NUHOMS®-MP197 TRANSPORT PACKAGING

CHAPTER 6

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CHAPTER 6

CRITICALITY EVALUATION

6.1 Design

The design criteria for the NUHOMS®-61BT Dry Shielded Canister (DSC) to be transported in the NUHOMS®-MP197 transport package require that the package remain subcritical under normal conditions of transport (NCT) and hypothetical accident conditions (HAC) as defined in 10CFR Part 71.

The NUHOMS®-61BT System's criticality safety is ensured by both fixed neutron absorbers and favorable geometry. Burnup credit is not taken in this criticality evaluation. The fixed neutron absorber may be one of several different types of borated metallic plates. The materials description, acceptance testing, and the boron 10 credit allowed for the various fixed absorber materials are included in Chapter 8.

No credit is taken for moderator exclusion by the DSC.

6.1.1 Discussion and Results

Figure 6-1 shows the cross section of the NUHOMS®-61BT DSC. The analysis presented herein is performed for a NUHOMS®-61BT DSC in a the MP-197 transportation cask. The cask consists of an inner stainless steel shell, and lead gamma shield, a stainless steel structural shell and a hydrogenous neutron shield. The NUHOMS®-MP197 configuration is shown to be subcritical under NCT and HAC.

The calculations determine k_{eff} with the CSAS25 control module of SCALE-4.4 [6.1] for various configurations and initial enrichments, including all uncertainties to assure criticality safety under all credible conditions.

The results of the evaluation demonstrate that the maximum k_{eff} - including statistical uncertainty - is less than the Upper Subcritical Limit (USL) determined from a statistical analysis of benchmark criticality experiments. The statistical analysis procedure includes a confidence band with an administrative safety margin of 0.05.

6.2 Package Fuel Loading

The NUHOMS®-MP-197 is capable of transporting intact BWR fuel assemblies with or without fuel channels. The maximum lattice-averaged enrichment of the fuel depends on the boron content in the fixed poison plates in the basket, as shown in Table 6-1. The fuel assemblies considered as authorized contents are listed in Table 6-2.

Table 6-3 lists the fuel parameters for the standard BWR fuel assemblies. The design basis fuel chosen for the NUHOMS®-MP197 Packaging criticality analysis is the GE 10×10 fuel assembly because it is the most reactive fuel assembly of the authorized contents, as demonstrated in the appendix to this chapter.

An infinite array of packages with optimal internal and interspersed moderation is evaluated to demonstrate compliance with 10CFR72.55(b), 10CFR71.59(a)(1), 10CFR71.59(a)(2). Because an infinite array of packages is used to evaluate both NCT and HAC, the transport index for criticality safety is zero.

6.3 Model Specification

The following subsections describe the physical models and materials of the NUHOMS®-MP197 packaging used for input to the CSAS25 module of SCALE-4.4 [6.1] to perform the criticality evaluation.

6.3.1 Description of Calculational Model

The cask and the DSC were explicitly modeled using the appropriate geometry options in KENO V.a of the CSAS25 module in SCALE-4.4.

Two models were developed. The first model is a full-active fuel height model and full-radial cross section of the DSC alone with water boundary conditions on the ends and reflective boundary conditions on the sides. The model does not include the gaps between the poison plates. This model is more fully described in Section 6.6.2. This model is only used to determine the most reactive fuel assembly/channel combination and to justify use of the lattice average enrichment for the intact fuel analysis. The second model is a full-active fuel height model and full radial cross section of the cask and DSC with reflective boundary conditions on all sides. This model includes the worst case gaps between the poison plates and the basket internals modeled at minimum material conditions. This model includes the GE12 10×10-fuel assembly only because this assembly type is determined to be the most reactive fuel assembly type of the authorized contents. The GE12 10×10-fuel assembly is modeled as a 10×10 array comprising 92 fuel rods, including fuel, gap and cladding and two large water holes. The fuel cladding OD is also reduced by 0.010 inches in the final models to conservatively bound fuel manufacturing tolerances.

Figure 6-2 is a sketch of each KENO V.a unit showing all materials and dimensions for each unit and an annotated cross section map showing the assembled geometry units in the radial direction of the model. The assembly-to-assembly pitch is a variable in the model with the fuel assemblies modeled in the center of the fuel cells and pushed towards the center and away from the center of the basket. The poison plates are modeled with minimum plate thickness, width and length. The maximum gap between the plates is modeled in the worst case orientation to maximize the amount of "uncovered" fuel. The gaps between the poison plates are due to the need to provide space for thermal expansion of the poison plates relative to the stainless steel parts of the basket and to allow for fabrication tolerances in the basket. In addition, the NUHOMS®-61BT DSC

design allows the poison plates to be fabricated in sections, rather than one continuous piece. In the axial direction, all gaps are modeled at the maximum width. Table 6-4 provides the axial position of the assembled KENO V.a geometry units. Figure 6-3 shows the second model in the bounding congiguration.

An infinite array of damaged packages in a rectangular lattice is modeled by the use of mirror reflection on all six sides of a cuboid surrounding the package model (the second model described above). Neither the neutron shield nor the impact limiters are modeled, which reduces the pitch between packages in the array.

6.3.2 Package Regional Densities

The Oak Ridge National Laboratory (ORNL) SCALE code package [6.1] contains a standard material data library for common elements, compounds, and mixtures. All the materials used for the cask and DSC analysis are available in this data library. The neutron shield material in the MP197 is modeled as water and the neutron shield skin is not modeled.

Table 6-5 provides a complete list of all the relevant materials used for the criticality evaluation. The B-10 areal density specified for manufacturing of the poison plates will be larger than the areal density used in the calculations (and listed in this table), in order the satisfy the 75% or 90% B10 credit allowance as specified in Chapter 8. The cask neutron shield material is conservatively modeled as water. The actual neutron shield hydrogen atom density is lower than that of water; therefore, replacing the neutron shield with water is slightly conservative.

6.4 Criticality Calculation

This section describes the models used for the criticality analysis. The analyses were performed with the CSAS25 module of the SCALE system. A series of calculations were performed to determine the most reactive fuel and configuration. The most reactive fuel, as demonstrated by the analyses, is the GE12 10×10 assembly. The most reactive credible configuration is an infinite array of flooded casks with minimum assembly-to-assembly pitch and the poison plate gaps located near the center of the basket and at the centerline of the active fuel region.

6.4.1 Calculational Method

6.4.1.1 Computer Codes

The CSAS25 control module of SCALE-4.4 [6.1] was used to calculate the effective multiplication factor (k_{eff}) of the fuel in the cask. The CSAS25 control module allows simplified data input to the functional modules BONAMI-S, NITAWL-S, and KENO V.a. These modules process the required cross sections and calculate the k_{eff} of the system. BONAMI-S performs resonance self-shielding calculations for nuclides that have Bondarenko data associated with their cross sections. NITAWL-S applies a

Nordheim resonance self-shielding correction to nuclides having resonance parameters. Finally, KENO V.a calculates the k_{eff} of a three-dimensional system. A sufficiently large number of neutron histories are run so that the standard deviation is below 0.0020 for all calculations.

6.4.1.2 Physical and Nuclear Data

The physical and nuclear data required for the criticality analysis include the fuel assembly data and cross-section data as described below.

The criticality analysis used the 44-group cross-section library built into the SCALE system. ORNL used ENDF/B-V data to develop this broad-group library specifically for criticality analysis of a wide variety of thermal systems.

6.4.1.3 Bases and Assumptions

The analytical results reported in chapter 2 demonstrate that the cask containment boundary and DSC basket structure do not experience any significant distortion under hypothetical accident conditions. Therefore, for both normal and hypothetical accident conditions the cask geometry is identical except for the neutron shield and skin. As discussed above, the neutron shield and skin are conservatively modeled as water.

The cask was modeled with KENO V.a using the available geometry input. This option allows a model to be constructed that uses regular geometric shapes to define the material boundaries. The following conservative assumptions were also incorporated into the criticality calculations:

1. Omission of grid plates, spacers, and hardware in the fuel assembly.

2. No burnable poisons accounted for in the fuel.

3. Water density at optimum internal and external moderator density.

4. Unirradiated fuel – no credit taken for fissile depletion due to burnup or fission product poisoning.

5. The lattice average fuel enrichment is modeled as uniform everywhere throughout the assembly. Natural Uranium blankets and axial or radial enrichment zones are modeled as enriched uranium. It is assumed that the fuel assemblies are of uniform enrichment everywhere.

6. All fuel rods are assumed to be filled with 100% moderator in the pellet/cladding gap.

7. Only the active fuel length of each assembly type is explicitly modeled. The presence of the plenum materials, end fittings, channel material above and below the active fuel reduce the k_{eff} of the system, therefore; these regions are

modeled as water or the reflective boundary conditions. For the cases with reflective boundary conditions, the model is effectively infinitely long.

8. It is assumed that for all Hypothetical Accident Conditions (HAC) cases the neutron shield and stainless steel skin of the cask are stripped away and replaced with moderator.

9. The least material condition (LMC) is assumed for the fuel clad OD, fuel compartment, poison plates and wrappers. This minimizes neutron absorption in the steel sheets and poison plates.

10. The maximum allowed gap between the poison plates in the worst case position is explicitly modeled to maximize k_{eff}.

11. The active fuel region is conservatively assumed to start level with the bottom of the poison plates.

12. Temperature at 20 °C (293 K).

13. Used 95% theoretical density for fuel although this assumption conservatively increases the total fuel content in the model.

6.4.1.4 Determination of k_{eff}.

The criticality calculations were performed with the CSAS25 control module in SCALE-4.4. The Monte Carlo calculations performed with CSAS25 (KENO V.a) used a flat neutron starting distribution. The total number of histories traced for each calculation was approximately 500,000. This number of histories was sufficient to converge the source and produce standard deviations of less than 0.2% in k_{eff}. The maximum k_{eff} for the calculation was determined with the following formula:

$$k_{eff} = k_{KENO} + 2\sigma_{KENO.}$$

6.4.2 Fuel Loading Optimization

A. Determination of the Most Reactive Fuel Lattice

All fuel lattices, with and without channels, listed in Table 6-3 are evaluated to determine the most reactive fuel assembly type. The lattices are analyzed with water in the fuel pellet cladding annulus and are centered in the fuel compartments. Each lattice is also analyzed with a 0.065, 0.080 and 0.120 inch thick channel to determine the most reactive configuration. The results show that the reactivity change due to the fuel channels is within the statistical uncertainty of the KENO V.a calculations. Finally, this model is used to demonstrate that the use of lattice average enrichment is conservative. Several cases are run to demonstrate that the use of the lattice average enrichment is conservative.

For this analysis, only the DSC is modeled. The DSC is modeled over the active fuel height of the fuel with water reflectors at the ends (z) and reflective boundary conditions

outside the DSC (infinite array in the x-y directions) The DSC model for this evaluation differs from the actual design in the following ways:

- the boron 10 areal density specified for manufacturing the poison plates will be greater than that used in the model, as described in Chapter 8,
- no gaps between poison plates are modeled,
- the stainless steel basket rails, which hold the basket together, are modeled as water.

In all other respects, the model is the same as that described in Sections 6.3.1 and 6.3.2. The sole purpose of this model is to determine the *relative* reactivity of different fuel lattices in a configuration similar to the actual DSC.

A typical input file is included in Section 6.6.2. The results of these calculations are listed in Table 6-6. The most reactive fuel lattice evaluated for the DSC design is the GE generation 12 lattice, 10×10 array, without a fuel channel.

B. Determination of the Most Reactive Configuration

The fuel-loading configuration of the DSC/cask affects the reactivity of the package. Several series of analyses determined the most reactive configuration for the DSC/cask.

For this analysis, the DSC/cask is modeled. The DSC/cask is modeled over the active fuel height of the fuel with reflective boundary conditions on all sides of the model, this represents and infinite array in the x-y direction of DSC/casks that are infinite in length. The DSC/cask model for this evaluation differs from the actual design in the following ways:

- the boron 10 areal density specified for manufacturing the poison plates will be greater than that used in the model, as described in Chapter 8,
- maximum gaps between poison plates are modeled in their worst case configuration,
- the stainless steel basket rails, which hold the basket together, are modeled as water.

The models are fully described in Section 6.3.1. The purpose of these models is to determine the most reactive configuration for intact fuel assemblies. A typical input file is included in Section 6.6.3.

