mass and Hydrogen-to-Zirconium (H/Zr) Ratio

The combination of zirconium mass and the H/Zr ratio determines the quantity of moderator (hydrogen) within the fuel matrix. Previous evaluations indicate that increasing the moderator quantity has the potential to increase system reactivity (i.e., the fuel element itself is under-moderated). Therefore, maximum system reactivity is obtained from a H/Zr ratio of 2.0 (maximum for zirconium hydride) and a maximum fuel zirconium content (limited by the fuel region volume).

Rod Diameter

Modifying rod diameter at a fixed fuel geometry and mass has a small negative effect for stainless steel clad elements, as it increases clad volume (stainless steel is a parasitic absorber). There is no significant effect on aluminum clad fuel. A secondary effect of a rod diameter increase is the separation of the fuel in the dry cavity cask case and reduction in water between elements in the wet cavity cask case. Both result in minor negative reactivity trends.

When allowing the fuel to expand to the clad inner surface, a maximum rod OD allows for additional moderator (in the form of ZrH), which more than offsets the minor reactivity effects discussed previously and, therefore, represents a bounding configuration.

Clad Thickness

Reducing clad thickness removes parasitic absorber for the stainless steel clad fuel element. At a fixed outer diameter, reduced clad thickness provides additional rod interior volume. For a fixed fuel mass, the reactivity effect of a reduced clad thickness is, therefore, limited to the parasitic absorber removal while, at a maximum fuel mass, the reduced thickness clad provides volume for additional ZrH.

Fuel Outer and Inner Diameter

Inner and outer fuel diameters have no effect on system reactivity at a fixed fuel mass. Maximum outer diameter (i.e., contact with the clad) and minimum inner diameter (i.e., contact with the center zirconium rod where applicable) provide for additional ZrH volume and, therefore, represent a bounding configuration.

Central Zirconium Rod Diameter

A change in the diameter of the central zirconium rod at a fixed fuel geometry has no significant system reactivity effect, as it involves neutronically transparent material. A minimum zirconium rod is bounding for the modified fuel dimensions (maximum ZrH).

Active Fuel Length

The reactivity variations associated with the active fuel length have distinctly different trends when considering a system at a fixed (nominal) ZrH quantity and for a system maximizing the ZrH quantity. At a fixed ZrH quantity, the minimum active fuel height compacts the fissile material region (potentially above theoretical density) and, therefore, increases system reactivity. At the maximum ZrH quantity, the effect of a compacted (reduced leakage) fuel region is offset by the reduced moderator ratio in the fuel region, resulting in a slight decrease in reactivity for a dry cask cavity and no statistically resolvable effect for a wet cask cavity (bounding for the finite array of casks modeled). Therefore, active fuel length variations have no significant effects on the highest system reactivity cases containing maximum ZrH.

g/cm^3) cask and wet can at 0.4 g/cm^3 moderator density (note that there is no statistically significant change in system reactivity as a function of can cavity moderator density).

Maximum normal condition reactivity for an infinite array of casks containing the screened cans with four TRIGA elements is 0.92484 ± 0.00068 (wet cask/wet can).

The overall system CSI for casks containing cans with up to four fuel elements per can, including fuel debris, is 25.

6.4.5.6.4 Higher Fissile Material Mass and Enrichment Study

The NAC-LWT cask is evaluated to contain increased fissile material mass and enrichment elements. Revised parameters are designed to bound TRIGA fuel elements up to 25 wt % enriched with 275g ^{235}U fissile mass, up to 71 wt % enriched with up to 138g ^{235}U, and up to 95 wt % enriched with up to 175g ^{235}U. The evaluation justifying the slight increase in fissile content for 20 wt % and 70 wt % elements and the signficantly higher 95 wt % elements is divided into intact and damaged fuel sections.

Intact Fuel Elements (No Canister)

Analysis in this section evaluates increases in fissile material mass and enrichment and provides loading restrictions where necessary for the increased payload definition.

Increased Fuel Enrichment (20 wt % ^{235}U and 70 wt % ^{235}U Base Cases)

The first analysis phase was an increase in the ^{235}U enrichment. The LEU was increased from 20 to 25 wt % ^{235}U, while the HEU had a smaller increase from 70 to 71 wt %. The cases model an NAC-LWT cask with a full payload of maximum reactivity fuel (maximum clad diameter, minimum clad thickness, and maximum H/Zr ratio). This fuel type has been documented in the previous TRIGA analysis section to be bounding. Table 6.4.5-22 displays the results of the increased enrichment analysis for the 20 wt % and 70 wt % fuels. The 20 wt % enriched fuel showed a small increase in reactivity, but is still significantly below the 70 wt % fuel in reactivity. The small increase in enrichment in the 70 wt % fuel yielded a similarly small change in reactivity. The change in reactivity is a fraction of the uncertainty associated with the reactivity and is statistically insignificant. The increased enrichment fuel payload remained well under the reactivity limit of 0.95.

Increase Mass of ^{235}U (25 wt % ^{235}U and 71 wt % ^{235}U Base Cases)

The next phase of the analysis increased the mass of ^{235}U in addition to the increased enrichment. The 71 wt % maximum ^{235}U mass was increased from 137 to 138 grams, while the LEU (25 wt %) maximum was increased from 169 to 275 grams. Results for this analysis, with four elements

per basket opening, are documented in Table 6.4.5-23. The increase in fissile material in the HEU fuel was small and, again, produced an insignificant change in reactivity when compared to the previous HEU run. All HEU reactivities remained under the 0.95 limit. Because the full payload of 25%, 275g ^{235}U enriched LEU exceeds the reactivity limit, the fuel must have loading restrictions implemented to meet the limits. The 275g ^{235}U LEU is restricted to the bottom and top baskets of the previously most reactive payload, the 71%, 138 g loading. To implement the restrictions, the material cards of the 25%, 275g LEU were copied and added to the input file of the 138g HEU and a MORE DATA card was added to allow for the Dancoff correction of the second fuel. The result of the LEU restriction to the bottom and top baskets of the HEU payload also exceeded the reactivity limit, so the LEU basket was further restricted, allowing only three rods per basket opening instead of four. Table 6.4.5-24 displays the results of the TRIGA payloads containing the 25%, 275g LEU fuel, as well as comparing them to the full payload of 71%, 138g fuel. A tube basket spacer will be used to limit the loading within the basket opening, while retaining the ability to flood and drain the basket freely.

95% HEU Fuel Loading

A full payload of 95% weight enriched and 175g ^{235}U HEU fuel was evaluated. As with the 25%, 275g LEU fuel, the full payload of 95% HEU fuel resulted in a reactivity over 0.95. The same loading restrictions were tested with the 95% HEU fuel, including restricting the fuel to the bottom and top baskets and only allowing three rods per basket opening. The loading evaluation, documented in Table 6.4.5-25, found that to remain under the 0.95 reactivity limit, the 95% HEU fuel must be restricted to the top and bottom baskets with only three rods per opening. The 71%, 138g HEU fuel was loaded in the middle three baskets of the payloads, while the 95% HEU fuel was restricted to the top and bottom baskets. Figure 6.4.5-12 lists the input for the 95% HEU three-element restricted configuration.

PICTURE, a module within the SCALE package, is used to generate representations of the system geometry. Figure 6.4.5-10 contains the image of a fully loaded basket containing four TRIGA elements or mixed loading of TRIGA elements and TRIGA cluster rods. This evaluation represents the center baskets of the transport configuration containing the 95 wt % enriched fuel in the top and bottom baskets. Figure 6.4.5-11 displays the cross-section of the top and bottom baskets with payload limited to three elements. A dummy TRIGA tube will be inserted into the basket to prohibit loading of a fourth element into the basket cell. The dummy tube is not included in the model.

Damaged Fuel

The NAC-LWT cask is licensed to transport both intact and damaged TRIGA fuel elements. Damaged fuel is restricted to the top and bottom basket modules. The most reactive 25%, 275g ^{235}U LEU, 71%, 138g ^{235}U HEU fuel and 95%, 175g ^{235}U HEU TRIGA fuel were modeled as damaged fuel and restricted to the top and bottom baskets of a payload. The remaining baskets were loaded with the previously most reactive full payload, which was the 71%, 138g HEU fuel.

The damaged fuel model was used as the base model, and the 71%, 138g HEU material cards were inserted into the input file. The damaged fuel was modeled as both intact and rubble fuel. The rubble fuel is sealed in a damaged fuel canister and limited to two rods worth of fuel, while the intact fuel was placed into basket openings in a screened canister and can contain full four rods per canister.

Results of the damaged, rubble fuel analyses shown in Table 6.4.5-26 demonstrate that the restriction to two fuel rods in the sealed canister reduces basket reactivity in the damaged fuel locations to that below the intact fuel center baskets (i.e., system reactivity is controlled by the center intact fuel baskets, and no significant system reactivity change results from the placement of the sealed damaged fuel canisters). Figure 6.4.5-13 lists the input for the 95% HEU damaged fuel configuration.

Screened canisters are expected to reduce reactivity for the full, four element per basket opening payload as a result of the additional stainless steel material in the canister body, axial fuel offset produced by the canister bottom and lid structure, and reduced element pitch available in the canister. The most reactive configuration study in previous evaluations documented the reduced reactivity for smaller fuel element pitch. This effect is verified for the higher load fuel elements in Table 6.4.5-27. Results in Table 6.4.5-27 also include the additional effect of adding the canister materials and the axial offset produced by the canister. The combination of these effects results in a lower screened canister basket reactivity than that of the central baskets with a resulting statistically insignificant change in system reactivity. Screened canister evaluations are performed for all increased payload definitions with the results documented in Table 6.4.5-28. None of the cases showed a statistically significant change in reactivity and no case exceeds the 0.95 allowable k_s.

6.4.5.6.5 Mixed TRIGA Fuel Element and Cluster Rod Study

The NAC-LWT cask may contain a mix payload of TRIGA fuel including cluster rods. The most reactive payload (71%, 138g HEU) was modeled with one of the basket openings loaded with TRIGA cluster fuel. The cluster rods were modeled both as intact in a 4 × 4 holder, and as damaged fuel rods as rubble in a sealed canister. The intact rods had a full loading of 16 rods per basket opening, while the damaged fuel was restricted to the equivalent of six rods in the sealed canister. The resulting reactivity is displayed in Table 6.4.5-29. Replacing the 71 wt % HEU rods with cluster rods in one basket opening shows no stastical change in reactivity, as the system reactivity is driven by the fully loaded fuel element baskets.

6.4.5.6.6 Revised Fuel Parameter Reactivity Summary

The reactivity evaluation of the NAC-LWT cask containing up to 120 TRIGA elements demonstrates that subcritical margin ($k_s \leq 0.95$) can be maintained under the following condition:

		Any Mix Loading				Top/Bottom Basket Only	
Fuel Type		LEU	LEU	HEU	Cluster	LEU	HEU
Clad Type		SS	Al	SS	Incoloy	SS	SS
^{235}U Enrichment (wt %)		25%	25%	71%	95%	25%	95%
^{235}U Content (grams)		≤169	≤41	≤138	≤46.5	≤275	≤175
Max.# of Elements/Rods per Opening	Intact	4			16	3	3
	Sealed	2			6	2	2
Rod Diameter		≤1.5 inch			≤0.53	≤1.5 inch	
H/ZR Ratio		2.0			1.7	2.0	
Fuel Material		$U\text{-}ZrH_x$					
Clad Thickness		≥0.01 inch					
Maximum Reactivity (k_s)		0.949					

Due to limitations on the array size for accident conditions, the criticality safety index (CSI) for the package is 12.5 for loading of intact fuel and sealed cans containing up to two fuel elements (in any condition, including severely damaged fuel and debris). The basket top module may contain TRIGA cluster rods in either intact or canned form.

6.4.5.7 Conclusion

Thus, including all calculational and mechanical uncertainties, an infinite array of NAC-LWT casks remains subcritical, and is below the 0.95 limit, corrected for bias and uncertainty, under normal and accident conditions with:

Nonpoisoned Baskets:

1. 120 TRIGA fuel elements,
2. Sealed cans (top and bottom baskets only) with two damaged TRIGA fuel elements or fuel debris equivalent to two elements.
3. TRIGA cluster rods in the rod holder described in Section 6.4.6 inserted into the top basket module of a TRIGA fuel element shipment.

Poisoned Baskets:

1. 140 TRIGA fuel elements,
2. Sealed cans (top and bottom baskets only) with two damaged TRIGA fuel elements or fuel debris equivalent to two elements.

Figure 6.4.5-1 Finite Cask Array Reactivity versus Fuel Zirconium Mass (Dry Cask Cavity)

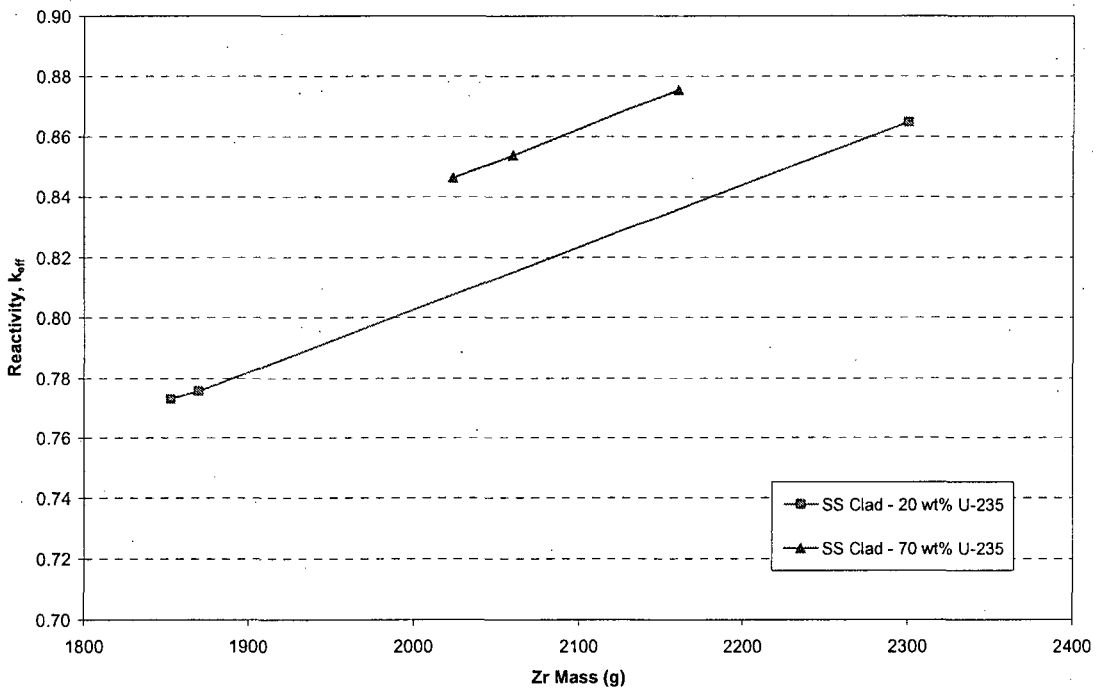


Figure 6.4.5-2 Finite Cask Array Reactivity versus H/Zr Ratio (Dry Cask Cavity)

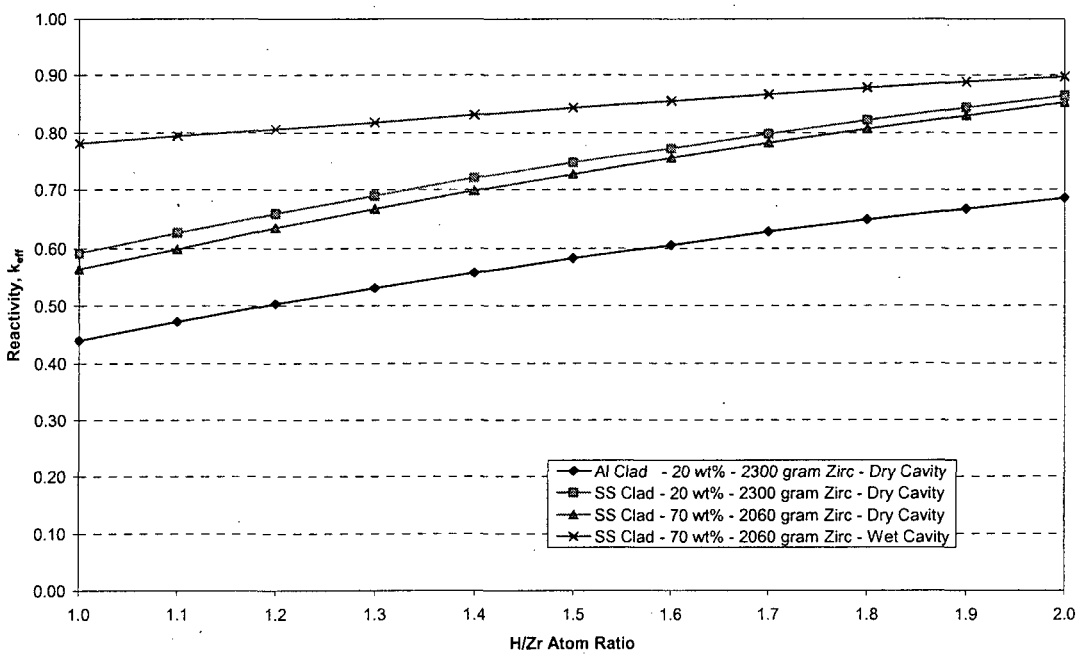


Figure 6.4.5-7 Screened and Sealed Can Debris Height Study – Maximum Reactivity Fuel Configuration – 70 wt% ^{235}U Steel Clad

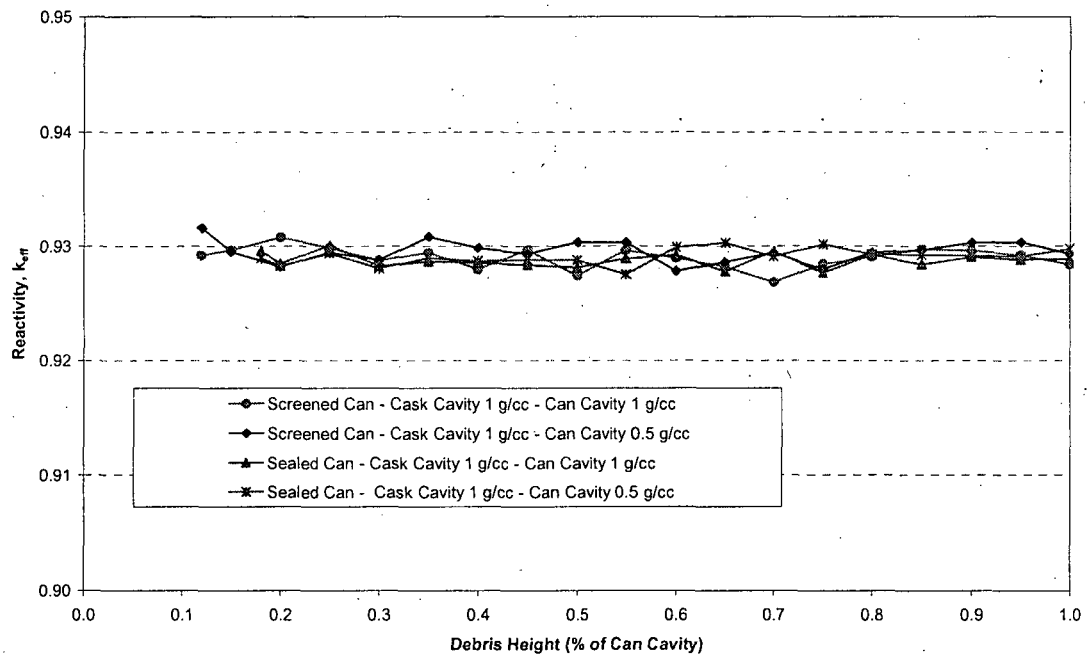


Figure 6.4.5-8 Screened Can – 4 Elements per Can – Maximum Reactivity Fuel Configuration – 70 wt% ^{235}U Steel Clad

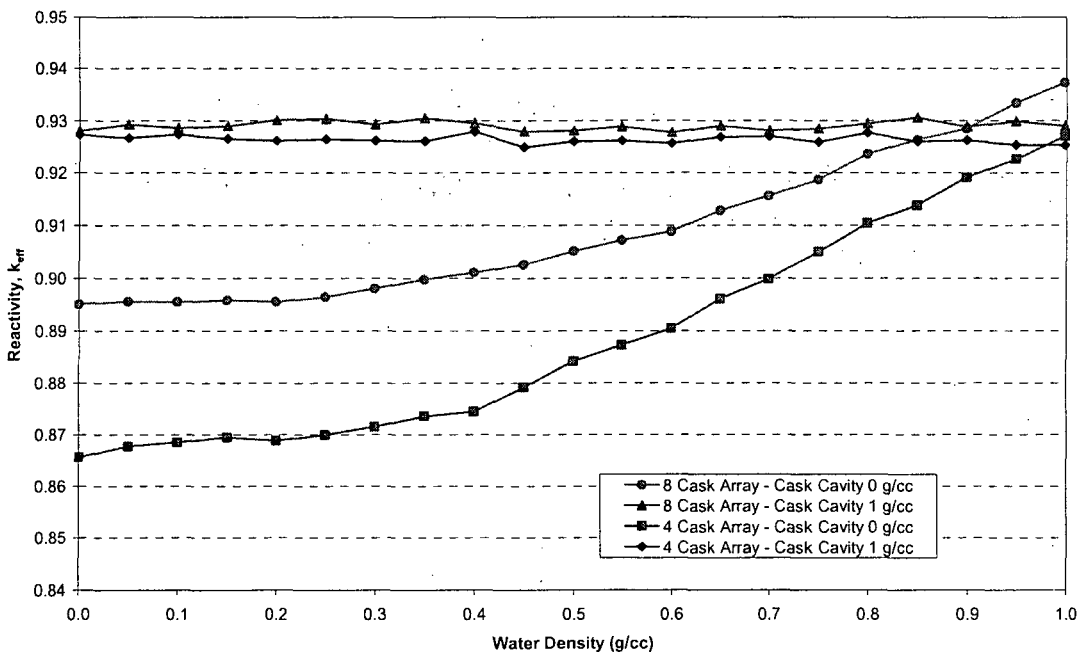


Figure 6.4.5-9 PICTURE Representation of NAC-LWT Eight Cask Array for Accident Condition TRIGA Unpoisoned Basket Analysis

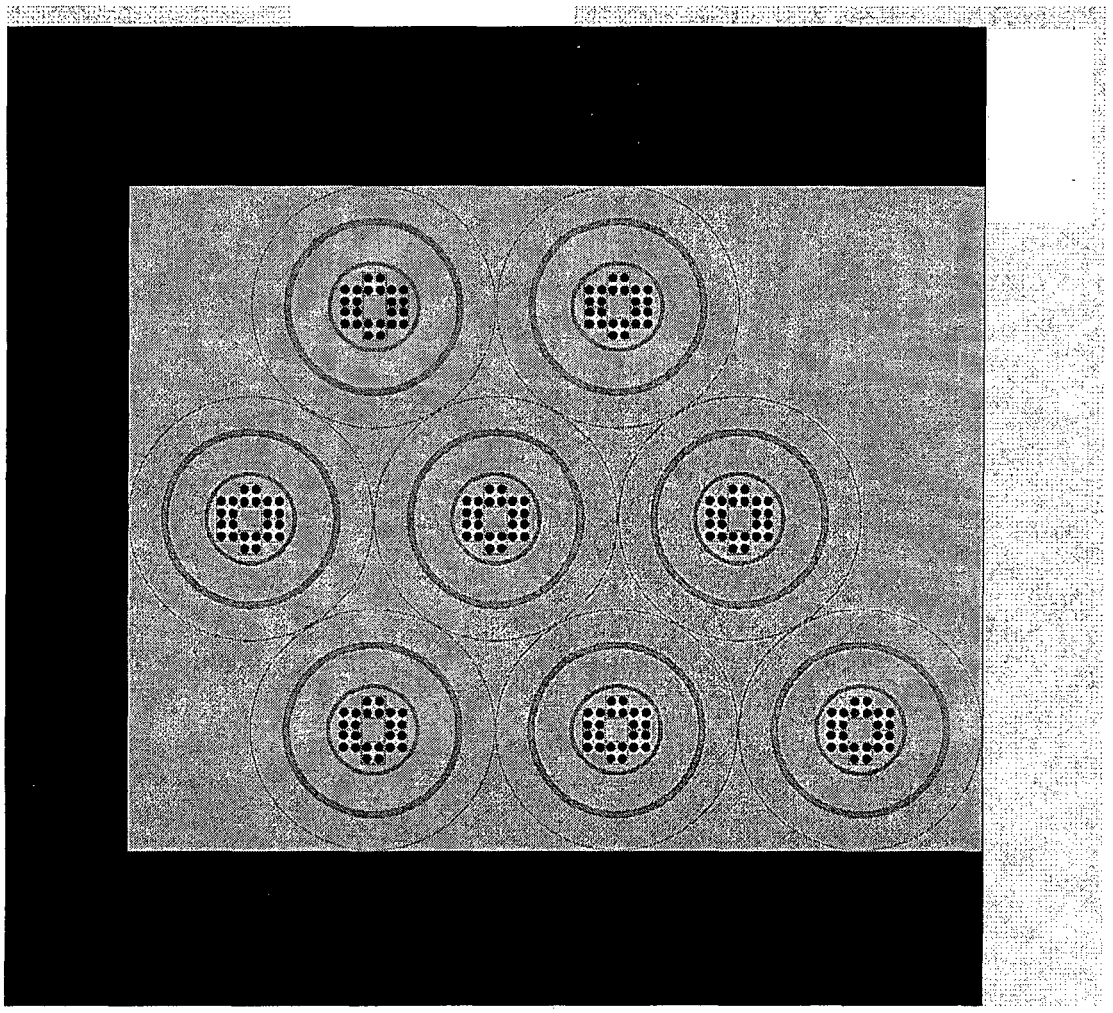


Figure 6.4.5-10 PICTURE Representation of NAC-LWT TRIGA Payload – Fully Loaded Basket Analysis and Mixed TRIGA Loading[1]