The first series of analyses determined the most reactive fuel assembly-to-assembly pitch. The maximum lattice average fuel enrichment (4.4 wt. % U-235) and a poison plate boron-10 areal density of 0.036 g/cm^2 are used in the model. The results in Table 6-7 show the most reactive configuration occurs with minimum assembly-to-assembly pitch. The model is similar to the model shown in Table 6-4 and Figure 6-2 except that the nominal fuel cell size, nominal poison sheet thickness, fuel clad OD are used and the assemblies are moved within the fuel compartment to vary the assembly-to-assembly pitch.

The second set of analysis evaluates the effect of canister shell thickness on the system reactivity. The model starts with the most reactive assembly-to-assembly pitch (minimum pitch) case above and the canister shell thickness is varied from 0.49 to 0.55 inches. As demonstrated by the results the variation of shell thickness within the tolerance range is statistically insignificant. The nominal shell thickness is used throughout the rest of the analysis except that one additional case is added for the most reactive canister configuration (minimum poison plate thickness and minimum fuel cell size) to demonstrate that the slightly higher result for the maximum shell thickness is indeed a result of the statistics of the calculation.

The third set of analysis evaluates the effect of poison plate thickness on the system reactivity. The model starts with the most reactive assembly-to-assembly pitch (minimum pitch) case above and the poison plate thickness is modeled at 0.3 inches (minimum). The poison plate B-10 areal density is increased to 0.04724 to account for the reduction in plate thickness to maintain the same areal density. Based on the results of this evaluation the balance of the calculations will use the minimum poison plate thickness because it represents a more reactive condition.

The fourth set of analysis evaluates the sensitivity of the system reactivity on fuel cladding OD. The model starts with the minimum poison plate case above and the fuel cladding thickness is varied from 0.404 to 0.394 inches. Based on the results of this analysis, it is conservative to model the GE12 10x10 assembly cladding as 0.010 inches less than that reported in Table 6-7 for the balance of this evaluation.

The fifth set of analysis evaluates the effect of fuel cell size on the system reactivity. The model starts with the most reactive fuel clad OD thickness case above and the canister fuel cell width is varied from 5.8 to 6.1 inches. The results show that the most reactive configuration is with the minimum fuel cell size. One additional run is made to verify that the canister maximum shell thickness does not increase reactivity. The balance of this evaluation will use the minimum cell size because it represents the most reactive configuration.

The second series of analyses determines minimum boron 10 areal density in the poison plate as a function of lattice average initial enrichment is evaluated. These models represent the most reactive intact fuel assembly (GE12, 10x10) with a minimum assembly-to-assembly pitch with full internal and external moderator density. The initial lattice average fuel enrichment is varied as well as the boron-10 density in the poison plates. These cases can be used to specify a minimum boron-10 areal density as a function of maximum lattice average assembly enrichment. The results are reported in Table 6-7.

The sixth set of analyses evaluates the effect of internal moderator density on reactivity. The model starts with the most fuel cell width (minimum fuel cell width) case above. The internal moderator is varied from 100 to 0 percent full density. The results in Table 6-7 confirm that the most reactive condition occurs at full internal moderator density.

The seventh set of analyses evaluates the effect of external moderator density on reactivity. The model uses the most reactive case with internal moderator (full density) density and the external internal moderator is varied from 100 to 0 percent full density. The results in Table 6-7 show that the system reactivity is not affected by external moderator density. The variation in the results is due entirely to the statistical uncertainties in Keno V.a. Nonetheless, the apparent maximum value of k_{eff}, which occurs at 70% external moderator density, is the value reported for the damaged package array.

Finally, minimum boron 10 areal density in the poison plate as a function of lattice average initial enrichment is evaluated. These models represent the most reactive intact fuel assembly (GE12, 10x10) with a minimum assembly-to-assembly pitch, nominal shell thickness, minimum poison plate thickness, minimum fuel clad OD, minimum fuel cell width with full internal and external moderator density. The initial lattice average fuel enrichment is varied as well as the boron-10 density in the poison plates. These cases are used to specify a minimum boron-10 areal density as a function of maximum lattice average assembly enrichment. The results are reported in Table 6-7.

6.4.3 Criticality Results

Table 6-8 lists the results that bound all normal and hypothetical accident conditions. These criticality calculations were performed with CSAS25 of SCALE-4.4. For each case, the result includes (1) the KENO-calculated k_{KENO}; (2) the one sigma uncertainty σ_{KENO}; and (3) the final k_{eff}, which is equal to $k_{KENO} + 2\sigma_{KENO}$ Table 6-8 lists the poison plate boron-10 areal density used in the calculations as a function of the initial lattice average enrichment for the fuel assemblies.

The criterion for subcriticality is that

$$k_{KENO} + 2\sigma_{KENO} < USL,$$

where USL is the upper subcritical limit established by an analysis of benchmark criticality experiments. From Section 6.5, the minimum USL over the parameter range (in this case, pitch) is 0.9414. From Table 6-8 for the most reactive case,

$$k_{KENO} + 2\sigma_{KENO} = 0.9340 + 2\,(0.0012) = 0.9364 < 0.9414.$$

6.5 Critical Benchmark Experiments

The criticality safety analysis of the NUHOMS®-MP197 System used the CSAS25 module of the SCALE system of codes.

The analysis presented herein uses the fresh fuel assumption for criticality analysis. The analysis employed the 44-group ENDF/B-V cross-section library because it has a small

bias, as determined by the 125 benchmark calculations described in reference [6.2]. The upper USL-1 was determined using the results of these 125 benchmark calculations.

The benchmark problems used to perform this verification are representative of benchmark arrays of commercial light water reactor (LWR) fuels with the following characteristics:

(1) water moderation

(2) boron neutron absorbers

(3) unirradiated light water reactor type fuel (no fission products or "burnup credit") near room temperature (vs. reactor operating temperature)

(4) close reflection

(5) Uranium Oxide

The 125 uranium oxide experiments were chosen to model a wide range of uranium enrichments, fuel pin pitches, assembly separation, concentration of soluble boron and control elements in order to test the codes ability to accurately calculate k_{eff}. These experiments are discussed in detail in reference [6.2]. The file-input names referred to in the following sub-sections are identical to those used in [6.2].

6.5.1 Benchmark Experiments and Applicability

A summary of all of the pertinent parameters for each experiment is included in Table 6-9 along with the results of each run. The best correlation is observed for fuel assembly separation distance with a correlation of 0.65. All other parameters show much lower correlation ratios indicating no real correlation. All parameters were evaluated for trends and to determine the most conservative USL.

The USL is calculated in accordance to NUREG/CR-6361 [6.3]. USL Method 1 (USL-1) applies a statistical calculation of the bias and its uncertainty plus an administrative margin (0.05) to the linear fit of results of the experimental benchmark data. The basis for the administrative margin is from reference [6.4]. Results from the USL evaluation are presented in Table 6-10.

The criticality evaluation used the same cross section set, fuel materials and similar material/geometry options that were used in the 125 benchmark calculations as shown in Table 6-9. The modeling techniques and the applicable parameters listed in Table 6-11 for the actual criticality evaluations fall within the range of those addressed by the benchmarks in Table 6-9.

6.5.2 Results of the Benchmark Calculations

The results from the comparisons of physical parameters of each of the fuel assembly types to the applicable USL value are presented in Table 6-11. The minimum value of the USL was determined to be 0.9414 based on comparisons to the limiting assembly parameters as shown in Table 6-11.

APPENDIX 6.6

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6.6 Appendix

6.6.1 References

6.1 Oak Ridge National Laboratory, RSIC Computer Code Collection, "SCALE: A Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluations for Workstations and Personal Computers," NUREG/CR-0200, Revision 6, ORNL/NUREG/CSD-2/V2/R6.

6.2 Transnuclear West Calculation No. SCE-01.0602, "Verification and Validation Document: SCALE 4.4 PC; CSAS25 For Uranium Oxide and Uranium Plutonium Mixed Oxide (MOX) Fuel," Revision 0.

6.3 U.S. Nuclear Regulatory Commission, "Criticality Benchmark Guide for Light-Water-Reactor fuel in Transportation and Storage Packages," NUREG/CR-6361, Published March 1997, ORNL-TM-13211.

6.4 U.S. Nuclear Regulatory Commission, "Standard Review Plan for Dry Cask Storage Systems," NUREG-1536, Published January 1997.

6.6.2 Most Reactive Fuel Analysis

The models used to determine the most reactive fuel are not based on the models used to perform the rest of the analysis. These models are simplified models of the basket and DSC only. Each model represents a different fuel assembly type or condition, such as fuel with fuel channels or variable pin enrichment. Each Unit in the KENO V.a model has a length equal to the active fuel height of the assembly modeled (See Table 6-3) with water boundary conditions on the ends and reflective boundary conditions on the sides.

Figure 6-4 is a graphical depiction of the fuel assembly layout for each assembly type, including a map of the variable enrichment case. A representative input is included below. The example input is for the GE5 fuel type with a variable rod enrichment. The fuel assembly pin by pin layouts for the variable enrichment cases are shown in Figure 6-5.