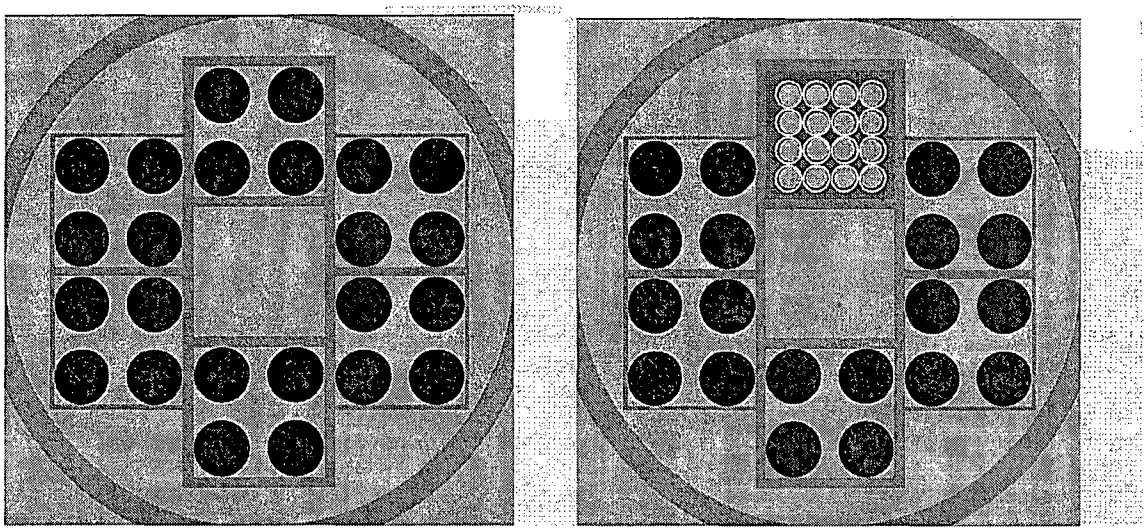
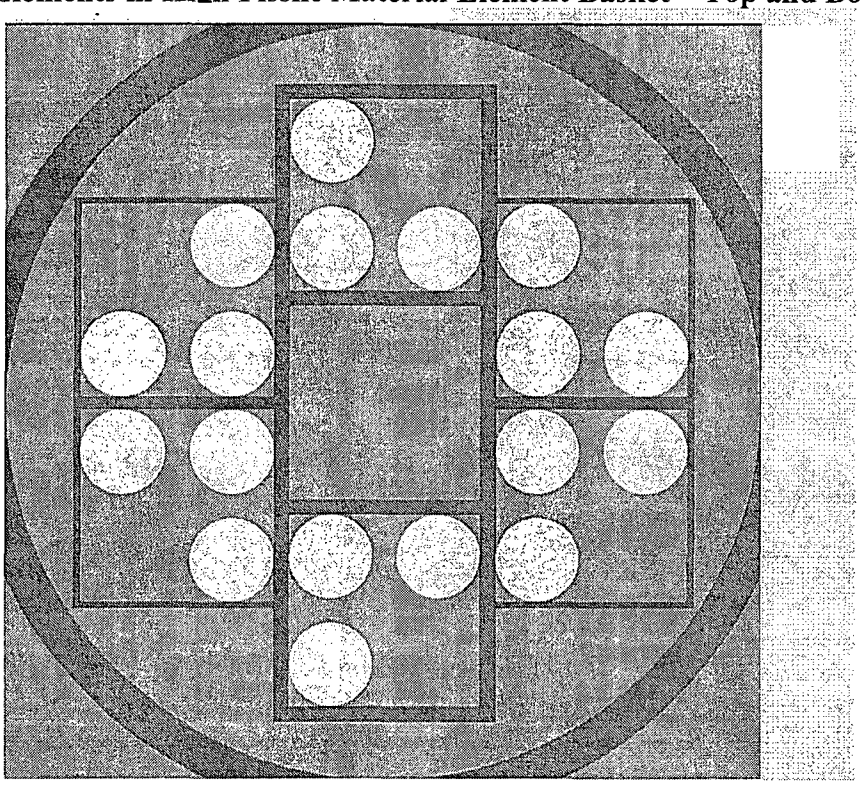


Figure 6.4.5-11 PICTURE Representation of NAC-LWT TRIGA Payload – Reduced Number of Elements in High Fissile Material Element Basket – Top and Bottom Baskets



[1] Fully loaded baskets represent the center baskets for the high fissile material load analysis (>138g ^{235}U for HEU and >169g ^{235}U for LEU) and any basket for lower fissile mass and/or mixed TRIGA element/TRIGA cluster rod contents.

Figure 6.4.5-12 Sample Input File for High Mass HEU TRIGA Analysis – 3 Intact Elements of 175 g ^{235}U at 95 wt % ^{235}U per Basket Opening in Top and Bottom Basket – Accident Array Calculation with 8 Casks

```
=CSAS25
TRIGA - WET INTERIOR, DRY EXTERIOR - FINITE CASK ARRAY
'2 Fuel run with 2nd fuel in bottom and top baskets
'Fuel 1: 71_2342Zr_U5_138g - middle 3 baskets
'Fuel 2: 95_2345Zr_U5_175g - top and bottom baskets
27GROUPNDF4  LATTICECELL
'FUEL 1
U-235      1 0.0 8.09244E-04 293.0 END
U-238      1 0.0 3.24241E-04 293.0 END
ZR         1 0.0 3.53871E-02 293.0 END
H          1 0.0 7.07742E-02 293.0 END
'CLAD
SS304      2 1.0 293.0 END
'CASK INTERNAL MODERATOR
H2O        3 1.0 293.0 END
'ZIRCONIUM ROD
ZR         4 1.0 293.0 END
'GRAPHITE REFLECTOR
C          5 1.0 293.0 END
'BASKET AND CASK STEEL
SS304      6 1.0 293.0 END
'LEAD SHIELD
PB         7 1.0 293.0 END
'NEUTRON SHIELD
H2O        8 1.0 293.0 END
'CASK EXTERNAL MATERIAL
H2O        9 1E-20 293.0 END
'END FITTING FOR FUEL ELEMENT
SS304      10 0.337137 293.0 END
H2O        10 0.662863 293.0 END
'FUEL 2
U-235      11 0.0 1.02622E-03 293.0 END
U-238      11 0.0 5.21101E-05 293.0 END
ZR         11 0.0 3.54310E-02 293.0 END
H          11 0.0 7.08620E-02 293.0 END
END COMP
SQUAREPITCH 3.8101 3.7592 1 3 3.81 2 3.7592 0 END
MORE DATA
RES=11  CYLINDER 1.87960  DAN(11)=8.52196E-01  END
TRIGA - WET INTERIOR, DRY EXTERIOR - MOST REACTIVE CONFIGURATION
READ PARAM TME=170.0 GEN=803 NPG=2000 RUN=YES PLT=NO
TBA=2.0 END PARAM
READ GEOM
UNIT 41
COM='TRIGA FUEL ELEMENT'
CYLINDER 4 1 0.00010 2P19.6850
'
CYLINDER 1 1 1.87960 2P19.6850
CYLINDER 5 1 1.87960 2P28.3718
'
CYLINDER 2 1 1.90500 2P28.3718
CYLINDER 10 1 1.90500 2P36.7030
UNIT 45
COM='3.38 in Width / 0.28 in Thickness DIVIDER CENTER STACK'
CUBOID   6 1 2P4.29260 0.71120 0.00000 2P36.7030
UNIT 46
```

```
COM='3.38 in Width / 0.24 in Thickness DIVIDER OUTSIDE STACK'
CUBOID   6 1 2P4.29260 0.60960 0.00000 2P36.7030
UNIT 50
COM='TRIGA ELEMENTS - Top of 3.38 in x 3.38 in OPENING'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 51
COM='TRIGA ELEMENTS - Bottom of 3.38 in x 3.38 in OPENING'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 52
COM='TRIGA ELEMENTS - Bottom Right of 3.38 in x 3.38 in OPENING'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 53
COM='TRIGA ELEMENTS - Top Right of 3.38 in x 3.38 in OPENING'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 54
COM='TRIGA ELEMENTS - Bottom Left of 3.38 in x 3.38 in OPENING'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 55
COM='TRIGA ELEMENTS - Top Left of 3.38 in x 3.38 in OPENING'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 56
COM='TRIGA BASKET 3.38 in x 3.38 in CENTER OPENING'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
UNIT 60
COM='CENTER COLUMN OF THREE OPENINGS w/ 0.28 in plate'
ARRAY 11 -4.2926 -13.5890 -36.7030
REPLICATE 6 1 4R0.7112 2R0.0 1
UNIT 61
COM='LEFT OUTSIDE COLUMN OF TWO OPENINGS w/ 0.12 in plate'
ARRAY 12 -4.2926 -8.8900 -36.7030
REPLICATE 6 1 0.0 0.3048 2R0.3048 2R0.0 1
UNIT 62
COM='RIGHT OUTSIDE COLUMN OF TWO OPENINGS w/ 0.12 in plate'
ARRAY 13 -4.2926 -8.8900 -36.7030
REPLICATE 6 1 0.3048 0.0 2R0.3048 2R0.0 1
UNIT 70
COM='NAC-LWT TRIGA BASKET WITH RADIAL CASK SHIELD'
```

```
CYLINDER 3 1 17.15000 2P36.7030
HOLE     60 0.0000 0.0000 0.0000
HOLE     61 -9.2965 0.0000 0.0000
HOLE     62 +9.2965 0.0000 0.0000
CYLINDER 6 1 18.91030 2P37.3379
CYLINDER 7 1 33.46450 2P37.3379
CYLINDER 6 1 36.51880 2P37.3379
CYLINDER 9 1 49.22270 2P37.3379
CYLINDER 6 1 49.82210 2P37.3379
'---------------2nd Fuel Units-------------------------------
UNIT 141
COM='TRIGA FUEL ELEMENT'
CYLINDER 4 1 0.00010 2P19.6850
'
CYLINDER 11 1 1.87960 2P19.6850
CYLINDER 5 1 1.87960 2P28.3718
'
CYLINDER 2 1 1.90500 2P28.3718
CYLINDER 10 1 1.90500 2P36.7030

UNIT 150
COM='TRIGA ELEMENTS - Top of 3.38 in x 3.38 in OPENING (Fuel 2)'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
'HOLE     141 +2.3875 +2.3875 0.0000
HOLE     141 -2.3875 +2.3875 0.0000
HOLE     141 -2.3875 -2.3875 0.0000
HOLE     141 +2.3875 -2.3875 0.0000
UNIT 151
COM='TRIGA ELEMENTS - Bottom of 3.38 in x 3.38 in OPENING (Fuel 2)'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
HOLE     141 +2.3875 +2.3875 0.0000
HOLE     141 -2.3875 +2.3875 0.0000
HOLE     141 -2.3875 -2.3875 0.0000
'HOLE     141 +2.3875 -2.3875 0.0000
UNIT 152
COM='TRIGA ELEMENTS - Bottom Right of 3.38 in x 3.38 in OPENING (Fuel 2)'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
HOLE     141 +2.3875 +2.3875 0.0000
HOLE     141 -2.3875 +2.3875 0.0000
HOLE     141 -2.3875 -2.3875 0.0000
'HOLE     141 +2.3875 -2.3875 0.0000
UNIT 153
COM='TRIGA ELEMENTS - Top Right of 3.38 in x 3.38 in OPENING (Fuel 2)'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
'HOLE     141 +2.3875 +2.3875 0.0000
HOLE     141 -2.3875 +2.3875 0.0000
HOLE     141 -2.3875 -2.3875 0.0000
HOLE     141 +2.3875 -2.3875 0.0000
UNIT 154
COM='TRIGA ELEMENTS - Bottom Left of 3.38 in x 3.38 in OPENING (Fuel 2)'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
HOLE     141 +2.3875 +2.3875 0.0000
HOLE     141 -2.3875 +2.3875 0.0000
'HOLE     141 -2.3875 -2.3875 0.0000
HOLE     141 +2.3875 -2.3875 0.0000
UNIT 155
COM='TRIGA ELEMENTS - Top Left of 3.38 in x 3.38 in OPENING (Fuel 2)'
CUBOID   3 1 2P4.29260 2P4.29260 2P36.7030
HOLE     141 +2.3875 +2.3875 0.0000
'HOLE     141 -2.3875 +2.3875 0.0000
HOLE     141 -2.3875 -2.3875 0.0000
```