6.6.3 Example CSAS25 Input Decks

6.6.3.1 Most Reactive Fuel Analysis, GE5 8x8

```
=csas25
```

```
61B Confirmatory Fuel Enrichment Analysis with GE5 8x8,
Jack Boshoven 12/28/00
44groupndf5 latticecell
uo2     1 0.95 293 92235 2.33 92238 97.67 end
zirc2   2 1.0  293 end
h2o     3 1.0  293 end
carbonsteel 4 1.0 293 end
ss304   5 1.0  293 end
h2o     6 1.0  293 end
h2o     7 1.0  293 end
b-10    8 den=0.046 1.0 293 end
al      8 0.9  293 end
uo2     9 0.95 293 92235 3.01 92238 96.99 end
uo2    10 0.95 293 92235 3.57 92238 96.43 end
uo2    11 0.95 293 92235 4.85 92238 95.15 end
end comp
squarepitch 1.6256  1.0414 11 3 1.22682 2 1.06426 6 end
more data res=9  cylinder 0.5207 dan(9)=0.18804820
          res=10 cylinder 0.5207 dan(10)=0.18804820
          res=1  cylinder 0.5207 dan(1)=0.18804820
end more data
Keno Title Card
read param
gen=500 npg=1000 nsk=5 nub=yes run=yes plt=yes
end param
read geom
unit 1     com='Fuel Rod w/2.33 wt%'
cylinder  1   1  0.5207       381.00        0.0
cylinder  6   1  0.53213      381.00        0.0
cylinder  2   1  0.61341      381.00        0.0
cuboid    3   1  4p0.8128     381.00        0.0
unit 2     com='GE 8x8 Center Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62       381.00        0.0
cuboid    5   1  4p7.9629     381.00        0.0
cuboid    8   1  4p8.3566     381.00        0.0
unit 3     com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62       381.00        0.0
cuboid    5   1  4p7.9629     381.00        0.0
cuboid    8   1  7.9629 -8.3566 2p8.3566       381.00
0.0
unit 4     com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62       381.00        0.0
cuboid    5   1  4p7.9629     381.00        0.0
```

```
cuboid    8   1  8.3566 -7.9629 2p8.3566        381.00
0.0
unit 5     com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  4p8.3566      381.00        0.0
unit 6     com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  8.3566 -7.9629 2p8.3566        381.00
0.0
unit 7     com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  7.9629 -8.3566 2p8.3566        381.00
0.0
unit 8     com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  4p8.3566      381.00        0.0
unit 9     com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  2p8.3566        7.9629 -8.3566 381.00
0.0
unit 10    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  7.9629 -8.3566 7.9629 -8.3566 381.00
0.0
unit 11    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  8.3566 -7.9629 7.9629 -8.3566 381.00
0.0
unit 12    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  4p8.3566      381.00        0.0
```

```
unit 13    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62       381.00        0.0
cuboid    5   1  4p7.9629     381.00        0.0
cuboid    8   1  2p8.3566 8.3566 -7.9629       381.00
0.0
unit 14    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62       381.00        0.0
cuboid    5   1  4p7.9629     381.00        0.0
cuboid    8   1  7.9629 -8.3566 8.3566 -7.9629 381.00
0.0
unit 15    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62       381.00        0.0
cuboid    5   1  4p7.9629     381.00        0.0
cuboid    8   1  7.9629 -8.3566 2p8.3566       381.00
0.0
unit 16    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62       381.00        0.0
cuboid    5   1  4p7.9629     381.00        0.0
cuboid    8   1  8.3566 -7.9629 8.3566 -7.9629 381.00
0.0
unit 17    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62       381.00        0.0
cuboid    5   1  4p7.9629     381.00        0.0
cuboid    8   1  8.3566 -7.9629 2p8.3566       381.00
0.0
unit 18    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62       381.00        0.0
cuboid    5   1  4p7.9629     381.00        0.0
cuboid    8   1  8.3566 -7.9629 8.3566 -7.9629 381.00
0.0
unit 19    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62       381.00        0.0
cuboid    5   1  4p7.9629     381.00        0.0
cuboid    8   1  2p8.3566 8.3566 -7.9629       381.00
0.0
unit 20    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62       381.00        0.0
cuboid    5   1  4p7.9629     381.00        0.0
```

```
cuboid    8   1  7.9629 -8.3566 8.3566 -7.9629 381.00
0.0
unit 21    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  8.3566 -7.9629 2p8.3566        381.00
0.0
unit 22    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  4p8.3566      381.00        0.0
unit 23    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  7.9629 -8.3566 2p8.3566        381.00
0.0
unit 24    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  8.3566 -7.9629 7.9629 -8.3566 381.00
0.0
unit 25    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  2p8.3566        7.9629 -8.3566 381.00
0.0
unit 26    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  7.9629 -8.3566 7.9629 -8.3566 381.00
0.0
unit 27    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  8.3566 -7.9629 8.3566 -7.9629 381.00
0.0
unit 28    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
```

```
cuboid    8   1  2p8.3566 8.3566 -7.9629        381.00
0.0
unit 29    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  7.9629 -8.3566 8.3566 -7.9629 381.00
0.0
unit 30    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  8.3566 -7.9629 7.9629 -8.3566 381.00
0.0
unit 31    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  2p8.3566        7.9629 -8.3566 381.00
0.0
unit 32    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  7.9629 -8.3566 7.9629 -8.3566 381.00
0.0
unit 33    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  8.3566 -7.9629 8.3566 -7.9629 381.00
0.0
unit 34    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  2p8.3566 8.3566 -7.9629        381.00
0.0
unit 35    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9629      381.00        0.0
cuboid    8   1  7.9629 -8.3566 8.3566 -7.9629 381.00
0.0
unit 36    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
```

```
cuboid    5   1  4p7.9629      381.00          0.0
cuboid    8   1  8.3566 -7.9629 7.9629 -8.3566 381.00
0.0
unit 37    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00          0.0
cuboid    5   1  4p7.9629      381.00          0.0
cuboid    8   1  2p8.3566        7.9629 -8.3566 381.00
0.0
unit 38    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00          0.0
cuboid    5   1  4p7.9629      381.00          0.0
cuboid    8   1  7.9629 -8.3566 7.9629 -8.3566 381.00
0.0
unit 39    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00          0.0
cuboid    5   1  4p7.9248      381.00          0.0
cuboid    8   1  8.3185 -7.9248 8.3185 -7.9248 381.00
0.0
unit 40    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00          0.0
cuboid    5   1  4p7.9248      381.00          0.0
cuboid    8   1  7.9248 -8.3185 8.3185 -7.9248 381.00
0.0
unit 41    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00          0.0
cuboid    5   1  4p7.9248      381.00          0.0
cuboid    8   1  8.3185 -7.9248 7.9248 -8.3185 381.00
0.0
unit 42    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00          0.0
cuboid    5   1  4p7.9248      381.00          0.0
cuboid    8   1  7.9248 -8.3185 7.9248 -8.3185 381.00
0.0
unit 43    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00          0.0
cuboid    5   1  4p7.9248      381.00          0.0
cuboid    8   1  8.3185 -7.9248 8.3185 -7.9248 381.00
0.0
unit 44    com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
```

```
cuboid    3   1  4p7.62        381.00         0.0
cuboid    5   1  4p7.9248      381.00         0.0
cuboid    8   1  7.9248 -8.3185 8.3185 -7.9248 381.00
0.0
unit 45  com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00         0.0
cuboid    5   1  4p7.9248      381.00         0.0
cuboid    8   1  8.3185 -7.9248 7.9248 -8.3185 381.00
0.0
unit 46  com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00         0.0
cuboid    5   1  4p7.9248      381.00         0.0
cuboid    8   1  7.9248 -8.3185 7.9248 -8.3185 381.00
0.0
unit 47   com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00         0.0
cuboid    5   1  4p7.9248      381.00         0.0
cuboid    8   1  8.3185 -7.9248 8.3185 -7.9248 381.00
0.0
unit 48  com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00         0.0
cuboid    5   1  4p7.9248      381.00         0.0
cuboid    8   1  7.9248 -8.3185 8.3185 -7.9248 381.00
0.0
unit 49  com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00         0.0
cuboid    5   1  4p7.9248      381.00         0.0
cuboid    8   1  8.3185 -7.9248 7.9248 -8.3185 381.00
0.0
unit 50  com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00         0.0
cuboid    5   1  4p7.9248      381.00         0.0
cuboid    8   1  7.9248 -8.3185 7.9248 -8.3185 381.00
0.0
unit 51   com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00         0.0
cuboid    5   1  4p7.9248      381.00         0.0
cuboid    8   1  8.3185 -7.9248 8.3185 -7.9248 381.00
0.0
unit 52  com='GE 8x8 Assembly'
```

```
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9248      381.00        0.0
cuboid    8   1  7.9248 -8.3185 8.3185 -7.9248 381.00
0.0
unit 53  com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9248      381.00        0.0
cuboid    8   1  8.3185 -7.9248 7.9248 -8.3185 381.00
0.0
unit 54  com='GE 8x8 Assembly'
array 1 -6.50240 -6.50240 0.0
cuboid    3   1  4p7.62        381.00        0.0
cuboid    5   1  4p7.9248      381.00        0.0
cuboid    8   1  7.9248 -8.3185 7.9248 -8.3185 381.00
0.0
unit 55  com='center 9x9 array'
array 2 -24.6761 -24.6761 0.0
cuboid    5   1  4p24.9428     381.00        0.0
cuboid    8   1  4p25.7302     381.00        0.0
unit 56  com='right 9x9 array'
array 3 -24.6761 -24.6761 0.0
cuboid    5   1  4p24.9428     381.00        0.0
unit 57  com='top 9x9 array'
array 4 -24.6761 -24.6761 0.0
cuboid    5   1  4p24.9428     381.00        0.0
unit 58  com='left 9x9 array'
array 5 -24.6761 -24.6761 0.0
cuboid    5   1  4p24.9428     381.00        0.0
unit 59  com='bottom 9x9 array'
array 6 -24.6761 -24.6761 0.0
cuboid    5   1  4p24.9428     381.00        0.0
unit 60  com='upper right 2x2 array'
array 7 -16.2433 -16.2433 0.0
cuboid    5   1  4p16.51       381.00        0.0
unit 61  com='upper left 2x2 array'
array 8 -16.2433 -16.2433 0.0
cuboid    5   1  4p16.51       381.00        0.0
unit 62  com='lower right 2x2 array'
array 9 -16.2433 -16.2433 0.0
cuboid    5   1  4p16.51       381.00        0.0
unit 63  com='lower right 2x2 array'
array 10 -16.2433 -16.2433 0.0
cuboid    5   1  4p16.51       381.00        0.0
unit 64  com='0.31" poison plate'
cuboid    8   1  2p16.51 2p0.3937 381.00     0.0
```

```
unit 65  com='0.31" poison plate'
cuboid    8   1  2p0.3937 2p16.51 381.00     0.0
unit 66  com='water hole'
cylinder  3  1  0.67437   381.00    0.0
cylinder  2  1  0.75057   381.00    0.0
cuboid    3  1  4P0.8128  381.00    0.0
unit 67    com='Fuel Rod w/3.01 wt%'
cylinder  9   1  0.5207       381.00        0.0
cylinder  6   1  0.53213      381.00        0.0
cylinder  2   1  0.61341      381.00        0.0
cuboid    3   1  4p0.8128     381.00        0.0
unit 68    com='Fuel Rod w/3.57 wt%'
cylinder 10   1  0.5207       381.00        0.0
cylinder  6   1  0.53213      381.00        0.0
cylinder  2   1  0.61341      381.00        0.0
cuboid    3   1  4p0.8128     381.00        0.0
unit 69    com='Fuel Rod w/4.85 wt%'
cylinder 11   1  0.5207       381.00        0.0
cylinder  6   1  0.53213      381.00        0.0
cylinder  2   1  0.61341      381.00        0.0
cuboid    3   1  4p0.8128     381.00        0.0
global unit 70
cylinder  3   1  84.757       381.00        0.0
    hole 55   0.0       0.0      0.0
    hole 56   50.673    0.0      0.0
    hole 57   0.0       50.673   0.0
    hole 58  -50.673    0.0      0.0
    hole 59   0.0      -50.673   0.0
    hole 60   42.2404   42.2404  0.0
    hole 61  -42.2404   42.2404  0.0
    hole 62  -42.2404  -42.2404  0.0
    hole 63   42.2404  -42.2404  0.0
    hole 64   42.2404   25.3366  0.0
    hole 64  -42.2404   25.3366  0.0
    hole 64  -42.2404  -25.3366  0.0
    hole 64   42.2404  -25.3366  0.0
    hole 65   25.3366   42.2404  0.0
    hole 65  -25.3366   42.2404  0.0
    hole 65  -25.3366  -42.2404  0.0
    hole 65   25.3366  -42.2404  0.0
cylinder  5   1  86.027       381.00        0.0
cuboid    7   1  4p86.03      381.00        0.0
end geom
read array
   com='GE 8x8 fuel assembly slice, sd, fuel regions'
   ara=1      nux=8      nuy=8      nuz=1
   fill
```

```
    67 68 68 68 68 68 67  1
    68 69 69 69 69 69 68 67
    69 69 69 69 69 69 69 68
    69 69 69 66 69 69 69 68
    69 69 69 69 66 69 69 68
    69 69 69 69 69 69 69 68
    69 69 69 69 69 69 69 68
    68 69 69 69 69 69 68 67
end fill
com='Center 9x9 Array of Fuel'
ara=2       nux=3       nuy=3       nuz=1
fill
     18 19 20
      6  2  3
     11  9 10
end fill
com='Right 9x9 Array of Fuel'
ara=3       nux=3       nuy=3       nuz=1
fill
     27 28 29
      4  5  3
     30 31 32
end fill
com='Top 9x9 Array of Fuel'
ara=4       nux=3       nuy=3       nuz=1
fill
     16 13 14
     17 12 15
     11  9 10
end fill
com='Left 9x9 Array of Fuel'
ara=5       nux=3       nuy=3       nuz=1
fill
     33 34 35
      6  8  7
     36 37 38
end fill
com='Bottom 9x9 Array of Fuel'
ara=6       nux=3       nuy=3       nuz=1
fill
     18 19 20
     21 22 23
     24 25 26
end fill
com='Upper Right 2x2 Array of Fuel'
ara=7       nux=2       nuy=2       nuz=1
fill
```

```
        39 40
        41 42
   end fill
   com='Upper Left 2x2 Array of Fuel'
   ara=8      nux=2      nuy=2      nuz=1
   fill
        43 44
        45 46
   end fill
   com='Lower Left 2x2 Array of Fuel'
   ara=9      nux=2      nuy=2      nuz=1
   fill
        47 48
        49 50
   end fill
   com='Lower Right 2x2 Array of Fuel'
   ara=10     nux=2      nuy=2      nuz=1
   fill
        51 52
        53 54
   end fill
end array
read bounds
   xyf=specular
   zfc=water
end bounds
read plot
   ttl='cask material plot  - plan view'
   pic=mat
   nch=' fzmcsblxg'
   xul=-87   yul=87    zul=200
   xlr=87    ylr=-87   zlr=200
   uax=1.0    vdn=-1.0
   nax=650
end plot
end data
end
```

6.6.3.2 Bounding Case, Infinite Array Damaged Package

```
=csas25
```

```
61B w/GE 10x10, including 0.125" gaps, assemblies in
Jack Boshoven 1/6/01
44groupndf5 latticecell
uo2     1 0.95 293 92235 4.4 92238 95.6 end
zirc2   2 1.0  293 end
h2o     3 1.0  293 end
carbonsteel 4 1.0 293 end
ss304   5 1.0  293 end
h2o     6 1.0  293 end
h2o     7 0.7  293 end
b-10    8 den=0.04724 1.0 293 end
al      8 0.9  293 end
pb      9 1.0  293 end
end comp
squarepitch 1.2954 0.87630 1 3 1.00076 2 0.89408 6 end
Assemblies pushed to center; clad OD 0.394"; minimum
fuel cell width
read param
gen=500 npg=1000 nsk=5 nub=yes run=yes plt=no
end param
read geom
unit 1      com='Fuel Rod'
cylinder  1   1  0.43815      0.635          0.0
cylinder  6   1  0.44704      0.635          0.0
cylinder  2   1  0.50038      0.635          0.0
cuboid    3   1  4p0.6477     0.635          0.0
unit 2      com='GE 10x10 center center 3x3 Assembly'
array 1 -6.47700 -6.47700 0.0
cuboid    3   1  4p7.366      0.635          0.0
cuboid    5   1  4p7.6327     0.635          0.0
unit 3      com='GE 10x10 shift left center 3x3 Assembly'
array 1 -7.366   -6.47700 0.0
cuboid    3   1  4p7.366      0.635          0.0
cuboid    5   1  4p7.6327     0.635          0.0
unit 4      com='GE 10x10 shift right center 3x3
Assembly'
array 1 -5.58810 -6.47700 0.0
cuboid    3   1  4p7.366      0.635          0.0
cuboid    5   1  4p7.6327     0.635          0.0
unit 5      com='GE 10x10 shift center down 3x3 Assembly'
array 1 -6.47700 -7.366   0.0
cuboid    3   1  4p7.366      0.635          0.0
cuboid    5   1  4p7.6327     0.635          0.0
unit 6      com='GE 10x10 shift center up 3x3 Assembly'
array 1 -6.47700 -5.58810 0.0
cuboid    3   1  4p7.366      0.635          0.0
cuboid    5   1  4p7.6327     0.635          0.0
```

```
unit 7      com='GE 10x10 shift left down 3x3 Assembly'
array 1 -7.366    -7.366    0.0
cuboid    3    1   4p7.366       0.635          0.0
cuboid    5    1   4p7.6327      0.635          0.0
unit 8      com='GE 10x10 shift right down 3x3 Assembly'
array 1 -5.58810 -7.366    0.0
cuboid    3    1   4p7.366       0.635          0.0
cuboid    5    1   4p7.6327      0.635          0.0
unit 9      com='GE 10x10 shift right up 3x3 Assembly'
array 1 -5.58810 -5.58810 0.0
cuboid    3    1   4p7.366       0.635          0.0
cuboid    5    1   4p7.6327      0.635          0.0
unit 10     com='GE 10x10 shift left up 3x3 Assembly'
array 1 -7.366    -5.58810 0.0
cuboid    3    1   4p7.366       0.635          0.0
cuboid    5    1   4p7.6327      0.635          0.0
unit 11     com='GE 10x10 shift left down 2x2 Assembly'
array 1 -7.366    -7.366    0.0
cuboid    3    1   4p7.366       0.635          0.0
cuboid    5    1   4p7.5946      0.635          0.0
unit 12     com='GE 10x10 shift right down 2x2 Assembly'
array 1 -5.58810 -7.366    0.0
cuboid    3    1   4p7.366       0.635          0.0
cuboid    5    1   4p7.5946      0.635          0.0
unit 13     com='GE 10x10 shift right up 2x2 Assembly'
array 1 -5.58810 -5.58810 0.0
cuboid    3    1   4p7.366       0.635          0.0
cuboid    5    1   4p7.5946      0.635          0.0
unit 14     com='GE 10x10 shift left up 2x2 Assembly'
array 1 -7.366    -5.58810 0.0
cuboid    3    1   4p7.366       0.635          0.0
cuboid    5    1   4p7.5946      0.635          0.0
unit 15     com='horizontal left gap poison 3x3'
cuboid    0    1   0.3175   0.0   2p0.3810   0.635      0.0
cuboid    8    1  15.2654   0.0   2p0.3810   0.635      0.0
unit 16     com='horizontal gap  3x3'
cuboid    0    1  15.2654   0.0   2p0.3810   0.635      0.0
unit 17     com='horizontal left and right gap poison
3x3'
cuboid    0    1   0.15875  0.0   2p0.3810   0.635      0.0
cuboid    8    1  15.09395  0.0   2p0.3810   0.635      0.0
cuboid    0    1  15.2654   0.0   2p0.3810   0.635      0.0
unit 18     com='horizontal right gap poison 3x3'
cuboid    8    1  14.9479   0.0   2p0.3810   0.635      0.0
cuboid    0    1  15.2654   0.0   2p0.3810   0.635      0.0
unit 19     com='horizontal left gap poison 2'
cuboid    0    1   0.3175   0.0   2p0.3810   0.635      0.0
```

```
cuboid    8   1 15.1892  0.0  2p0.3810  0.635     0.0
unit 20   com='horizontal gap  3x3'
cuboid    0   1 15.1892  0.0  2p0.3810  0.635     0.0
unit 21    com='horizontal right gap poison 2x2'
cuboid    8   1 14.8717  0.0  2p0.3810  0.635     0.0
cuboid    0   1 15.1892  0.0  2p0.3810  0.635     0.0
unit 22    com='vertical top gap poison 3x3'
cuboid    8   1 2p0.3810  14.9479  0.0  0.635     0.0
cuboid    0   1 2p0.3810  15.2654  0.0  0.635     0.0
unit 23    com='vertical gap  3x3'
cuboid    0   1 2p0.3810  15.2654  0.0  0.635     0.0
unit 24    com='vertical bottom gap poison 3x3'
cuboid    0   1 2p0.3810   0.3175  0.0  0.635     0.0
cuboid    8   1 2p0.3810  15.2654  0.0  0.635     0.0
unit 25    com='horizontal center gap poison 3x3'
cuboid    0   1 2p0.3175  2p0.3810      0.635     0.0
cuboid    8   1 2p23.6601 2p0.3810      0.635     0.0
unit 26    com='horizontal gap  3x3'
cuboid    0   1 2p23.6601 2p0.3810      0.635     0.0
unit 27    com='vertical center gap poison 3x3'
cuboid    0   1 2p0.3810  2p0.3175      0.635     0.0
cuboid    8   1 2p0.3810  2p23.6601     0.635     0.0
unit 28    com='vertical gap  3x3'
cuboid    0   1 2p0.3810  2p23.6601     0.635     0.0
unit 29    com='vertical bottom gap poison 2x2'
cuboid    0   1 2p0.3810  0.3175   0.0  0.635     0.0
cuboid    8   1 2p0.3810 15.41145  0.0  0.635     0.0
cuboid    0   1 2p0.3810 16.04645  0.0  0.635     0.0
cuboid    8   1 2p0.3810 31.1404   0.0  0.635     0.0
unit 30   com='vertical gap  2x2'
cuboid    0   1 2p0.3810 31.1404   0.0  0.635     0.0
unit 31   com='vertical top gap poison 2x2'
cuboid    8   1 2p0.3810 15.09395  0.0  0.635     0.0
cuboid    0   1 2p0.3810 15.72895  0.0  0.635     0.0
cuboid    8   1 2p0.3810 30.8229   0.0  0.635     0.0
cuboid    0   1 2p0.3810 31.1404   0.0  0.635     0.0
unit 32   com='Upper Right 2x2 w/poison'
array 2   -7.5946 -15.5702 0.0
unit 33   com='Upper Left 2x2 w/poison'
array 3   -7.5946 -15.5702 0.0
unit 34   com='Upper Right 2x2 w/poison'
array 4   -7.5946 -15.5702 0.0
unit 35   com='Uppwe Left 2x2 w/poison'
array 5   -7.5946 -15.5702 0.0
unit 36   com='3x3 with poison'
array 6   -7.6327 -23.6601 0.0
unit 37   com='3x3 with poison'
```

```
array 7    -7.6327 -23.6601 0.0
unit 38    com='3x3 with poison'
array 8    -7.6327 -23.6601 0.0
unit 39    com='3x3 with poison'
array 9    -7.6327 -23.6601 0.0
unit 40    com='3x3 with poison'
array 10   -7.6327 -23.6601 0.0
unit 41    com='Center 3x3 fuel with poison'
array 11 -23.6601 -23.6601 0.0
cuboid     5   1 4p23.8506      0.635          0.0
unit 42    com='Right 3x3 fuel with poison'
array 12 -23.6601 -23.6601 0.0
cuboid     5   1 4p23.8506      0.635          0.0
unit 43    com='Top 3x3 fuel with poison'
array 13 -23.6601 -23.6601 0.0
cuboid     5   1 4p23.8506      0.635          0.0
unit 44    com='Left 3x3 fuel with poison'
array 14 -23.6601 -23.6601 0.0
cuboid     5   1 4p23.8506      0.635          0.0
unit 45    com='Bottom 3x3 fuel with poison'
array 15 -23.6601 -23.6601 0.0
cuboid     5   1 4p23.8506      0.635          0.0
unit 46    com='Upper Right 2x2 fuel with poison'
array 16 -15.5702 -15.5702 0.0
cuboid     5   1 4p15.7607     0.635          0.0
unit 47    com='Upper Left 2x2 fuel with poison'
array 17 -15.5702 -15.5702 0.0
cuboid     5   1 4p15.7607     0.635          0.0
unit 48    com='Lower Left 2x2 fuel with poison'
array 18 -15.5702 -15.5702 0.0
cuboid     5   1 4p15.7607     0.635          0.0
unit 49    com='Lower Right 2x2 fuel with poison'
array 19 -15.5702 -15.5702 0.0
cuboid     5   1 4p15.7607     0.635          0.0
unit 50    com='vertical poison between 3x3 compartments'
cuboid     8   1 2p0.3810  2p23.69185  0.635     0.0
cuboid     0   1 2p0.3810  2p23.8506    0.635     0.0
unit 51    com='vertical poison between 3x3 compartments,
gap'
cuboid     0   1 2p0.3810  2p23.8506    0.635     0.0
unit 52    com='center horizontal strip of 3x3 arrays'
array 20 -72.3138 -23.8506 0.0
unit 53    com='center horizontal strip of poison'
cuboid     8   1 2p56.2102 2p0.3810    0.635     0.0
unit 54    com='center horizontal strip of poison, gap'
cuboid     0   1 2p56.2102 2p0.3810    0.635     0.0
unit 55    com='top vertical strip of poison'
```

```
cuboid     8   1 2p0.3810  15.7607 -15.4432 0.635      0.0
cuboid     0   1 2p0.3810 2p15.7607 0.635      0.0
unit 56    com='top vertical strip of poison gap'
cuboid     0   1 2p0.3810 2p15.7607 0.635      0.0
unit 57    com='top vertical strip of poison'
cuboid     8   1 2p0.3810  15.4432 -15.7607 0.635      0.0
cuboid     0   1 2p0.3810 2p15.7607 0.635      0.0
unit 58    com='poison everywhere'
cylinder  3   1  84.1375       0.635          0.0
    hole 52   0.0       0.0      0.0
    hole 53   0.0      24.2316   0.0
    hole 53   0.0     -24.2316   0.0
    hole 43   0.0      48.4633   0.0
    hole 45   0.0     -48.4633   0.0
    hole 55  24.2316   40.3734   0.0
    hole 55 -24.2316   40.3734   0.0
    hole 57  24.2316  -40.3734   0.0
    hole 57 -24.2316  -40.3734   0.0
    hole 46  40.3734   40.3734   0.0
    hole 47 -40.3734   40.3734   0.0
    hole 48 -40.3734  -40.3734   0.0
    hole 49  40.3734  -40.3734   0.0
cylinder  5   1  85.4075       0.635          0.0
cylinder  3   1  86.36         0.635          0.0
cylinder  5   1  89.535        0.635          0.0
cylinder  9   1  97.79         0.635          0.0
cylinder  5   1 104.14         0.635          0.0
cuboid    7   1 4p104.15       0.635          0.0
unit 59    com='poison inside, gap outside'
cylinder  3   1  84.1375       0.635          0.0
    hole 60   0.0       0.0      0.0
    hole 54   0.0      24.2316   0.0
    hole 54   0.0     -24.2316   0.0
    hole 43   0.0      48.4633   0.0