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HOLE     141 +2.3875 -2.3875 0.0000
UNIT 160
COM='CENTER COLUMN OF THREE OPENINGS w/ 0.28 in plate'
ARRAY 111 -4.2926 -13.5890 -36.7030
REPLICATE 6 1 4R0.7112 2R0.0 1
UNIT 161
COM='LEFT OUTSIDE COLUMN OF TWO OPENINGS w/ 0.12 in plate'
ARRAY 112 -4.2926 -8.8900 -36.7030
REPLICATE 6 1 0.0 0.3048 2R0.3048 2R0.0 1
UNIT 162
COM='RIGHT OUTSIDE COLUMN OF TWO OPENINGS w/ 0.12 in plate'
ARRAY 113 -4.2926 -8.8900 -36.7030
REPLICATE 6 1 0.3048 0.0 2R0.3048 2R0.0 1
UNIT 170
COM='NAC-LWT TRIGA BASKET WITH RADIAL CASK SHIELD'
CYLINDER 3 1 17.15000 2P36.7030
HOLE     160 0.0000 0.0000 0.0000
HOLE     161 -9.2965 0.0000 0.0000
HOLE     162 +9.2965 0.0000 0.0000
CYLINDER 6 1 18.91030 2P37.3379
CYLINDER 7 1 33.46450 2P37.3379
CYLINDER 6 1 36.51880 2P37.3379
CYLINDER 9 1 49.22270 2P37.3379
CYLINDER 6 1 49.82210 2P37.3379
'-----------End 2nd Fuel Units-------------------------------
UNIT 80
COM='NAC-LWT WITH 5 TRIGA BASKETS - NO LID OR BOTTOM WELDMENT'
CYLINDER 3 1 49.82210 373.3800 0.0000
HOLE     170 0.0000 0.0000 +37.3380
HOLE     70 0.0000 0.0000 +112.0140
HOLE     70 0.0000 0.0000 +186.6900
HOLE     70 0.0000 0.0000 +261.3660
HOLE     170 0.0000 0.0000 +336.0420
UNIT 90
COM='SIMPLIFIED LID STRUCTURE NAC-LWT'
CYLINDER 6 1 36.5188 2P14.1351
CYLINDER 9 1 49.8221 2P14.1351
UNIT 91
COM='SIMPLIFIED CASK BOTTOM STRUCTURE NAC-LWT'
CYLINDER 7 1 26.3525 2P3.81
CYLINDER 6 1 36.6188 +13.97 -12.7
CYLINDER 9 1 49.8221 +13.97 -12.7
UNIT 92
COM='SINGLE CASK'
CYLINDER 9 1 49.82210 428.3204 0.0000
HOLE     91 0.0000 0.0000 +12.7000
HOLE     80 0.0000 0.0000 +26.6700
HOLE     90 0.0000 0.0000 +414.1852
GLOBAL UNIT 93
COM='FINITE CASK ARRAY - 8 CASKS'
CUBOID   9 1 199.28960 -149.46660 2P136.11700 428.3204 0.0000
HOLE     92 0.0000 0.0000 0.0000
HOLE     92 +99.6444 0.0000 0.0000
HOLE     92 +49.8222 +86.2946 0.0000
HOLE     92 -49.8222 +86.2946 0.0000
HOLE     92 -99.6444 0.0000 0.0000
HOLE     92 -49.8222 -86.2946 0.0000
HOLE     92 +49.8222 -86.2946 0.0000
HOLE     92 +149.4666 -86.2946 0.0000
END GEOM
READ ARRAY
```

```
ARA=11 NUX=1 NUY=5 NUZ=1 FILL 50 45 56 45 51 END FILL
ARA=12 NUX=1 NUY=3 NUZ=1 FILL 53 46 52 END FILL
ARA=13 NUX=1 NUY=3 NUZ=1 FILL 55 46 54 END FILL
ARA=111 NUX=1 NUY=5 NUZ=1 FILL 151 45 56 45 150 END FILL
ARA=112 NUX=1 NUY=3 NUZ=1 FILL 154 46 155 END FILL
ARA=113 NUX=1 NUY=3 NUZ=1 FILL 152 46 153 END FILL
END ARRAY
READ BOUNDS ALL=H2O END BOUNDS
READ PLOT
TTL='X-Y PLOT OF BASKET'
SCR=YES PIC=MAT LPI=10
UAX=1.0 VDN=-1.0 NAX=1600
XUL=-17.2 YUL=17.2 ZUL=215
XLR=17.2 YLR=-17.2 ZLR=215 END
TTL='X-Y PLOT OF PERIPHERAL OPENING'
SCR=YES PIC=MAT LPI=10
UAX=1.0 VDN=-1.0 NAX=1600
XUL=-7.0 YUL=16.0 ZUL=215
XLR=7.0  YLR=4.0 ZLR=215 END
TTL='Y-Z PLOT OF BASKET (CENTER OF FUEL ELEMENTS,CANISTER ELEVATION)'
SCR=YES PIC=MAT LPI=10
VAX=1.0 WDN=-1.0 NAX=1600
XUL=2.12 YUL=-14.0 ZUL=330
XLR=2.12 YLR=-4.5 ZLR=235 END
TTL='Y-Z PLOT OF BASKET (CASK)'
SCR=YES PIC=MAT LPI=10
VAX=1.0 WDN=-1.0 NAX=1600
XUL=2.12 YUL=-51 ZUL=465
XLR=2.12 YLR=+51 ZLR=0 END
TTL='X-Y PLOT OF ARRAY'
SCR=YES PIC=MAT LPI=10
UAX=1.0 VDN=-1.0 NAX=1600
XUL=-200 YUL=200 ZUL=215
XLR=200  YLR=-200 ZLR=215
END PLOT
END DATA
END
```

Figure 6.4.5-13 Sample Input File for High Mass HEU TRIGA Analysis – 2 Damaged Elements of 175 g ^{235}U at 95 wt % ^{235}U per Basket Opening in Top and Bottom Basket – Accident Array Calculation with 8 Casks

```
=CSAS25
TRIGA - PREF. FLOOD DEBRIS CANISTER - SEALED CAN - 2 RODS
27GROUPNDF4  INFHOMMEDIUM
'Sealed Fuel: 95_2345Zr_U5_175g
'Middle Baskets Fuel: 71_2342Zr_U5_138g'FUEL
U-235      1 0.0 1.80754E-04 293.0 END
U-238      1 0.0 9.17849E-06 293.0 END
ZR         1 0.0 6.24069E-03 293.0 END
H          1 0.0 1.24814E-02 293.0 END
H2O        1 0.823864 293.0 END
'
'
'CANISTER INTERNAL MODERATOR
H2O        3 1.0 293.0 END
'ZIRCONIUM ROD
ZR         4 1.0 293.0 END
'GRAPHITE REFLECTOR
C          5 1.0 293.0 END
'BASKET AND CASK STEEL
SS304      6 1.0 293.0 END
'LEAD SHIELD
PB         7 1.0 293.0 END
'NEUTRON SHIELD
H2O        8 1.0 293.0 END
'CASK EXTERNAL MATERIAL
H2O        9 1E-20 293.0 END
'
'
'
'INTACT FUEL MATERIAL COMPOSITION
U-235      11 0.0 8.09244E-04 293.0 END
U-238      11 0.0 3.24241E-04 293.0 END
ZR         11 0.0 3.53871E-02 293.0 END
H          11 0.0 7.07742E-02 293.0 END
'INTACT FUEL CLAD
SS304      12 1.0 293.0 END
'CASK INTERIOR MODERATOR MATERIAL
H2O        13 1.0 293.0 END
'INTACT FUEL END-FITTING
SS304      14 0.337137 293.0 END
H2O        14 0.662863 293.0 END
END COMP
MORE DATA
RES=11  CYLINDER 1.8796 DAN(11)=8.52196E-01
END MORE
TRIGA - PREF. FLOOD CANISTER  - 2 ROD FILLING CANISTER + TOLERANCE
READ PARAM TME=170.0 GEN=803 NPG=2000 RUN=YES PLT=NO
TBA=2.0 END PARAM
READ GEOM
UNIT 1
COM='TRIGA FUEL (SEALED)'
CYLINDER 1 1 3.98770 99.3130 0.0010
UNIT 5
COM='3.38 in Width / 0.28 in Thickness DIVIDER CENTER STACK (SEALED)'
CUBOID   6 1 2P4.29260 0.71120 0.00000 112.6490 -8.2550
UNIT 6
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COM='3.38 in Width / 0.24 in Thickness DIVIDER OUTSIDE STACK (SEALED)'
CUBOID   6 1 2P4.29260 0.60960 0.00000 112.6490 -8.2550
UNIT 7
COM=' SEALED CANISTER'
CYLINDER 3 1 3.98780 99.3140 0.0000
HOLE     1 0.0000 0.0000 0.0000
CYLINDER 6 1 4.15290 101.8540 -1.2700
CYLINDER 13 1 4.15290 112.6490 -8.2550
UNIT 10
COM='TRIGA ELEMENTS - Top of 3.38 in x 3.38 in OPENING (SEALED)'
CUBOID   13 1 2P4.29260 2P4.29260 112.6490 -8.2550
HOLE     7 0.0000 +0.1396 0.0000
UNIT 11
COM='TRIGA ELEMENTS - Bottom of 3.38 in x 3.38 in OPENING (SEALED)'
CUBOID   13 1 2P4.29260 2P4.29260 112.6490 -8.2550
HOLE     7 0.0000 -0.1396 0.0000
UNIT 12
COM='TRIGA ELEMENTS - Bottom Right of 3.38 in x 3.38 in OPENING (SEALED)'
CUBOID   13 1 2P4.29260 2P4.29260 112.6490 -8.2550
HOLE     7 +0.1396 -0.1396 0.0000
UNIT 13
COM='TRIGA ELEMENTS - Top Right of 3.38 in x 3.38 in OPENING (SEALED)'
CUBOID   13 1 2P4.29260 2P4.29260 112.6490 -8.2550
HOLE     7 +0.1396 +0.1396 0.0000
UNIT 14
COM='TRIGA ELEMENTS - Bottom Left of 3.38 in x 3.38 in OPENING (SEALED)'
CUBOID   13 1 2P4.29260 2P4.29260 112.6490 -8.2550
HOLE     7 -0.1396 -0.1396 0.0000
UNIT 15
COM='TRIGA ELEMENTS - Top Left of 3.38 in x 3.38 in OPENING (SEALED)'
CUBOID   13 1 2P4.29260 2P4.29260 112.6490 -8.2550
HOLE     7 -0.1396 +0.1396 0.0000
UNIT 16
COM='TRIGA BASKET 3.38 in x 3.38 in CENTER OPENING (SEALED)'
CUBOID   13 1 2P4.29260 2P4.29260 112.6490 -8.2550
UNIT 20
COM='CENTER COLUMN OF THREE OPENINGS w/ 0.28 in plate (SEALED)'
ARRAY 1 -4.2926 -13.5890 -8.2550
REPLICATE 6 1 4R0.7112 2R0.0 1
UNIT 21
COM='LEFT OUTSIDE COLUMN OF TWO OPENINGS w/ 0.12 in plate (SEALED)'
ARRAY 2 -4.2926 -8.8900 -8.2550
REPLICATE 6 1 0.0 0.3048 2R0.3048 2R0.0 1
UNIT 22
COM='RIGHT OUTSIDE COLUMN OF TWO OPENINGS w/ 0.12 in plate (SEALED)'
ARRAY 3 -4.2926 -8.8900 -8.2550
REPLICATE 6 1 0.3048 0.0 2R0.3048 2R0.0 1
UNIT 30
COM='NAC-LWT TRIGA BASKET (SEALED)'
CYLINDER 13 1 17.15000 112.6491 -8.2551
HOLE     20 0.0000 0.0000 0.0000
HOLE     21 -9.2965 0.0000 0.0000
HOLE     22 +9.2965 0.0000 0.0000
CYLINDER 6 1 18.91030 113.2838 -8.8898
CYLINDER 7 1 33.46450 113.2838 -8.8898
CYLINDER 6 1 36.51880 113.2838 -8.8898
CYLINDER 9 1 49.22270 113.2838 -8.8898
CYLINDER 6 1 49.82210 113.2838 -8.8898
UNIT 41
COM='TRIGA FUEL ELEMENT'
CYLINDER 4 1 0.00010 2P19.6850
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CYLINDER 11 1 1.87960 2P19.6850
CYLINDER 5 1 1.87960 2P28.3718

CYLINDER 12 1 1.90500 2P28.3718
CYLINDER 14 1 1.90500 2P36.7030
UNIT 45
COM='3.38 in Width / 0.28 in Thickness DIVIDER CENTER STACK'
CUBOID   6 1 2P4.29260 0.71120 0.00000 2P36.7030
UNIT 46
COM='3.38 in Width / 0.24 in Thickness DIVIDER OUTSIDE STACK'
CUBOID   6 1 2P4.29260 0.60960 0.00000 2P36.7030
UNIT 50
COM='TRIGA ELEMENTS - Top of 3.38 in x 3.38 in OPENING'
CUBOID   13 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 51
COM='TRIGA ELEMENTS - Bottom of 3.38 in x 3.38 in OPENING'
CUBOID   13 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 52
COM='TRIGA ELEMENTS - Bottom Right of 3.38 in x 3.38 in OPENING'
CUBOID   13 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 53
COM='TRIGA ELEMENTS - Top Right of 3.38 in x 3.38 in OPENING'
CUBOID   13 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 54
COM='TRIGA ELEMENTS - Bottom Left of 3.38 in x 3.38 in OPENING'
CUBOID   13 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 55
COM='TRIGA ELEMENTS - Top Left of 3.38 in x 3.38 in OPENING'
CUBOID   13 1 2P4.29260 2P4.29260 2P36.7030
HOLE     41 +2.3875 +2.3875 0.0000
HOLE     41 -2.3875 +2.3875 0.0000
HOLE     41 -2.3875 -2.3875 0.0000
HOLE     41 +2.3875 -2.3875 0.0000
UNIT 56
COM='TRIGA BASKET 3.38 in x 3.38 in CENTER OPENING'
CUBOID   13 1 2P4.29260 2P4.29260 2P36.7030
UNIT 60
COM='CENTER COLUMN OF THREE OPENINGS w/ 0.28 in plate'
ARRAY 11 -4.2926 -13.5890 -36.7030
REPLICATE 6 1 4R0.7112 2R0.0 1
```

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UNIT 61
COM='LEFT OUTSIDE COLUMN OF TWO OPENINGS w/ 0.12 in plate'
ARRAY 12 -4.2926 -8.8900 -36.7030
REPLICATE 6 1 0.0 0.3048 2R0.3048 2R0.0 1
UNIT 62
COM='RIGHT OUTSIDE COLUMN OF TWO OPENINGS w/ 0.12 in plate'
ARRAY 13 -4.2926 -8.8900 -36.7030
REPLICATE 6 1 0.3048 0.0 2R0.3048 2R0.0 1
UNIT 70
COM='NAC-LWT TRIGA BASKET WITH RADIAL CASK SHIELD'
CYLINDER 13 1 17.15000 2P36.7030
HOLE     60 0.0000 0.0000 0.0000
HOLE     61 -9.2965 0.0000 0.0000
HOLE     62 +9.2965 0.0000 0.0000
CYLINDER 6 1 18.91030 2P37.3379
CYLINDER 7 1 33.46450 2P37.3379
CYLINDER 6 1 36.51880 2P37.3379
CYLINDER 9 1 49.22270 2P37.3379
CYLINDER 6 1 49.82210 2P37.3379
UNIT 81
COM='NAC-LWT WITH 5 TRIGA BASKETS - NO LID OR BOTTOM WELDMENT'
CYLINDER 13 1 49.82210 468.3760 0.0000
HOLE     30 0.0000 0.0000 +8.8900
HOLE     70 0.0000 0.0000 +159.5120
HOLE     70 0.0000 0.0000 +234.1880
HOLE     70 0.0000 0.0000 +308.8640
HOLE     30 0.0000 0.0000 +355.0920
UNIT 90
COM='SIMPLIFIED LID STRUCTURE NAC-LWT'
CYLINDER 6 1 36.5188 2P14.1351
CYLINDER 9 1 49.8221 2P14.1351
UNIT 91
COM='SIMPLIFIED CASK BOTTOM STRUCTURE NAC-LWT'
CYLINDER 7 1 26.3525 2P3.81
CYLINDER 6 1 36.6188 +13.97 -12.7
CYLINDER 9 1 49.8221 +13.97 -12.7
UNIT 92
COM='SINGLE CASK'
CYLINDER 9 1 49.82210 523.3164 0.0000
HOLE     91 0.0000 0.0000 +12.7000
HOLE     81 0.0000 0.0000 +26.6700
HOLE     90 0.0000 0.0000 +509.1812
GLOBAL UNIT 93
COM='FINITE CASK ARRAY - 8 CASKS'
CUBOID   9 1 199.28960 -149.46660 2P136.11700 523.3164 0.0000
HOLE     92 0.0000 0.0000 0.0000
HOLE     92 +99.6444 0.0000 0.0000
HOLE     92 +49.8222 +86.2946 0.0000
HOLE     92 -49.8222 +86.2946 0.0000
HOLE     92 -99.6444 0.0000 0.0000
HOLE     92 -49.8222 -86.2946 0.0000
HOLE     92 +49.8222 -86.2946 0.0000
HOLE     92 +149.4666 -86.2946 0.0000
END GEOM
READ ARRAY
ARA=1 NUX=1 NUY=5 NUZ=1 FILL 10 5 16 5 11 END FILL
ARA=2 NUX=1 NUY=3 NUZ=1 FILL 13 6 12 END FILL
ARA=3 NUX=1 NUY=3 NUZ=1 FILL 15 6 14 END FILL
ARA=11 NUX=1 NUY=5 NUZ=1 FILL 50 45 56 45 51 END FILL
ARA=12 NUX=1 NUY=3 NUZ=1 FILL 53 46 52 END FILL
ARA=13 NUX=1 NUY=3 NUZ=1 FILL 55 46 54 END FILL
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```
END ARRAY
READ BOUNDS ALL=H2O END BOUNDS
READ PLOT
TTL='X-Y PLOT OF CASK (CANISTER ELEVATION)'
SCR=YES PIC=MAT LPI=10
UAX=1.0 VDN=-1.0 NAX=1600
XUL=-50.0 YUL=50.0 ZUL=50
XLR=50.0 YLR=-50.0 ZLR=50 END
TTL='X-Y PLOT OF BASKET (CANISTER ELEVATION)'
SCR=YES PIC=MAT LPI=10
UAX=1.0 VDN=-1.0 NAX=1600
XUL=-17.2 YUL=17.2 ZUL=50
XLR=17.2 YLR=-17.2 ZLR=50 END
TTL='X-Y PLOT OF BASKET (CAVITY MID PLANE)'
SCR=YES PIC=MAT LPI=10
UAX=1.0 VDN=-1.0 NAX=1600
XUL=-17.2 YUL=17.2 ZUL=210.0
XLR=17.2 YLR=-17.2 ZLR=210.0 END
TTL='X-Y PLOT OF CENTER OPENING (CANISTER ELEVATION)'
SCR=YES PIC=MAT LPI=10
UAX=1.0 VDN=-1.0 NAX=1600
XUL=-7.0 YUL=7.0 ZUL=50
XLR=7.0 YLR=-7.0 ZLR=50 END
TTL='X-Y PLOT OF PERIPHERAL OPENING (CANISTER ELEVATION)'
SCR=YES PIC=MAT LPI=10
UAX=1.0 VDN=-1.0 NAX=1600
XUL=-7.0 YUL=16.0 ZUL=50
XLR=7.0  YLR=4.0 ZLR=50 END
TTL='Y-Z PLOT OF BASKET (CENTER OF FUEL ELEMENTS,CANISTER ELEVATION)'
SCR=YES PIC=MAT LPI=10
VAX=1.0 WDN=-1.0 NAX=1600
XUL=2.12 YUL=-14.0 ZUL=100.69
XLR=2.12 YLR=-4.5 ZLR=20 END
TTL='Y-Z PLOT OF BASKET (CASK)'
SCR=YES PIC=MAT LPI=10
VAX=1.0 WDN=-1.0 NAX=1600
XUL=2.12 YUL=-51 ZUL=500
XLR=2.12 YLR=+51 ZLR=0 END
TTL='X-Y PLOT OF ARRAY'
SCR=YES PIC=MAT LPI=10
UAX=1.0 VDN=-1.0 NAX=1600
XUL=-200 YUL=200 ZUL=215
XLR=200  YLR=-200 ZLR=215
END PLOT
END DATA
END
```

Table 6.4.5-1 Parametric Study – Fuel / Basket k-infinity versus TRIGA Fuel Element Type, Nonpoisoned Basket

(Infinite Array of Nonpoisoned TRIGA Basket Cells with Four (4) Elements)

Fuel Element Type	Initial U Content wt%	Total U grams	^{235}U wt%	Wet Case Results K(infinity) ± σ	Dry Case Results k(infinity) ± σ
Original Al Clad 14 inch Active Fuel	8-8.5	205	20.0	1.01740 ± 0.00081	1.04129 ± 0.00066
Original Al Clad 15 inch Active Fuel	8-8.5	205	20.0	1.00636 ± 0.00081	1.02634 ± 0.00065
Stand. Streamlined Steel Clad 15 inch Active Fuel (FLIP)	8.5	196	70.0	1.33900 ± 0.00094	1.43012 ± 0.00078
Stand. Plain Steel Clad 15 Active Fuel (FLIP)	8.5	196	70.0	1.33969 ± 0.00097	1.43009 ± 0.00077
Stand. Streamlined Steel Clad FLIP-LEU-II	30.6	845	20.0	1.28517 ± 0.00087	1.31180 ± 0.00073
Stand. Plain Steel Clad FLIP-LEU-II	30.6	845	20.0	1.28512 ± 0.00088	1.31198 ± 0.00072
FFCR Element FLIP-LEU-I	20.0	484	20.0	1.16407 ± 0.00086	1.23186 ± 0.00071
1-70 wt% ^{235}U + 3-20 wt% ^{235}U	--	--	--	1.30429 ± 0.00091	1.34060 ± 0.00071
3-70 wt% ^{235}U + 1-20 wt% ^{235}U	--	--	--	1.32896 ± 0.00092	1.40083 ± 0.00077
2-70 wt% ^{235}U + 2-20 wt% ^{235}U	--	--	--	1.31601 ± 0.00094	1.37156 ± 0.00076

LEU Low Enriched Uranium
FLIP Fuel Life Improvement Program
FFCR Fuel Follower Control Rod

* Resonance treatment for two different fuel types is included.

Table 6.4.5-2 Parametric Study – Cask k_{eff} versus TRIGA Fuel Element Type, Poisoned Basket

Fuel Element Type	Initial U Content wt%	Total U grams	^{235}U wt%	Wet Case Results $k_{eff} \pm \sigma$	Dry Case Results $K_{eff} \pm \sigma$
Original Al Clad 15 inch Active Fuel	8-8.5	205	20.0	0.58906 ± 0.00097	0.47118 ± 0.00076
Stand. Streamlined Steel Clad 15 inch Active Fuel (FLIP)	8.5	196	70.0	0.86504 ± 0.00134	0.85705 ± 0.00112
Stand. Plain Steel Clad 15 Active Fuel (FLIP)	8.5	196	70.0	0.86647 ± 0.00137	0.86610 ± 0.00115
Stand. Streamlined Steel Clad FLIP-LEU-II	30.6	845	20.0	0.83413 ± 0.00130	0.80073 ± 0.00103
Stand. Plain Steel Clad FLIP-LEU-II	30.6	845	20.0	0.83604 ± 0.00127	0.80492 ± 0.00099
1-70 wt% ^{235}U + 3-20 wt% ^{235}U	--	--	--	0.84391 ± 0.00133	0.81589 ± 0.00101
3-70 wt% ^{235}U + 1-20 wt% ^{235}U	--	--	--	0.85826 ± 0.00131	0.84917 ± 0.00108
2-70 wt% ^{235}U + 2-20 wt% ^{235}U	--	--	--	0.85162 ± 0.00129	0.83177 ± 0.00103

Table 6.4.5-3 Axially Infinite Cask k_{eff} with TRIGA Fuel Elements- Fuel Element Placement Perturbations, Nonpoisoned Basket

Basket Configuration	Wet Case Results $k_{eff} \pm \sigma$	Dry Case Results $k_{eff} \pm \sigma$
Elements Touching, Moved In	-	0.93434 ± 0.00115
Elements Touching, Centered	0.77382 ± 0.00109	0.92672 ± 0.00185
Elements Out	0.83468 ± 0.00101	0.90817 ± 0.00105
Elements Centered, Quadrants	0.81340 ± 0.00107	-
Three - 70 wt% ^{235}U Elements (Equilateral)	0.83646 ± 0.00112	-
Three - 70 wt% ^{235}U Elements (in corner)	0.83579 ± 0.00101	0.80629 ± 0.00110
Three - 70 wt% ^{235}U Elements (Isosceles)	0.83468 ± 0.00101	-
Two - 70 wt% ^{235}U Elements (Center)	0.67480 ± 0.00097	0.63503 ± 0.00108
One - 70 wt% ^{235}U Elements (Center)	0.44428 ± 0.00091	-