    hole 45   0.0     -48.4633   0.0
    hole 56  24.2316   40.3734   0.0
    hole 56 -24.2316   40.3734   0.0
    hole 56  24.2316  -40.3734   0.0
    hole 56 -24.2316  -40.3734   0.0
    hole 46  40.3734   40.3734   0.0
    hole 47 -40.3734   40.3734   0.0
    hole 48 -40.3734  -40.3734   0.0
    hole 49  40.3734  -40.3734   0.0
cylinder  5   1  85.4075       0.635          0.0
cylinder  3   1  86.36         0.635          0.0
cylinder  5   1  89.535        0.635          0.0
cylinder  9   1  97.79         0.635          0.0
```

```
cylinder  5   1 104.14        0.635         0.0
cuboid    7   1 4p104.15      0.635         0.0
unit 60   com='center horizontal strip of 3x3 arrays
with gap'
array 22 -72.3138 -23.8506 0.0
unit 61   com='Upper Right 2x2 w/o poison'
array 23  -7.5946 -15.5702 0.0
unit 62   com='Upper Left 2x2 w/o poison'
array 24  -7.5946 -15.5702 0.0
unit 63   com='Upper Right 2x2 w/o poison'
array 25  -7.5946 -15.5702 0.0
unit 64   com='Uppwe Left 2x2 w/o poison'
array 26  -7.5946 -15.5702 0.0
unit 65   com='3x3 with out poison'
array 27  -7.6327 -23.6601 0.0
unit 66   com='3x3 with out poison'
array 28  -7.6327 -23.6601 0.0
unit 67   com='3x3 with out poison'
array 29  -7.6327 -23.6601 0.0
unit 68   com='3x3 with out poison'
array 30  -7.6327 -23.6601 0.0
unit 69   com='3x3 with out poison'
array 31  -7.6327 -23.6601 0.0
unit 70   com='Center 3x3 fuel with out poison'
array 32 -23.6601 -23.6601 0.0
cuboid    5   1 4p23.8506      0.635         0.0
unit 71   com='Right 3x3 fuel with out poison'
array 33 -23.6601 -23.6601 0.0
cuboid    5   1 4p23.8506      0.635         0.0
unit 72   com='Top 3x3 fuel with out poison'
array 34 -23.6601 -23.6601 0.0
cuboid    5   1 4p23.8506      0.635         0.0
unit 73   com='Left 3x3 fuel with out poison'
array 35 -23.6601 -23.6601 0.0
cuboid    5   1 4p23.8506      0.635         0.0
unit 74   com='Bottom 3x3 fuel with out poison'
array 36 -23.6601 -23.6601 0.0
cuboid    5   1 4p23.8506      0.635         0.0
unit 75   com='Upper Right 2x2 fuel with out poison'
array 37 -15.5702 -15.5702 0.0
cuboid    5   1 4p15.7607     0.635         0.0
unit 76   com='Upper Left 2x2 fuel with out poison'
array 38 -15.5702 -15.5702 0.0
cuboid    5   1 4p15.7607     0.635         0.0
unit 77   com='Lower Left 2x2 fuel with out poison'
array 39 -15.5702 -15.5702 0.0
cuboid    5   1 4p15.7607     0.635         0.0
```

```
unit 78   com='Lower Right 2x2 fuel with out poison'
array 40 -15.5702 -15.5702 0.0
cuboid    5   1 4p15.7607     0.635          0.0
unit 79   com='gap inside, gap outside'
cylinder  3   1  84.1375      0.635          0.0
    hole 80   0.0       0.0      0.0
    hole 54   0.0      24.2316   0.0
    hole 54   0.0     -24.2316   0.0
    hole 72   0.0      48.4633   0.0
    hole 74   0.0     -48.4633   0.0
    hole 56  24.2316   40.3734   0.0
    hole 56 -24.2316   40.3734   0.0
    hole 56  24.2316  -40.3734   0.0
    hole 56 -24.2316  -40.3734   0.0
    hole 75  40.3734   40.3734   0.0
    hole 76 -40.3734   40.3734   0.0
    hole 77 -40.3734  -40.3734   0.0
    hole 78  40.3734  -40.3734   0.0
cylinder  5   1  85.4075      0.635          0.0
cylinder  3   1  86.36        0.635          0.0
cylinder  5   1  89.535       0.635          0.0
cylinder  9   1  97.79        0.635          0.0
cylinder  5   1 104.14        0.635          0.0
cuboid    7   1 4p104.15      0.635          0.0
unit 80   com='center horizontal strip of 3x3 arrays
with all gaps'
array 41 -72.3138 -23.8506 0.0
unit 81  com='water hole'
cuboid    3  1  4P0.6477      0.635          0.0
global unit 82
array 21 -85.41   -85.41  0.0
end geom
read array
   com='GE 10x10 fuel assembly slice, sd, fuel regions'
   ara=1      nux=10     nuy=10     nuz=1
   fill
        1  1  1  1  1  1  1  1  1  1
        1  1  1  1  1  1  1  1  1  1
        1  1  1  1  1  1  1  1  1  1
        1  1  1 81 81  1  1  1  1  1
        1  1  1 81 81  1  1  1  1  1
        1  1  1  1  1 81 81  1  1  1
        1  1  1  1  1 81 81  1  1  1
        1  1  1  1  1  1  1  1  1  1
        1  1  1  1  1  1  1  1  1  1
        1  1  1  1  1  1  1  1  1  1
   end fill
```

```
com='Upper Right 2x2 Array of Fuel w/poison'
ara=2       nux=1       nuy=3       nuz=1
fill
     11
     19
     11
end fill
com='Upper Left 2x2 Array of Fuel w/poison'
ara=3       nux=1       nuy=3       nuz=1
fill
     12
     21
     12
end fill
com='Lower Left 2x2 Array of Fuel w/poison'
ara=4       nux=1       nuy=3       nuz=1
fill
     13
     21
     13
end fill
com='Lower Left 2x2 Array of Fuel w/poison'
ara=5       nux=1       nuy=3       nuz=1
fill
     14
     19
     14
end fill
com='3x3 Array of Fuel w/poison'
ara=6       nux=1       nuy=5       nuz=1
fill
      9
     18
      4
     18
      8
end fill
com='3x3 Array of Fuel w/poison'
ara=7       nux=1       nuy=5       nuz=1
fill
      6
     17
      2
     17
      5
end fill
com='3x3 Array of Fuel w/poison'
```

```
ara=8       nux=1       nuy=5       nuz=1
fill
     10
     15
      3
     15
      7
end fill
com='3x3 Array of Fuel w/poison'
ara=9       nux=5       nuy=1       nuz=1
fill
      9  22   6  22  10
end fill
com='3x3 Array of Fuel w/poison'
ara=10      nux=5       nuy=1       nuz=1
fill
      8  24   5  24   7
end fill
com='Center 3x3 Array of Fuel w/poison'
ara=11      nux=5       nuy=1       nuz=1
fill
     36  27  37  27  38
end fill
com='Right 3x3 Array of Fuel w/poison'
ara=12      nux=5       nuy=1       nuz=1
fill
     38  27  38  27  38
end fill
com='Top 3x3 Array of Fuel w/poison'
ara=13      nux=1       nuy=5       nuz=1
fill
     40
     25
     40
     25
     40
end fill
com='Left 3x3 Array of Fuel w/poison'
ara=14      nux=5       nuy=1       nuz=1
fill
     36  27  36  27  36
end fill
com='Bottom 3x3 Array of Fuel w/poison'
ara=15      nux=1       nuy=5       nuz=1
fill
     39
     25
```

```
        39
        25
        39
    end fill
    com='Upper Right 2x2 Array of Fuel w/poison'
    ara=16      nux=3       nuy=1       nuz=1
    fill
        32  29  32
    end fill
    com='Upper Left 2x2 Array of Fuel w/poison'
    ara=17      nux=3       nuy=1       nuz=1
    fill
        33  29  33
    end fill
    com='Lower Left 2x2 Array of Fuel w/poison'
    ara=18      nux=3       nuy=1       nuz=1
    fill
        34  31  34
    end fill
    com='Lower Right 2x2 Array of Fuel w/poison'
    ara=19      nux=3       nuy=1       nuz=1
    fill
        35  31  35
    end fill
    com='Center row of 3x3 arrays of Fuel w/poison'
    ara=20     nux=5       nuy=1       nuz=1
    fill
        44  50  41  50  42
    end fill
    com='Axail Cask'
    ara=21     nux=1       nuy=1       nuz=576
    fill
        58 58 58 58 58 58 58 58 58 58 58 58 58 58 58 58
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        59
   end fill
   com='Center row of 3x3 arrays of Fuel w/poison'
   ara=22    nux=5      nuy=1      nuz=1
   fill
        44  51  41  51  42
   end fill
   com='Upper Right 2x2 Array of Fuel w/o poison'
   ara=23     nux=1      nuy=3      nuz=1
   fill
        11
        20
        11
   end fill
   com='Upper Left 2x2 Array of Fuel w/o poison'
   ara=24     nux=1      nuy=3      nuz=1
   fill
        12
        20
        12
   end fill
   com='Lower Left 2x2 Array of Fuel w/o poison'
   ara=25     nux=1      nuy=3      nuz=1
   fill
        13
        20
        13
   end fill
   com='Lower Left 2x2 Array of Fuel w/o poison'
   ara=26     nux=1      nuy=3      nuz=1
   fill
        14
        20
        14
   end fill
   com='3x3 Array of Fuel w/o poison'
   ara=27     nux=1      nuy=5      nuz=1
   fill
         9
        16
```

```
      4
     16
      8
end fill
com='3x3 Array of Fuel w/o poison'
ara=28      nux=1       nuy=5       nuz=1
fill
      6
     16
      2
     16
      5
end fill
com='3x3 Array of Fuel w/o poison'
ara=29      nux=1       nuy=5       nuz=1
fill
     10
     16
      3
     16
      7
end fill
com='3x3 Array of Fuel w/o poison'
ara=30      nux=5       nuy=1       nuz=1
fill
      9  23   6  23  10
end fill
com='3x3 Array of Fuel w/o poison'
ara=31      nux=5       nuy=1       nuz=1
fill
      8  23   5  23   7
end fill
com='Center 3x3 Array of Fuel w/o poison'
ara=32      nux=5       nuy=1       nuz=1
fill
     65  28  66  28  67
end fill
com='Right 3x3 Array of Fuel w/o poison'
ara=33      nux=5       nuy=1       nuz=1
fill
     67  28  67  28  67
end fill
com='Top 3x3 Array of Fuel w/o poison'
ara=34      nux=1       nuy=5       nuz=1
fill
     69
     26
```

```
        69
        26
        69
    end fill
    com='Left 3x3 Array of Fuel w/o poison'
    ara=35     nux=5      nuy=1      nuz=1
    fill
        65  28  65  28  65
    end fill
    com='Bottom 3x3 Array of Fuel w/o poison'
    ara=36     nux=1      nuy=5      nuz=1
    fill
        68
        26
        68
        26
        68
    end fill
    com='Upper Right 2x2 Array of Fuel w/o poison'
    ara=37     nux=3      nuy=1      nuz=1
    fill
        61  30  61
    end fill
    com='Upper Left 2x2 Array of Fuel w/o poison'
    ara=38     nux=3      nuy=1      nuz=1
    fill
        62  30  62
    end fill
    com='Lower Left 2x2 Array of Fuel w/o poison'
    ara=39     nux=3      nuy=1      nuz=1
    fill
        63  30  63
    end fill
    com='Lower Right 2x2 Array of Fuel w/o poison'
    ara=40     nux=3      nuy=1      nuz=1
    fill
        64  30  64
    end fill
    com='Center row of 3x3 arrays of Fuel w/o poison'
    ara=41    nux=5      nuy=1      nuz=1
    fill
        73  51  70  51  71
    end fill
end array
read bounds
    xyf=specular
    zfc=specular
```

```
end bounds
read plot
   ttl='cask material plot  - plan view all poison'
   pic=mat
   nch=' fzmcsblxg'
   xul=-105  yul=105   zul=20
   xlr=105   ylr=-105  zlr=20
   uax=1.0    vdn=-1.0
   nax=650
end plot
end data
end
```