Table 6.4.5-4 Axially Infinite Cask k_{eff} with TRIGA Fuel Elements - Fuel Element Placement Perturbations, Poisoned Basket

Basket Configuration	Wet Case Results $k_{eff} \pm \sigma$	Dry Case Results $k_{eff} \pm \sigma$
Elements Touching, Moved In	-	0.88969 ± 0.00122
Elements Touching, Centered	0.82705 ± 0.00136	0.87833 ± 0.00122
Elements Touching, Moved Out	-	0.87871 ± 0.00112
Elements Centered, Quadrants	0.86647 ± 0.00134	0.86610 ± 0.00115
Elements Out	0.87874 ± 0.00123	0.85348 ± 0.00114
27 Elements, Touching	0.85014 ± 0.00131	0.66829 ± 0.00114
27 Elements, Corners	0.84686 ± 0.00124	-
26 Elements, Touching	0.82959 ± 0.00124	0.64354 ± 0.00117
26 Elements, Corners	0.81959 ± 0.00126	-
21 Elements, Touching	0.70693 ± 0.00127	0.55021 ± 0.00110
21 Elements, Corners	0.73134 ± 0.00133	-
14 Elements, Touching	0.58154 ± 0.00136	0.39354 ± 0.00097
14 Elements, Corners	0.55112 ± 0.00117	-

Table 6.4.5-5 Axially Infinite Cask k_{eff} with TRIGA Fuel Elements – Basket Manufacturing Tolerance Perturbations, Nonpoisoned Basket

Basket Configuration	Wet Case Results w/ Dry Neutron Shield $k_{eff} \pm \sigma$	Dry Case Results $k_{eff} \pm \sigma$
Base Case[1]	0.86190 ± 0.00089[3]	0.90053 ± 0.00115[4]
Thin SS Plates	0.86861 ± 0.00094	0.90501 ± 0.00109
Maximum Basket Opening[2]	0.86864 ± 0.00097	0.90023 ± 0.00107
Minimum Basket Opening[2]	0.86489 ± 0.00091	0.90817 ± 0.00105

Notes:

1. Both wet and dry base case configurations include elements out to corners of basket openings.
2. Incorporates minimum thickness stainless steel, basket divider plates.
3. Comparable to the "elements out," $k_{eff} = 0.83468 \pm 0.00101$, configuration of Table 6.4.5-3 except the neutron shield is dry.
4. Incorporates the "elements out" configuration.

Table 6.4.5-6 Axially Infinite Cask k_{eff} with TRIGA Fuel Elements – Basket Manufacturing Tolerance Perturbations, Poisoned Basket

Basket Configuration	Wet Case Results $k_{eff} \pm \sigma$	Dry Case Results $k_{eff} \pm \sigma$
Base Case[1]	0.87874 ± 0.00123	0.88969 ± 0.00122
Minimum Opening[2]	0.87832 ± 0.00127	0.89054 ± 0.00107
Increased Central Opening[2]	0.87981 ± 0.00133	0.88722 ± 0.00118
Increased Exterior Openings[2]	0.87875 ± 0.00134	0.88998 ± 0.00120
Increased Central Opening, Decreased Exterior Openings[2]	0.87475 ± 0.00134	0.88724 ± 0.00116

Notes:

1. Most reactive configurations from Table 6.4.5-4.
2. Incorporates minimum thickness stainless steel, basket divider plates.

Table 6.4.5-7 Screened Can Preferential Flooding and Partial Loading Reactivity Evaluations for TRIGA Fuel Elements, Nonpoisoned and Poisoned Baskets

Description	$k_{eff} \pm \sigma$ Nonpoisoned Basket	$k_{eff} \pm \sigma$ Poisoned Basket
Wet Cask / Wet Can	0.84040 ± 0.00132	0.88010 ± 0.00139
Dry Cask / Dry Can	0.89383 ± 0.00120	0.86228 ± 0.00128
Dry Cask / Wet Can – Elements To Center of Cask	0.89778 ± 0.00124	0.88272 ± 0.00124
Dry Cask / Wet Can – Elements To Center of Can	0.89435 ± 0.00124	0.87727 ± 0.00124
Dry Cask / Wet Can – Elements Quadrant Centered	0.89821 ± 0.00129	0.88737 ± 0.00123
Dry Cask / Wet Can – Elements in Corners	0.90926 ± 0.00126	0.89957 ± 0.00118
Dry Cask / Wet Can – Elements in Corners, Max. Can	0.90673 ± 0.00123	0.90224 ± 0.00128
18 Elements per Basket Module	0.84896 ± 0.00121	0.82527 ± 0.00114
12 Elements per Basket Module	0.82532 ± 0.00125	0.80281 ± 0.00119

Table 6.4.5-8 Sealed Can Preferential Flooding and Partial Loading Reactivity Evaluations for TRIGA Fuel Elements, Nonpoisoned and Poisoned Baskets

Description	$k_{eff} \pm \sigma$ Nonpoisoned Basket	$k_{eff} \pm \sigma$ Poisoned Basket
Wet Cask / Wet Can, Elements Out	-	0.88574 ± 0.00130
Wet Cask / Wet Can	0.84331 ± 0.00129	0.88036 ± 0.00125
Dry Cask / Dry Can	0.85693 ± 0.00121	0.83021 ± 0.00118
Dry Cask / Wet Can	0.84376 ± 0.00129	0.78084 ± 0.00114
2 Rods per Can - 3 Five Inch Fuel Pellets	0.84346 ± 0.00128	0.88212 ± 0.00133
Mixture Solid (No Moderator)- 2 Rods Per Can	0.87512 ± 0.00122	0.88371 ± 0.00125
Mixture Half Can Height - 2 Rods Per Can	0.90691 ± 0.00212	0.88564 ± 0.00146
Mixture Full Can Height - 2 Rods Per Can	0.91088 ± 0.00106	0.88411 ± 0.00129
Mixture - Solid (No Moderator) - 1 Rod Per Can	0.85868 ± 0.00132	0.88472 ± 0.00131
Mixture - Half Can Height - 1 Rod Per Can	0.87411 ± 0.00117	0.88204 ± 0.00130
Mixture - Full Can Height - 1 Rod Per Can	0.85913 ± 0.00117	0.88477 ± 0.00142
2 Rods Per Can + Graphite – Solid	0.87208 ± 0.00117	0.88616 ± 0.00138
2 Rods Per Can + Graphite – Full Can Height	0.89867 ± 0.00118	0.88431 ± 0.00129
Increased Can Diameter (+0.02 inch)[1]	0.91355 ± 0.00119	0.88436 ± 0.00138

Note:

1. The increased can diameter cases were analyzed using the most reactive cases for each basket configuration (nonpoisoned/poisoned). The "Wet Cask / Wet Can, Elements Out" case was selected for the poisoned basket configuration due to the lack of statistically significant differences in the above reported results.

Table 6.4.5-9 Summary of Most Reactive Configurations, TRIGA Fuel Elements, Nonpoisoned Basket

	Wet	Dry	Preferential
Intact Fuel	0.86861 ± 0.00094	0.93434 ± 0.00115 [1]	-
Screened Fuel Cans	0.84040 ± 0.00132	0.89383 ± 0.00120	0.90926 ± 0.00126
Sealed Fuel Cans	0.84331 ± 0.00129	0.85693 ± 0.00121	0.91355 ± 0.00199

Note:

1. As reported in Section 6.4.5.4, this case is reevaluated with a finite axial length model, making the preferentially flooded, sealed can case the most reactive.

Table 6.4.5-10 Summary of Most Reactive Configurations, TRIGA Fuel Elements, Poisoned Basket

	Wet	Dry	Preferential
Intact Fuel	0.87874 ± 0.00123	0.88969 ± 0.00122	-
Screened Fuel Cans	0.88010 ± 0.00139	0.86228 ± 0.00128	0.90224 ± 0.00128
Sealed Fuel Cans	0.88574 ± 0.00130	0.83021 ± 0.00118	0.88564 ± 0.00146

Table 6.4.5-11 Reactivity Results for TRIGA Fuel Elements, Sealed Cans, Normal Conditions, Nonpoisoned Basket

Moderator SG	Casks Touching ($k_{eff} \pm \sigma$)	8 Foot Center-To-Center ($k_{eff} \pm \sigma$)
Dry Exterior, Vary Internal Density		
0.00000	0.7239 ± 0.0012	0.7203 ± 0.0012
0.00100	0.7205 ± 0.0012	0.7212 ± 0.0012
0.00178	0.7231 ± 0.0013	0.7201 ± 0.0012
0.00316	0.7216 ± 0.0012	0.7202 ± 0.0012
0.00562	0.7227 ± 0.0012	0.7181 ± 0.0012
0.01000	0.7234 ± 0.0012	0.7224 ± 0.0012
0.01780	0.7205 ± 0.0012	0.7223 ± 0.0013
0.03160	0.7249 ± 0.0012	0.7242 ± 0.0012
0.05620	0.7263 ± 0.0012	0.7285 ± 0.0012
0.10000	0.7295 ± 0.0012	0.7303 ± 0.0012
0.17800	0.7446 ± 0.0012	0.7415 ± 0.0012
0.31600	0.7674 ± 0.0012	0.7647 ± 0.0013
0.56200	0.7887 ± 0.0013	0.7884 ± 0.0013
0.70000	0.7977 ± 0.0014	0.7961 ± 0.0014
0.80000	0.8009 ± 0.0013	0.7974 ± 0.0013
0.90000	0.8000 ± 0.0013	0.8008 ± 0.0012
1.00000	0.8020 ± 0.0013	0.8022 ± 0.0014
Optimally Moderated Cask Interior (SG = 1.0), Vary External Density		
0.00000	0.8020 ± 0.0013	0.8022 ± 0.0013
0.00100	0.8013 ± 0.0014	0.8010 ± 0.0013
0.00178	0.7993 ± 0.0014	0.8003 ± 0.0013
0.00316	0.8017 ± 0.0014	0.8024 ± 0.0013
0.00562	0.8041 ± 0.0014	0.8002 ± 0.0013
0.01000	0.8018 ± 0.0013	0.8032 ± 0.0013
0.01780	0.8025 ± 0.0013	0.8018 ± 0.0013
0.03160	0.8001 ± 0.0013	0.8023 ± 0.0013
0.05620	0.8004 ± 0.0014	0.7993 ± 0.0013
0.10000	0.8008 ± 0.0012	0.8000 ± 0.0013
0.17800	0.8018 ± 0.0014	0.8019 ± 0.0013
0.31600	0.8034 ± 0.0014	0.8019 ± 0.0013
0.56200	0.7996 ± 0.0013	0.8025 ± 0.0013
0.70000	0.8018 ± 0.0014	0.8026 ± 0.0014
0.80000	0.8013 ± 0.0013	0.8009 ± 0.0013
0.90000	0.7998 ± 0.0013	0.8009 ± 0.0012
1.00000	0.8019 ± 0.0015	0.8003 ± 0.0013
Vary Internal and External Density Simultaneously		
0.00000	0.7239 ± 0.0012	0.7203 ± 0.0013
0.00100	0.7212 ± 0.0012	0.7192 ± 0.0012
0.00178	0.7210 ± 0.0011	0.7236 ± 0.0012
0.00316	0.7202 ± 0.0012	0.7217 ± 0.0012
0.00562	0.7225 ± 0.0012	0.7218 ± 0.0012
0.01000	0.7229 ± 0.0012	0.7236 ± 0.0012
0.01780	0.7230 ± 0.0012	0.7239 ± 0.0012
0.03160	0.7253 ± 0.0013	0.7236 ± 0.0012
0.05620	0.7273 ± 0.0012	0.7261 ± 0.0013
0.10000	0.7311 ± 0.0012	0.7296 ± 0.0013
0.17800	0.7439 ± 0.0013	0.7429 ± 0.0012
0.31600	0.7634 ± 0.0013	0.7650 ± 0.0013
0.56200	0.7882 ± 0.0014	0.7898 ± 0.0013
0.70000	0.7950 ± 0.0014	0.7941 ± 0.0012
0.80000	0.7950 ± 0.0013	0.7973 ± 0.0013
0.90000	0.7984 ± 0.0012	0.8002 ± 0.0012
1.00000	0.8000 ± 0.0013	0.8029 ± 0.0014

Table 6.4.5-12 Reactivity Results for TRIGA Fuel Elements, Sealed Cans, Accident Conditions, Nonpoisoned Basket

Moderator SG	Casks Touching ($k_{eff} \pm \sigma$)	8 Foot Center-To-Center ($k_{eff} \pm \sigma$)
Dry Exterior and Neutron Shield, Vary Internal Moderator		
0.00000	0.9136 ± 0.0012	0.9057 ± 0.0011
0.00100	0.9119 ± 0.0012	0.9054 ± 0.0011
0.00178	0.9101 ± 0.0012	0.9041 ± 0.0011
0.00316	0.9110 ± 0.0011	0.9040 ± 0.0011
0.00562	0.9095 ± 0.0012	0.9046 ± 0.0011
0.01000	0.9059 ± 0.0012	0.8999 ± 0.0012
0.01780	0.9021 ± 0.0012	0.8979 ± 0.0012
0.03160	0.8965 ± 0.0012	0.8908 ± 0.0011
0.05620	0.8842 ± 0.0013	0.8793 ± 0.0012
0.10000	0.8660 ± 0.0012	0.8622 ± 0.0012
0.17800	0.8432 ± 0.0012	0.8419 ± 0.0012
0.31600	0.8275 ± 0.0013	0.8222 ± 0.0012
0.56200	0.8185 ± 0.0013	0.8153 ± 0.0014
0.70000	0.8144 ± 0.0013	0.8124 ± 0.0013
0.80000	0.8140 ± 0.0013	0.8091 ± 0.0013
0.90000	0.8154 ± 0.0012	0.8082 ± 0.0013
1.00000	0.8117 ± 0.0013	0.8081 ± 0.0013
Optimally Moderated Internal (SG = 0.0), Vary Neutron Shield and Exterior		
0.00000	0.9136 ± 0.0012	0.9057 ± 0.0011
0.00100	0.8950 ± 0.0011	0.8208 ± 0.0012
0.00178	0.8887 ± 0.0011	0.7931 ± 0.0012
0.00316	0.8732 ± 0.0012	0.7651 ± 0.0012
0.00562	0.8505 ± 0.0012	0.7454 ± 0.0011
0.01000	0.8210 ± 0.0011	0.7311 ± 0.0012
0.01780	0.7957 ± 0.0012	0.7233 ± 0.0012
0.03160	0.7655 ± 0.0012	0.7192 ± 0.0011
0.05620	0.7432 ± 0.0012	0.7195 ± 0.0013
0.10000	0.7325 ± 0.0013	0.7177 ± 0.0012
0.17800	0.7252 ± 0.0011	0.7206 ± 0.0012
0.31600	0.7216 ± 0.0012	0.7213 ± 0.0012
0.56200	0.7211 ± 0.0012	0.7211 ± 0.0012
0.70000	0.7199 ± 0.0012	0.7190 ± 0.0012
0.80000	0.7213 ± 0.0012	0.7184 ± 0.0012
0.90000	0.7183 ± 0.0013	0.7196 ± 0.0012
1.00000	0.7189 ± 0.0011	0.7194 ± 0.0013
Vary Interior, Exterior and Neutron Shield Simultaneously		
0.00000	0.9136 ± 0.0012	0.9057 ± 0.0011
0.00100	0.8964 ± 0.0012	0.8189 ± 0.0012
0.00178	0.8879 ± 0.0011	0.7913 ± 0.0013
0.00316	0.8726 ± 0.0012	0.7673 ± 0.0013
0.00562	0.8496 ± 0.0011	0.7459 ± 0.0012
0.01000	0.8223 ± 0.0012	0.7345 ± 0.0012
0.01780	0.7903 ± 0.0012	0.7237 ± 0.0012
0.03160	0.7685 ± 0.0012	0.7223 ± 0.0011
0.05620	0.7504 ± 0.0012	0.7242 ± 0.0012
0.10000	0.7415 ± 0.0013	0.7296 ± 0.0012
0.17800	0.7445 ± 0.0013	0.7404 ± 0.0013
0.31600	0.7674 ± 0.0013	0.7658 ± 0.0013
0.56200	0.7904 ± 0.0013	0.7898 ± 0.0013
0.70000	0.7972 ± 0.0014	0.7936 ± 0.0014
0.80000	0.7969 ± 0.0013	0.7956 ± 0.0014
0.90000	0.8003 ± 0.0013	0.8007 ± 0.0013
1.00000	0.8000 ± 0.0013	0.8013 ± 0.0013

Table 6.4.5-13 Reactivity Results for TRIGA Fuel Elements, Screened Cans, Normal Conditions, Poisoned Basket

Moderator SG	Casks Touching ($k_{eff} \pm \sigma$)	8 Foot Center-To-Center ($k_{eff} \pm \sigma$)
Dry Exterior, Vary Internal Density		
0.00000	0.8376 ± 0.0018	0.8381 ± 0.0017
0.00100	0.8408 ± 0.0017	0.8418 ± 0.0016
0.00178	0.8408 ± 0.0018	0.8412 ± 0.0018
0.00316	0.8390 ± 0.0017	0.8432 ± 0.0016
0.00562	0.8371 ± 0.0017	0.8399 ± 0.0017
0.01000	0.8420 ± 0.0017	0.8397 ± 0.0018
0.01780	0.8383 ± 0.0017	0.8419 ± 0.0017
0.03160	0.8413 ± 0.0017	0.8427 ± 0.0017
0.05620	0.8466 ± 0.0017	0.8448 ± 0.0017
0.10000	0.8433 ± 0.0016	0.8479 ± 0.0017
0.17800	0.8510 ± 0.0017	0.8502 ± 0.0017
0.31600	0.8497 ± 0.0016	0.8505 ± 0.0016
0.56200	0.8453 ± 0.0017	0.8484 ± 0.0017
0.70000	0.8444 ± 0.0016	0.8464 ± 0.0017
0.80000	0.8321 ± 0.0017	0.8432 ± 0.0017
0.90000	0.8458 ± 0.0017	0.8437 ± 0.0017
1.00000	0.8527 ± 0.0017	0.8540 ± 0.0017
Optimally Moderated Cask Interior (SG = 1.0), Vary External Density		
0.00000	0.8527 ± 0.0017	0.8540 ± 0.0017
0.00100	0.8482 ± 0.0018	0.8513 ± 0.0016
0.00178	0.8532 ± 0.0017	0.8513 ± 0.0016
0.00316	0.8516 ± 0.0017	0.8531 ± 0.0017
0.00562	0.8546 ± 0.0017	0.8539 ± 0.0017
0.01000	0.8521 ± 0.0018	0.8517 ± 0.0019
0.01780	0.8528 ± 0.0018	0.8515 ± 0.0018
0.03160	0.8543 ± 0.0017	0.8526 ± 0.0017
0.05620	0.8506 ± 0.0018	0.8503 ± 0.0017
0.10000	0.8523 ± 0.0018	0.8542 ± 0.0016
0.17800	0.8507 ± 0.0018	0.8478 ± 0.0016
0.31600	0.8539 ± 0.0017	0.8518 ± 0.0016
0.56200	0.8545 ± 0.0017	0.8525 ± 0.0017
0.70000	0.8512 ± 0.0017	0.8534 ± 0.0017
0.80000	0.8548 ± 0.0017	0.8529 ± 0.0017
0.90000	0.8523 ± 0.0016	0.8522 ± 0.0017
1.00000	0.8540 ± 0.0018	0.8523 ± 0.0017
Vary Internal and External Density Simultaneously		
0.00000	0.8376 ± 0.0018	0.8381 ± 0.0017
0.00100	0.8396 ± 0.0017	0.8382 ± 0.0017
0.00178	0.8404 ± 0.0016	0.8404 ± 0.0017
0.00316	0.8430 ± 0.0016	0.8413 ± 0.0017
0.00562	0.8448 ± 0.0017	0.8391 ± 0.0016
0.01000	0.8400 ± 0.0017	0.8398 ± 0.0017
0.01780	0.8419 ± 0.0017	0.8424 ± 0.0018
0.03160	0.8394 ± 0.0017	0.8439 ± 0.0017
0.05620	0.8437 ± 0.0017	0.8385 ± 0.0017
0.10000	0.8477 ± 0.0017	0.8477 ± 0.0017
0.17800	0.8502 ± 0.0017	0.8469 ± 0.0017
0.31600	0.8463 ± 0.0017	0.8494 ± 0.0018
0.56200	0.8484 ± 0.0017	0.8513 ± 0.0017
0.70000	0.8471 ± 0.0017	0.8459 ± 0.0018
0.80000	0.8440 ± 0.0017	0.8462 ± 0.0016
0.90000	0.8429 ± 0.0017	0.8451 ± 0.0017
1.00000	0.8540 ± 0.0018	0.8523 ± 0.0017

Table 6.4.5-14 Reactivity Results for TRIGA Fuel Elements, Screened Cans, Accident Conditions, Poisoned Basket

Moderator SG	Casks Touching ($k_{eff} \pm \sigma$)	8 Foot Center-To-Center ($k_{eff} \pm \sigma$)
Dry Exterior and Neutron Shield, Vary Internal Moderator		
0.00000	0.9022 ± 0.0015	0.9015 ± 0.0016
0.00100	0.9019 ± 0.0016	0.9022 ± 0.0016
0.00178	0.8998 ± 0.0016	0.9003 ± 0.0016
0.00316	0.8992 ± 0.0016	0.9009 ± 0.0016
0.00562	0.8995 ± 0.0017	0.9015 ± 0.0017
0.01000	0.8998 ± 0.0017	0.8956 ± 0.0017
0.01780	0.8979 ± 0.0017	0.9003 ± 0.0017
0.03160	0.8966 ± 0.0018	0.8946 ± 0.0016
0.05620	0.8949 ± 0.0015	0.8889 ± 0.0015
0.10000	0.8893 ± 0.0018	0.8844 ± 0.0017
0.17800	0.8843 ± 0.0018	0.8822 ± 0.0016
0.31600	0.8772 ± 0.0017	0.8765 ± 0.0016
0.56200	0.8635 ± 0.0018	0.8640 ± 0.0017
0.70000	0.8586 ± 0.0017	0.8657 ± 0.0017
0.80000	0.8620 ± 0.0016	0.8594 ± 0.0016
0.90000	0.8622 ± 0.0016	0.8600 ± 0.0017
1.00000	0.8662 ± 0.0017	0.8629 ± 0.0018
Optimally Moderated Internal (SG = 0.0), Vary Neutron Shield and Exterior		
0.00000	0.9022 ± 0.0015	0.9015 ± 0.0016
0.00100	0.8970 ± 0.0016	0.8644 ± 0.0017
0.00178	0.8910 ± 0.0016	0.8596 ± 0.0018
0.00316	0.8862 ± 0.0015	0.8542 ± 0.0016
0.00562	0.8789 ± 0.0016	0.8457 ± 0.0016
0.01000	0.8687 ± 0.0015	0.8438 ± 0.0017
0.01780	0.8618 ± 0.0017	0.8409 ± 0.0018
0.03160	0.8539 ± 0.0016	0.8386 ± 0.0017
0.05620	0.8482 ± 0.0017	0.8403 ± 0.0018
0.10000	0.8427 ± 0.0015	0.8381 ± 0.0017
0.17800	0.8433 ± 0.0017	0.8418 ± 0.0016
0.31600	0.8424 ± 0.0018	0.8405 ± 0.0018
0.56200	0.8422 ± 0.0017	0.8391 ± 0.0017
0.70000	0.8438 ± 0.0017	0.8399 ± 0.0016
0.80000	0.8429 ± 0.0018	0.8407 ± 0.0017
0.90000	0.8423 ± 0.0017	0.8445 ± 0.0016
1.00000	0.8398 ± 0.0016	0.8383 ± 0.0017
Vary Interior, Exterior and Neutron Shield Simultaneously		
0.00000	0.9022 ± 0.0015	0.9015 ± 0.0016
0.00100	0.8948 ± 0.0016	0.8662 ± 0.0016
0.00178	0.8932 ± 0.0017	0.8577 ± 0.0016
0.00316	0.8881 ± 0.0016	0.8524 ± 0.0017
0.00562	0.8762 ± 0.0016	0.8429 ± 0.0017
0.01000	0.8722 ± 0.0017	0.8431 ± 0.0017
0.01780	0.8628 ± 0.0016	0.8412 ± 0.0017
0.03160	0.8586 ± 0.0016	0.8450 ± 0.0017
0.05620	0.8533 ± 0.0017	0.8448 ± 0.0018
0.10000	0.8496 ± 0.0017	0.8458 ± 0.0017
0.17800	0.8494 ± 0.0017	0.8489 ± 0.0017
0.31600	0.8500 ± 0.0017	0.8459 ± 0.0017
0.56200	0.8489 ± 0.0018	0.8488 ± 0.0018
0.70000	0.8443 ± 0.0017	0.8463 ± 0.0017
0.80000	0.8459 ± 0.0017	0.8407 ± 0.0018
0.90000	0.8421 ± 0.0017	0.8483 ± 0.0017
1.00000	0.8540 ± 0.0018	0.8504 ± 0.0019