Table 6-1
Minimum B-10 Content in the Neutron Poison Plates

NUHOMS®-61BT DSC Type	Maximum Lattice Averaged Enrichment (wt % U235)	B10 Areal Density in Calculations (mg B10/cm^2)
A	3.7	19
B	4.1	29
C	4.4	36

Table 6-2
Authorized Contents for MP-197 Packaging

Assembly Type[1]	Array
General Electric 7x7 /GE2	7x7
General Electric 7x7 /GE3	7x7
General Electric 8x8 /GE4	8x8
General Electric 8x8 /GE5	8x8
General Electric 8x8 /GE-Pres	8x8
General Electric 8x8 /GE-Barrier	8x8
General Electric 8x8 /GE8 Type I	8x8
General Electric 8x8 /GE8 Type II	8x8
General Electric 8x8 /GE9	8x8
General Electric 8x8 /GE10	8x8
General Electric 9x9 /GE11	9x9
General Electric 9x9 /GE13	9x9
General Electric 10x10/GE12	10x10

(1) Reload fuel from other manufactures with the same parameters as those listed in Table 6-3 are also considered as authorized contents.

Table 6-3
Parameters for BWR Assemblies

Manufacturer[1]	Array	Version	Active Fuel Length (in)	Number Fuel Rods per Assembly	Pitch (in)	Fuel Pellet OD (in)
GE	7x7	GE2	144	49	0.738	0.487
GE	7x7	GE3	144	49	0.738	0.487
GE	8x8	GE4	146	63	0.640	0.416
GE	8x8	GE5	150	62	0.640	0.410
GE	8x8	GE-Pres	150	62	0.640	0.410
GE	8x8	GE-Barrier	150	62	0.640	0.410
GE	8x8	GE8 Type I	150	62	0.640	0.410
GE	8x8	GE8 Type II	150	60	0.640	0.410
GE	8x8	GE9	150	60	0.640	0.411
GE	8x8	GE10	150	60	0.640	0.411
GE	9x9	GE11	146-Full 90-Partial	66-Full 8-Partial	0.566	0.376
GE	9x9	GE13	146-Full 90-Partial	66-Full 8-Partial	0.566	0.376
GE	10x10	GE12	150-Full 93-Partial	78-Full 14-Partial	0.510	0.345

Manufacturer [1]	Array	Version	Clad Thickness (in)	Clad OD (in)	Water Rod OD (in)	Water Rod ID (in)
GE	7x7	GE2	0.032	0.563	NA	NA
GE	7x7	GE3	0.032	0.563	NA	NA
GE	8x8	GE4	0.034	0.493	0.591	0.531
GE	8x8	GE5	0.032	0.483	0.591	0.531
GE	8x8	GE-Pres	0.032	0.483	0.591	0.531
GE	8x8	GE-Barrier	0.032	0.483	0.591	0.531
GE	8x8	GE8 Type I	0.032	0.483	0.591	0.531
GE	8x8	GE8 Type II	0.032	0.483	2@0.591 2@0.483	2@0.531 2@0.419
GE	8x8	GE9	0.032	0.483	1.34	1.26
GE	8x8	GE10	0.032	0.483	1.34	1.26
GE	9x9	GE11	0.028	0.440	0.98	0.92
GE	9x9	GE13	0.028	0.440	0.98	0.92
GE	10x10	GE12	0.026	0.404	0.98	0.92

(1) Reload fuel from other manufacturers with these parameters are also acceptable

Table 6-4
Axial Layout of the KENO V.a Model of MP-197

Number of Times Unit is Repeated	Unit Number	Description (Reflective Boundary Conditions on All Sides)
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
3	79	0.75 inches of Fuel w/out poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
1	59	0.25 inches of Fuel w/poison in the compartments but no poison between the compartments
40	58	10 Inches of Fuel w/ poison in the compartments and between the compartments
365.76	Total Length of Model, cm	
144	Total Length of Model, cm	

Table 6-5
Material Property Data

Material	Density g/cm^3	Element	Weight %	Atom Density (atoms/b-cm)
UO_2 (Enrichment - 4.4 wt%)	10.41	U-235	3.88	1.0347E-03
		U-238	84.26	2.2197E-02
		O	11.86	4.6464E-02
UO_2 (Enrichment - 4.1 wt%)	10.41	U-235	3.61	9.6415E-04
		U-238	84.53	2.2267E-02
		O	11.86	4.6462E-02
UO_2 (Enrichment - 3.7 wt%)	10.41	U-235	3.26	8.7010E-04
		U-238	84.88	2.2360E-02
		O	11.86	4.6460E-02
Zircaloy-2	6.56	Zr	98.250	4.2550E-02
		Sn	1.450	4.8254E-04
		Fe	0.135	9.5501E-05
		Cr	0.100	7.5978E-05
		Ni	0.055	3.7023E-05
		Hf	0.010	2.2133E-06
Water	0.9982	H	11.1	6.6769E-02
		O	88.9	3.3385E-02
Carbon Steel	7.8212	Fe	99	8.3498E-02
		C	1	3.9250E-03
Stainless Steel (SS304)	7.94	C	0.080	3.1877E-04
		Si	1.000	1.7025E-03
		P	0.045	6.9468E-05
		Cr	19.000	1.7473E-02
		Mn	2.000	1.7407E-03
		Fe	68.375	5.8545E-02
		Ni	9.500	7.7402E-03
Lead	11.344	Pb	100	3.2969E-02
Aluminum - Boron Poison Plate (0.036 g/cm^2 B-10)	2.479	B-10	1.906	2.8412E-03
		Al	98.094	5.4276E-02
Aluminum - Boron Poison Plate (0.029 g/cm^2 B-10)	2.470	B-10	1.531	2.2734E-03
		Al	98.469	5.4276E-02
Aluminum - Boron Poison Plate (0.019 g/cm^2 B-10)	2.457	B-10	1.010	1.4916E-03
		Al	98.990	5.4276E-02

Table 6-6
Most Reactive Fuel Type

Manufacturer	Array	Version	k_{KENO}	1σ	k_{eff}
GE	7x7	GE2, GE3	0.9037	0.0012	0.9061
GE	7x7 0.120 channel	GE2, GE3	0.9033	0.0015	0.9063
GE	7x7 0.080 channel	GE2, GE3	0.9028	0.0012	0.9052
GE	7x7 0.065 channel	GE2, GE3	0.9043	0.0013	0.9069
GE	8x8	GE4	0.8951	0.0013	0.8977
GE	8x8 0.120 channel	GE4	0.8927	0.0013	0.8953
GE	8x8 0.080 channel	GE4	0.8930	0.0013	0.8956
GE	8x8 0.065 channel	GE4	0.8940	0.0012	0.8964
GE	8x8	GE5	0.9009	0.0011	0.9031
		GE-Pres			
		GE-Barrier			
		GE8 Type I			
		GE8 Type II			
GE	8x8 0.120 channel	GE5	0.9015	0.0012	0.9039
GE	8x8 0.080 channel	GE5	0.9027	0.0013	0.9053
GE	8x8 0.065 channel	GE5	0.9012	0.0011	0.9034
GE	8x8	GE8 Type II	0.9020	0.0012	0.9044
GE	8x8 0.120 channel	GE8 Type II	0.9054	0.0014	0.9082
GE	8x8 0.080 channel	GE8 Type II	0.9043	0.0014	0.9071
GE	8x8 0.065 channel	GE8 Type II	0.9023	0.0013	0.9049
GE	8x8	GE9, GE10	0.9043	0.0013	0.9069
GE	8x8 0.120 channel	GE9, GE10	0.9062	0.0013	0.9088
GE	8x8 0.080 channel	GE9, GE10	0.9054	0.0011	0.9076
GE	8x8 0.065 channel	GE9, GE10	0.9052	0.0014	0.9080
GE	9x9	GE11, GE13	0.9042	0.0014	0.9070
GE	9x9 0.120 channel	GE11, GE13	0.9025	0.0014	0.9053
GE	9x9 0.080 channel	GE11, GE13	0.9066	0.0012	0.9090
GE	9x9 0.065 channel	GE11, GE13	0.9040	0.0013	0.9066
GE	10x10	GE12	0.9095	0.0013	0.9121
GE	10x10 0.120 channel	GE12	0.9094	0.0010	0.9114
GE	10x10 0.080 channel	GE12	0.9092	0.0013	0.9118
GE	10x10 0.065 channel	GE12	0.9076	0.0011	0.9098
GE	7x7 w/variable enrichment	GE2, GE3	0.8947	0.0012	0.8971
GE	8x8 w/variable enrichment	GE5	0.8951	0.0011	0.8973
GE	8x8 w/variable enrichment	GE9	0.9008	0.0013	0.9034

Table 6-7
Most Reactive Configuration

Model Description	k_{KENO}	1σ	k_{eff}
Assembly-to-Assembly Pitch Evaluation			
Maximum Assembly-to-Assembly Pitch	0.8710	0.0013	0.8736
Assemblies Centered in Sleeves	0.9110	0.0012	0.9134
Minimum Assembly-to-Assembly Pitch	0.9110	0.0014	0.9138
Canister Shell Variation Evaluation			
Minimum Shell Thickness	0.9125	0.0012	0.9149
Nominal Shell Thickness	0.9110	0.0014	0.9138
Maximum Shell Thickness	0.9141	0.0011	0.9163
Poison Thickness Evaluation			
Nominal PoisonThickness (0.31 inches)	0.9110	0.0014	0.9138
Minimum Poison Thickness (0.3 inches)	0.9163	0.0012	0.9187
Fuel Cladding O.D. Evaluation			
Fuel Clad OD = 0.404 inches	0.9163	0.0012	0.9187
Fuel Clad OD = 0.402 inches	0.9157	0.0010	0.9177
Fuel Cald OD = 0.400 inches	0.9183	0.0011	0.9205
Fuel Clad OD = 0.398 inches	0.9201	0.0013	0.9227
Fuel Clad OD = 0.396 inches	0.9222	0.0012	0.9246
Fuel Clad OD = 0.394 inches	0.9229	0.0012	0.9253
Fuel Cell Width Evaluation			
Maximum Fuel Cell Width	0.9194	0.0011	0.9216
Nominal Fuel Cell Width	0.9229	0.0012	0.9253
Minimum Fuel Cell Width	0.9349	0.0011	0.9371
Minimum Fuel Cell Width with Maximum Shell Thickness	0.9326	0.0014	0.9354
Internal Moderator Density Evaluation			
Internal Moderator at 100% TD	0.9349	0.0011	0.9371
Internal Moderator at 90% TD	0.9079	0.0013	0.9105
Internal Moderator at 80% TD	0.8772	0.0013	0.8798
Internal Moderator at 70% TD	0.8401	0.0012	0.8425
Internal Moderator at 60% TD	0.7980	0.0010	0.8000
Internal Moderator at 50% TD	0.7466	0.0010	0.7486
Internal Moderator at 40% TD	0.6862	0.0010	0.6882
Internal Moderator at 30% TD	0.6236	0.0008	0.6252
Internal Moderator at 20% TD	0.5628	0.0010	0.5648
Internal Moderator at 10% TD	0.5078	0.0006	0.5090
Internal Moderator at 0% TD	0.4364	0.0004	0.4372
External Moderator Density Evaluation			
External Moderator at 100% TD	0.9349	0.0011	0.9371
External Moderator at 90% TD	0.9340	0.0011	0.9362
External Moderator at 80% TD	0.9324	0.0012	0.9348
External Moderator at 70% TD	0.9365	0.0011	0.9387
External Moderator at 60% TD	0.9363	0.0011	0.9385
External Moderator at 50% TD	0.9336	0.0011	0.9358
External Moderator at 40% TD	0.9345	0.0011	0.9367
External Moderator at 30% TD	0.9332	0.0013	0.9358
External Moderator at 20% TD	0.9332	0.0012	0.9356
External Moderator at 10% TD	0.9321	0.0013	0.9347
External Moderator at 0% TD	0.9321	0.0012	0.9345
Minimum Boron-10 Loading as a Function of Maximum Lattice Average Enrichment			
4.4 wt% U-235; 0.040 g/cm^2 B-10	0.9349	0.0011	0.9371
4.1 wt% U-235; 0.032 g/cm^2 B-10	0.9336	0.0011	0.9358
3.7 wt% U-235; 0.021 g/cm^2 B-10	0.9343	0.0013	0.9369