Table 6.4.5-15 Single Package 10 CFR 71.55(b)(3) Evaluation k_{eff} Summary, TRIGA Fuel Element, Nonpoisoned Basket

Description	$k_{eff} \pm \sigma$	k_s
Single Cask / Inner Shell Reflected with H_2O	0.80664 ± 0.00136	0.82616
Single Cask / Inner Shell and Lead Reflected with H_2O	0.84194 ± 0.00130	0.86134
Single Cask / Inner Shell, Lead & Outer Shell Reflected with H_2O	0.84398 ± 0.00128	0.86334
Single Intact Cask Reflected with H_2O	0.84446 ± 0.00126	0.86392

Table 6.4.5-16 Single Package 10 CFR 71.55(b)(3) Evaluation k_{eff} Summary, TRIGA Fuel Element, Poisoned Basket

Description	$k_{eff} \pm \sigma$	k_s
Single Cask / Inner Shell Reflected with H_2O	0.85480 ± 0.00135	0.87430
Single Cask / Inner Shell and Lead Reflected with H_2O	0.87788 ± 0.00136	0.89740
Single Cask / Inner Shell, Lead & Outer Shell Reflected with H_2O	0.88369 ± 0.00133	0.90315
Single Intact Cask Reflected with H_2O	0.88117 ± 0.00131	0.90059

Table 6.4.5-17 Fuel Element Physical Characteristics Evaluation

Parameter							Cask Cavity Moderator Condition/Fuel Location							
							Dry - In Shift		0.5 g/cc - In Shift		1 g/cc - In Shift		1 g/cc – Shifted Out	
Fuel Rod OD	Clad Thickness	Fuel OD	Fuel ID	Active Fuel Length	Zirc Interior Rod OD	Zirc Mass (gram)	k_{eff}	Δk/σ	k_{eff}	Δk/σ	k_{eff}	Δk/σ	k_{eff}	Δk/σ
Nominal	Nominal	Nominal	Nominal	Nominal	Nominal	2059	0.85521	-	0.87591	-	0.87217	-	0.89939	-
Max	Nominal	Nominal	Nominal	Nominal	Nominal	2059	0.85102	-2.8	0.87063	-5.6	0.86795	-4.4	0.89480	-4.8
Nominal	Min	Nominal	Nominal	Nominal	Nominal	2059	0.85966	6.2	0.88920	14.0	0.89067	19.4	0.92184	23.3
Nominal	Nominal	Min	Nominal	Nominal	Nominal	1765	0.78425	-72.2	0.82168	-58.1	0.82388	-51.7	0.85987	-42.6
Nominal	Nominal	Max	Nominal	Nominal	Nominal	2068	0.85611	2.6	0.87530	-0.6	0.87327	1.2	0.90107	1.8
Nominal	Nominal	Nominal	Min	Nominal	Nominal	2071	0.85409	0.4	0.87776	2.0	0.87334	1.2	0.90196	2.7
Nominal	Nominal	Nominal	Nominal	Min	Nominal	1988	0.84974	-4.2	0.87304	-3.0	0.87192	-0.3	0.89885	-0.6
Nominal	Nominal	Nominal	Nominal	Max	Nominal	2129	0.85762	4.2	0.87705	1.2	0.87078	-1.5	0.89995	0.6
Nominal	Nominal	Nominal	Nominal	Nominal	Min	2059	0.85370	0.0	0.87322	-2.8	0.87095	-1.3	0.89785	-1.6
Nominal	Nominal	Nominal	Nominal	Nominal	Max	2059	0.85360	-0.1	0.87502	-0.9	0.87125	-1.0	0.89966	0.3
Nominal	Min	Max	Nominal	Nominal	Nominal	2191	0.88846	36.9	0.91259	37.9	0.91057	39.6	0.93977	42.6
Max	Min	Max	Nominal	Nominal	Nominal	2261	0.89797	46.7	0.92086	47.8	0.91631	44.9	0.94365	46.4
Max	Min	Max	Nominal	Nominal	Min	2261	0.89729	45.3	0.92035	46.6	0.91583	46.1	0.94260	44.9
Max	Min	Max	Min	Nominal	Min	2327	0.91165	60.7	0.92950	55.7	0.92648	56.0	0.94983	51.3
Max	Min	Max	Min	Max	Min	2406	0.91646	66.2	0.93183	57.7	0.92716	56.3	0.95048	52.7
Max	Min	Max	Min	Min	Min	2248	0.90919	58.1	0.92962	57.1	0.92491	54.8	0.95030	52.2

Table 6.4.5-18 Element Variation to Reduce k_s Below 0.95

Variation	k_{eff}	σ	k_s	Δk
Base	0.95048	0.00069	0.9687	
Single Cask	0.94221	0.00068	0.9604	-0.00827
Min Clad 0.01 inch	0.93007	0.00068	0.9482	-0.02041
Center rod 0.1 inch	0.94559	0.00066	0.9637	-0.00489
Center Rod 0.1 inch and Clad 0.01 inch	0.92465	0.00069	0.9428	-0.02583

Table 6.4.5-19 General Model Configuration – Dry to Wet System Reactivity Changes, 70 wt% ^{235}U Stainless Steel Clad Fuel - Nominal Fuel Parameters

Model Type	Fuel Material	Dry Interior		Wet Interior		Dry to Wet	Dry to Wet
		k_{eff}	σ	k_{eff}	σ	Δk	Δk/σ
Unit Cell	2060 g Zirc 1.6 H/Zr	1.43854	0.00074	1.34434	0.00088	-0.0942	-82
Unit Cell	2060 g Zirc 2.0 H/Zr	1.47297	0.00072	1.37063	0.00095	-0.1023	-86
Infinite Cask Array	2060 g Zirc 1.6 H/Zr	0.91389	0.00058	0.82201	0.00069	-0.0919	-102
Infinite Cask Array	2060 g Zirc 2.0 H/Zr	0.99893	0.00060	0.87887	0.00069	-0.1201	-131
Finite Cask Array	2060 g Zirc 2.0 H/Zr	0.85371	0.00068	0.87160	0.00067	0.0179	19
Single Cask	2060 g Zirc 1.6 H/Zr	0.69491	0.00059	0.80561	0.00066	0.1107	125

Table 6.4.5-20 Primary Fuel Type Reactivity Comparison[1] – Accident Conditions Eight-Cask Array (No Cans)

Fuel Type	Cask Cavity Moderator	Fuel Characteristics	Rod Location	k_{eff}	σ	k_s	Δk/σ
Al Clad	Dry	Nominal	Shifted In	0.61831	0.00053	0.63617	-
14 inch	Wet	Nominal	Shifted In	0.67516	0.00056	0.69308	73.7
	Wet	Most Reactive	Shifted In	0.68914	0.00056	0.70706	91.9
	Wet	Most Reactive	Shifted Out	0.68690	0.00054	0.70478	90.7
Al Clad -	Dry	Nominal	Shifted In	0.60606	0.00051	0.62388	-
15 inch	Wet	Nominal	Shifted In	0.66104	0.00058	0.67900	71.2
	Wet	Most Reactive	Shifted In	0.68272	0.00055	0.70062	102.2
	Wet	Most Reactive	Shifted Out	0.67985	0.00052	0.69769	101.3
SS Clad -	Dry	Nominal	Shifted In	0.77575	0.00058	0.79371	-
20% Enriched	Wet	Nominal	Shifted In	0.82684	0.00064	0.84492	59.2
	Wet	Most Reactive	Shifted In	0.86114	0.00061	0.87916	101.4
	Wet	Most Reactive	Shifted Out	0.89909	0.00064	0.91717	142.8
SS Clad	Dry	Nominal	Shifted In	0.85521	0.00068	0.87337	-
70% Enriched	Wet	Nominal	Shifted In	0.87217	0.00067	0.89031	17.8
	Wet	Most Reactive	Shifted In	0.90587	0.00069	0.92405	52.3
	Wet	Most Reactive	Shifted Out	0.93024	0.00069	0.94842	77.4

Table 6.4.5-21 Normal Condition Maximum System Reativities (No Cans)[2]

Array Size	Neutron Shield	Cask Cavity	Fuel Config	k_{eff}	σ	k_s
Infinite	Yes	Dry	MRE	0.84554	0.00066	0.86366
Infinite	Yes	Wet	MRE	0.92398	0.00068	0.94214

[1] Fueled follower rods are not evaluated separately as their physical characteristics and fuel compositions are bounded by a stainless steel clad 20% enriched element.

[2] Most reactive element configuration as documented under accident conditions.

Table 6.4.5-22 Increased Enrichment for 20 wt % and 70 wt % TRIGA Fuel Elements

wt %	g ^{235}U	k_{eff}	σ	k_s	$\Delta k_s/\sigma$
20	169	0.89973	0.00064	0.91781	--
25	169	0.91236	0.00065	0.93046	13.9
70	137	0.93063	0.00067	0.94877	--
71	137	0.93066	0.00068	0.94882	0.1

Table 6.4.5-23 Increased ^{235}U Mass TRIGA Fuel Elements

wt %	g ^{235}U	k_{eff}	σ	k_s	$\Delta k_s/\sigma$
25	169	0.91236	0.00065	0.93046	--
25	275	0.95139	0.00068	0.96955	41.6
71	137	0.93066	0.00068	0.94882	--
71	138	0.93159	0.00066	0.94971	0.9

Table 6.4.5-24 Limited Quantity Study for LEU Fissile Mass Increase

Baskets									
Bottom/Top			Three Middle						
# Rods	wt %	g ^{235}U	# Rods	wt %	g ^{235}U	k_{eff}	σ	k_s	$\Delta k_s/\sigma$
4	71	138	4	71	138	0.93159	0.00066	0.94971	--
4	25	275	4	25	275	0.95139	0.00068	0.96955	20.9
4	25	275	4	71	138	0.94928	0.00067	0.96742	18.8
3	25	275	4	71	138	0.92997	0.00067	0.94811	-1.7

Table 6.4.5-25 95 wt% TRIGA Fuel Elements

Baskets									
Bottom/Top			Three Middle						
# Rods	wt %	g ^{235}U	# Rods	wt %	g ^{235}U	k_{eff}	σ	k_s	$\Delta k_s/\sigma$
4	71	138	4	71	138	0.93159	0.00066	0.94971	--
4	95	175	4	95	175	0.97990	0.00069	0.99808	50.7
4	95	175	4	71	138	0.97662	0.00066	0.99474	48.2
3	95	175	4	71	138	0.93030	0.00064	0.94838	-1.4

Table 6.4.5-26 TRIGA Damaged Fuel Canister – Sealed Canister in Top and Bottom Basket Module

Baskets									
Bottom / Top			Three Middle						
# Rods	wt %	g ^{235}U	# Rods	wt %	g ^{235}U	k_{eff}	σ	k_s	$\Delta k_s/\sigma$
4	71	138	4	71	138	0.93159	0.00066	0.94971	--
2	71	138	4	71	138	0.93032	0.00068	0.94848	-1.3
2	25	275	4	71	138	0.93109	0.00070	0.94929	-0.4
2	95	175	4	71	138	0.93071	0.00068	0.94887	-0.9

Table 6.4.5-27 TRIGA Fuel Element Pitch/Screened Canister Evaluation

	Baskets									
	Bottom / Top			Three Middle						
DFC	Pitch	wt %	g ^{235}U	Pitch	wt %	g ^{235}U	k_{eff}	σ	k_s	$\Delta k_s/\sigma$
No	4.7750	95	175	4.775	71	138	0.97662	0.00066	0.99474	--
No	4.1924	95	175	4.775	71	138	0.95679	0.00068	0.97495	-20.9
Yes	4.1924	95	175	4.775	71	138	0.92977	0.00068	0.94793	-49.4

Table 6.4.5-28 TRIGA Structural Intact Fuel Canister -- Screened Canister in Top and Bottom Basket Module

Baskets									
Bottom / Top			Three Middle						
# Rods	wt %	g ^{235}U	# Rods	wt %	g ^{235}U	k_{eff}	σ	k_s	$\Delta k_s/\sigma$
4	71	138	4	71	138	0.93159	0.00066	0.94971	--
4	71	138	4	71	138	0.92971	0.00069	0.94789	-1.9
4	25	275	4	71	138	0.93055	0.00065	0.94865	-1.1
4	95	175	4	71	138	0.92977	0.00068	0.94793	-1.9

Table 6.4.5-29 TRIGA Cluster Rod Study in TRIGA Fuel Element Shipment

Baskets									
1 Opening			Remaining Payload						
# Rods	wt %	g ^{235}U	# Rods	wt %	g ^{235}U	k_{eff}	σ	k_s	$\Delta k_s/\sigma$
4	71	138	4	71	138	0.93159	0.00066	0.94971	--
6	95	46.5	4	71	138	0.93085	0.00064	0.94893	-0.8
16	95	46.5	4	71	138	0.93141	0.00065	0.94951	-0.2