Table 6-8
Criticality Results

Model Description	k_{KENO}	1σ	k_{eff}
Infinite array of damaged packages per 10CFR Part 71.59 (a) (2) 4.4 wt% U-235; 0.040 g/cm^2 B-10 100% internal, 70% external water density	0.9365	0.0011	0.9387
Minimum Boron-10 Loading as a Function of Maximum Lattice Average Enrichment (same model as above, but external water at 100% density)			
4.4 wt% U-235; 0.040 g/cm^2 B-10	0.9349	0.0011	0.9371
4.1 wt% U-235; 0.032 g/cm^2 B-10	0.9336	0.0011	0.9358
3.7 wt% U-235; 0.021 g/cm^2 B-10	0.9343	0.0013	0.9369

Table 6-9
Benchmarking Results

Run ID	U Enrich. Wt%	Pu Enrich. Wt%	Pitch (cm)	H_2O/fuel volume	Separation of assemblies (cm)	AEG	k_{eff}	1σ
B1645SO1	2.46		1.41	1.015		32.8194	0.9967	0.0009
B1645SO2	2.46		1.41	1.015		32.7584	1.0002	0.0011
BW1231B1	4.02		1.511	1.139		31.1427	0.9966	0.0012
BW1231B2	4.02		1.511	1.139		29.8854	0.9972	0.0009
BW1273M	2.46		1.511	1.376		32.2106	0.9965	0.0009
BW1484A1	2.46		1.636	1.841	1.636	34.5304	0.9962	0.0010
BW1484A2	2.46		1.636	1.841	4.908	35.1629	0.9931	0.0010
BW1484B1	2.46		1.636	1.841		33.9421	0.9979	0.0010
BW1484B2	2.46		1.636	1.841	1.636	34.5820	0.9955	0.0012
BW1484B3	2.46		1.636	1.841	4.908	35.2609	0.9969	0.0011
BW1484C1	2.46		1.636	1.841	1.636	34.6463	0.9931	0.0011
BW1484C2	2.46		1.636	1.841	4.908	35.2422	0.9939	0.0012
BW1484S1	2.46		1.636	1.841	1.636	34.5105	1.0001	0.0010
BW1484S2	2.46		1.636	1.841	1.636	34.5569	0.9992	0.0010
BW1484SL	2.46		1.636	1.841	6.544	35.4151	0.9935	0.0011
BW1645S1	2.46		1.209	0.383	1.778	30.1040	0.9990	0.0010
BW1645S2	2.46		1.209	0.383	1.778	29.9961	1.0037	0.0011
BW1810A	2.46		1.636	1.841		33.9465	0.9984	0.0008
BW1810B	2.46		1.636	1.841		33.9631	0.9984	0.0009
BW1810C	2.46		1.636	1.841		33.1569	0.9992	0.0010
BW1810D	2.46		1.636	1.841		33.0821	0.9985	0.0013
BW1810E	2.46		1.636	1.841		33.1600	0.9988	0.0009
BW1810F	2.46		1.636	1.841		33.9556	1.0031	0.0011
BW1810G	2.46		1.636	1.841		32.9409	0.9973	0.0011
BW1810H	2.46		1.636	1.841		32.9420	0.9972	0.0011
BW1810I	2.46		1.636	1.841		33.9655	1.0037	0.0009
BW1810J	2.46		1.636	1.841		33.1403	0.9983	0.0011
DSN399-1	4.74		1.6	3.807	1.8	33.9520	1.0036	0.0015
DSN399-2	4.74		1.6	3.807	5.8	34.4207	0.9989	0.0016
DSN399-3	4.74		1.6	3.807		35.3140	1.0024	0.0015
DSN399-4	4.74		1.6	3.807		35.3784	0.9977	0.0013
EPRU65	2.35		1.562	1.196		33.9106	0.9960	0.0011
EPRU65B	2.35		1.562	1.196		33.4013	0.9993	0.0012
EPRU75	2.35		1.905	2.408		35.8671	0.9958	0.0010
EPRU75B	2.35		1.905	2.408		35.3043	0.9996	0.0010
EPRU87	2.35		2.21	3.687		36.6129	1.0007	0.0011
EPRU87B	2.35		2.21	3.687		36.3499	1.0007	0.0011
NSE71SQ	4.74		1.26	1.823		33.7610	0.9979	0.0012
NSE71W1	4.74		1.26	1.823		34.0129	0.9988	0.0013
NSE71W2	4.74		1.26	1.823		36.3037	0.9957	0.0010
P2438BA	2.35		2.032	2.918	5.05	36.2277	0.9979	0.0013
P2438SLG	2.35		2.032	2.918	8.39	36.2889	0.9986	0.0012
P2438SS	2.35		2.032	2.918	6.88	36.2705	0.9974	0.0011
P2438ZR	2.35		2.032	2.918	8.79	36.2840	0.9987	0.0010
P2615BA	4.31		2.54	3.883	6.72	35.7286	1.0019	0.0014
P2615SS	4.31		2.54	3.883	8.58	35.7495	0.9952	0.0015
P2615ZR	4.31		2.54	3.883	10.92	35.7700	0.9977	0.0014
P2827L1	2.35		2.032	2.918	13.27	36.2526	1.0057	0.0011
P2827L2	2.35		2.032	2.918	11.25	36.2908	0.9999	0.0012

Table 6-9
Benchmarking Results, continued

Run ID	U Enrich. Wt%	Pu Enrich. Wt%	Pitch (cm)	H_2O/fuel volume	Separation of assemblies (cm)	AEG	k_{eff}	1σ
P2827L3	4.31		2.54	3.883	20.78	35.6766	1.0092	0.0012
P2827L4	4.31		2.54	3.883	19.04	35.7131	1.0073	0.0012
P2827SLG	2.35		2.032	2.918	8.31	36.3037	0.9957	0.0010
P3314BA	4.31		1.892	1.6	2.83	33.1881	0.9988	0.0012
P3314BC	4.31		1.892	1.6	2.83	33.2284	0.9992	0.0012
P3314BF1	4.31		1.892	1.6	2.83	33.2505	1.0037	0.0013
P3314BF2	4.31		1.892	1.6	2.83	33.2184	1.0009	0.0013
P3314BS1	2.35		1.684	1.6	3.86	34.8594	0.9956	0.0013
P3314BS2	2.35		1.684	1.6	3.46	34.8356	0.9949	0.0010
P3314BS3	4.31		1.892	1.6	7.23	33.4247	0.9970	0.0013
P3314BS4	4.31		1.892	1.6	6.63	33.4162	0.9998	0.0012
P3314SLG	4.31		1.892	1.6	2.83	34.0198	0.9974	0.0012
P3314SS1	4.31		1.892	1.6	2.83	33.9601	0.9999	0.0012
P3314SS2	4.31		1.892	1.6	2.83	33.7755	1.0022	0.0012
P3314SS3	4.31		1.892	1.6	2.83	33.8904	0.9992	0.0013
P3314SS4	4.31		1.892	1.6	2.83	33.7625	0.9958	0.0011
P3314SS5	2.35		1.684	1.6	7.8	34.9531	0.9949	0.0013
P3314SS6	4.31		1.892	1.6	10.52	33.5333	1.0020	0.0011
P3314W1	4.31		1.892	1.6		34.3994	1.0024	0.0013
P3314W2	2.35		1.684	1.6		35.2167	0.9969	0.0011
P3314ZR	4.31		1.892	1.6	2.83	33.9954	0.9971	0.0013
P3602BB	4.31		1.892	1.6	8.3	33.3221	1.0029	0.0013
P3602BS1	2.35		1.684	1.6	4.8	34.7750	1.0027	0.0012
P3602BS2	4.31		1.892	1.6	9.83	33.3679	1.0039	0.0012
P3602N11	2.35		1.684	1.6	8.98	34.7438	1.0023	0.0012
P3602N12	2.35		1.684	1.6	9.58	34.8391	1.0030	0.0012
P3602N13	2.35		1.684	1.6	9.66	34.9337	1.0013	0.0012
P3602N14	2.35		1.684	1.6	8.54	35.0282	0.9974	0.0013
P3602N21	2.35		2.032	2.918	11.2	36.2821	0.9987	0.0011
P3602N22	2.35		2.032	2.918	10.36	36.1896	1.0025	0.0011
P3602N31	4.31		1.892	1.6	14.87	33.2094	1.0057	0.0013
P3602N32	4.31		1.892	1.6	15.74	33.3067	1.0093	0.0012
P3602N33	4.31		1.892	1.6	15.87	33.4174	1.0107	0.0012
P3602N34	4.31		1.892	1.6	15.84	33.4683	1.0045	0.0013
P3602N35	4.31		1.892	1.6	15.45	33.5185	1.0013	0.0012
P3602N36	4.31		1.892	1.6	13.82	33.5855	1.0004	0.0014
P3602N41	4.31		2.54	3.883	12.89	35.5276	1.0109	0.0013
P3602N42	4.31		2.54	3.883	14.12	35.6695	1.0071	0.0014
P3602N43	4.31		2.54	3.883	12.44	35.7542	1.0053	0.0015
P3602SS1	2.35		1.684	1.6	8.28	34.8701	1.0025	0.0013
P3602SS2	4.31		1.892	1.6	13.75	33.4202	1.0035	0.0012
P3926L1	2.35		1.684	1.6	10.06	34.8519	1.0000	0.0011
P3926L2	2.35		1.684	1.6	10.11	34.9324	1.0017	0.0011
P3926L3	2.35		1.684	1.6	8.5	35.0641	0.9949	0.0012
P3926L4	4.31		1.892	1.6	17.74	33.3243	1.0074	0.0014
P3926L5	4.31		1.892	1.6	18.18	33.4074	1.0057	0.0013
P3926L6	4.31		1.892	1.6	17.43	33.5246	1.0046	0.0013
P3926SL1	2.35		1.684	1.6	6.59	33.4737	0.9995	0.0012
P3926SL2	4.31		1.892	1.6	12.79	33.5776	1.0007	0.0012

Table 6-9
Benchmarking Results, continued

Run ID	U Enrich. Wt%	Pu Enrich. Wt%	Pitch (cm)	H_2O/fuel volume	Separation of assemblies (cm)	AEG	k_{eff}	1σ
P4267B1	4.31		1.8901	1.59		31.8075	0.9990	0.0010
P4267B2	4.31		0.89	1.59		31.5323	1.0033	0.0010
P4267B3	4.31		1.715	1.09		30.9905	1.0050	0.0011
P4267B4	4.31		1.715	1.09		30.5061	0.9996	0.0011
P4267B5	4.31		1.715	1.09		30.1011	1.0004	0.0011
P4267SL1	4.31		1.89	1.59		33.4737	0.9995	0.0012
P4267SL2	4.31		1.715	1.09		31.9460	0.9988	0.0016
P62FT231	4.31		1.891	1.6	5.19	32.9196	1.0012	0.0013
P71F14F3	4.31		1.891	1.6	5.19	32.8237	1.0009	0.0014
P71F14V3	4.31		1.891	1.6	5.19	32.8597	0.9972	0.0014
P71F14V5	4.31		1.891	1.6	5.19	32.8609	0.9993	0.0013
P71F214R	4.31		1.891	1.6	5.19	32.8778	0.9969	0.0012
PAT80L1	4.74		1.6	3.807	4.9	35.0253	1.0012	0.0012
PAT80L2	4.74		1.6	3.807	4.9	35.1136	0.9993	0.0015
PAT80SS1	4.74		1.6	3.807	4.9	35.0045	0.9988	0.0013
PAT80SS2	4.74		1.6	3.807	4.9	35.1072	0.9960	0.0013
W3269A	5.7		1.422	1.93		33.1480	0.9988	0.0012
W3269B1	3.7		1.105	1.432		32.4055	0.9961	0.0011
W3269B2	3.7		1.105	1.432		32.3921	0.9963	0.0011
W3269B3	3.7		1.105	1.432		32.2363	0.9944	0.0011
W3269C	2.72		1.524	1.494		33.7727	0.9989	0.0012
W3269SL1	2.72		1.524	1.494		33.3850	0.9981	0.0014
W3269SL2	5.7		1.422	1.93		33.0910	1.0005	0.0013
W3269W1	2.72		1.524	1.494		33.5114	0.9966	0.0014
W3269W2	5.7		1.422	1.93		33.1680	1.0014	0.0014
W3385SL1	5.74		1.422	1.932		33.2387	1.0009	0.0012
W3385SL2	5.74		2.012	5.067		35.8818	0.9997	0.0013
EPRI70UN	0.71	2	1.778	1.2		31.6775	0.9983	0.0012
EPRI70B	0.71	2	1.778	1.2		30.9021	1.0009	0.0012
EPRI87UN	0.71	2	2.2098	2.53		33.3230	1.0096	0.0011
EPRI87B	0.71	2	2.2098	2.53		31.6775	0.9983	0.0012
EPRI99UN	0.71	2	2.5146	3.64		35.1817	1.0063	0.0011
EPRI99B	0.71	2	2.5146	3.64		34.4098	1.0095	0.0011
SAXTON52	0.71	6.6	1.3208	1.68		30.2980	1.0020	0.0014
SAXTON56	0.71	6.6	1.4224	2.16		31.4724	1.0010	0.0014
SAXTON56B	0.71	6.6	1.4224	2.16		31.0038	0.9994	0.0013
SAXTN735	0.71	6.6	1.8669	4.7		34.1848	1.0007	0.0016
SATN792	0.71	6.6	2.01168	5.67		34.6401	1.0026	0.0013
SAXTN104	0.71	6.6	2.6416	10.75		35.8333	1.0054	0.0014
Correlation	0.31	-0.26	0.43	0.25	0.65	-0.01	N/A	N/A

Table 6-10
USL-1 Results

Parameter	Range of applicability	USL-1
U Enrichment (wt. % U-235)	2.4 2.8 3.3 3.8 – 5.7	0.9424 0.9430 0.9435 0.9438
Pu Enrichment (wt. % Pu)	2.0 – 6.6	0.9417
Fuel Rod Pitch (cm)	0.89 1.1 1.4 1.6 1.9 – 2.6	0.9396 0.9408 0.9421 0.9433 0.9439
Water/Fuel Volume Ratio	0.38 1.9 3.3 – 11	0.9414 0.9425 0.9426
Assembly Separation (cm)	1.6 4.4 7.1 9.8 – 21	0.9410 0.9425 0.9440 0.9441
Average Energy Group Causing Fission (AEG)	30 – 37	0.9433

Table 6-11
USL Determination for Criticality Analysis

Parameter	Value from Limiting Analysis	Bounding USL-1
U Enrichment (wt% U-235)	3.7 - 4.4	0.9438
Fuel Rod Pitch (cm)	1.875	0.9433
Water/Fuel Ratio	1.6	**0.9414**
Assembly Separation (cm)	16.56	0.9441
Average Energy Group Causing Fission (AEG)	~33	0.9433

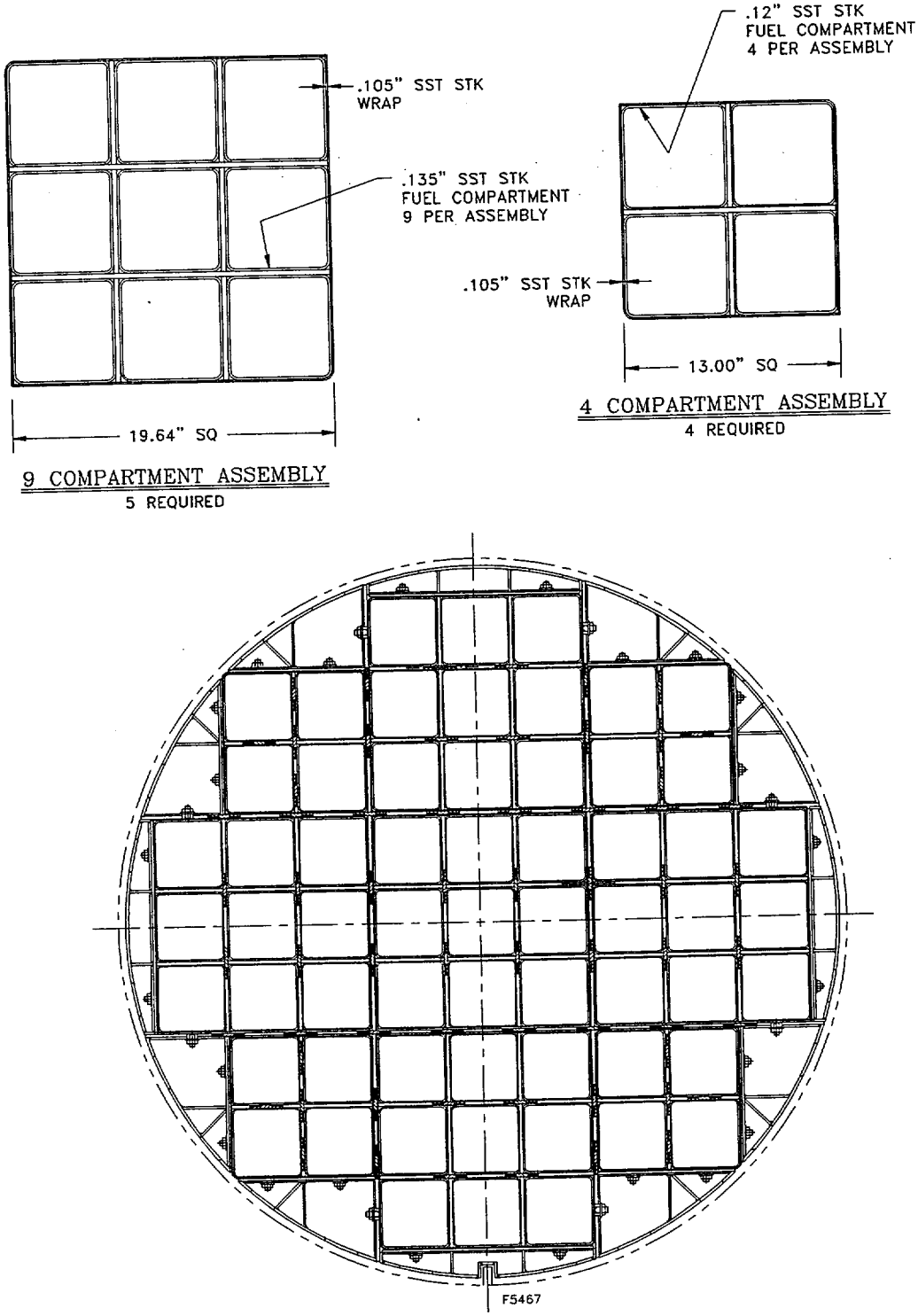
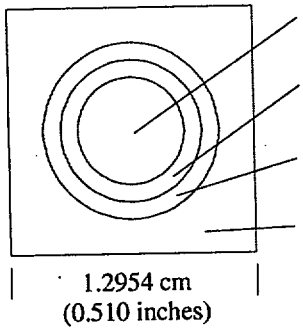
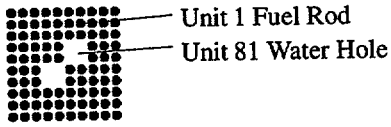


Figure 6-1 NUHOMS®-61BT DSC Axial Cross Section

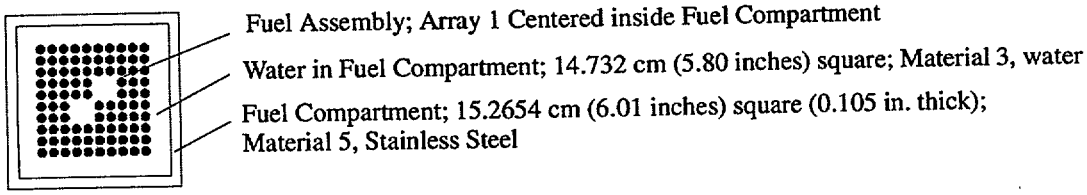
Unit 1 GE 10x10 Fuel Rod



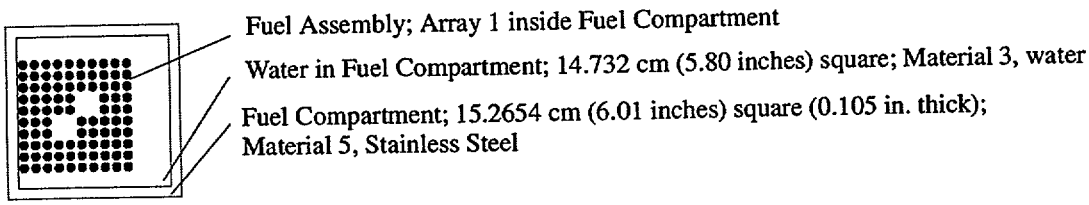
Array 1 GE 10x10 Fuel Assembly made up by a 10x10 array of Units 1 (fuel) and 81 (Water Holes)



Unit 2 GE 10x10 Fuel Assembly Centered in a Fuel Compartment for a 3x3 Compartment



Unit 3 GE 10x10 Fuel Assembly Shifted to the Left in a Fuel Compartment for a 3x3 Compartment



Unit 4 GE 10x10 Fuel Assembly Shifted to the Right in a Fuel Compartment for a 3x3 Compartment

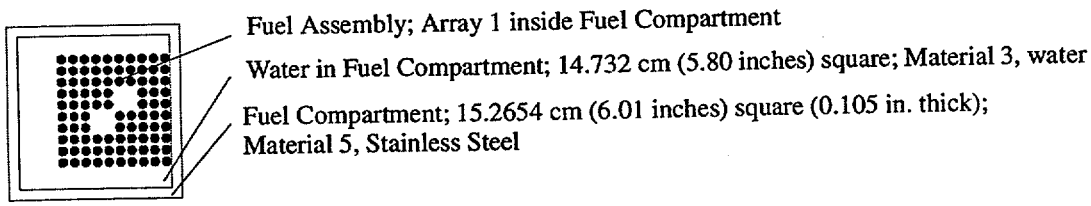
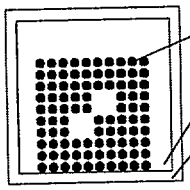


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model

PART 1 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

Unit 5 GE 10x10 Fuel Assembly Shifted Down in a Fuel Compartment for a 3x3 Compartment

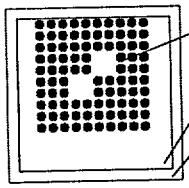


Fuel Assembly; Array 1 inside Fuel Compartment

Water in Fuel Compartment; 14.732 cm (5.80 inches) square; Material 3, water

Fuel Compartment; 15.2654 cm (6.01 inches) square (0.105 in. thick); Material 5, Stainless Steel

Unit 6 GE 10x10 Fuel Assembly Shifted Up in a Fuel Compartment for a 3x3 Compartment

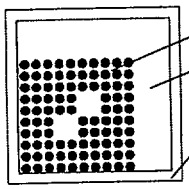


Fuel Assembly; Array 1 inside Fuel Compartment

Water in Fuel Compartment; 14.732 cm (5.80 inches) square; Material 3, water

Fuel Compartment; 15.2654 cm (6.01 inches) square (0.105 in. thick); Material 5, Stainless Steel

Unit 7 GE 10x10 Fuel Assembly Shifted to the Lower Left in a Fuel Compartment for a 3x3 Compartment

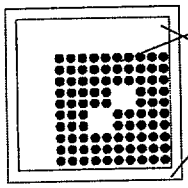


Fuel Assembly; Array 1 inside Fuel Compartment

Water in Fuel Compartment; 14.732 cm (5.80 inches) square; Material 3, water

Fuel Compartment; 15.2654 cm (6.01 inches) square (0.105 in. thick); Material 5, Stainless Steel

Unit 8 GE 10x10 Fuel Assembly Shifted to the Lower Right in a Fuel Compartment for a 3x3 Compartment

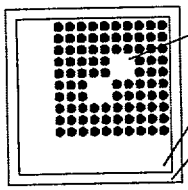


Fuel Assembly; Array 1 inside Fuel Compartment

Water in Fuel Compartment; 14.732 cm (5.80 inches) square; Material 3, water

Fuel Compartment; 15.2654 cm (6.01 inches) square (0.105 in. thick); Material 5, Stainless Steel

Unit 9 GE 10x10 Fuel Assembly Shifted to the Upper Right in a Fuel Compartment for a 3x3 Compartment



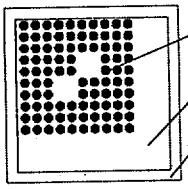
Fuel Assembly; Array 1 inside Fuel Compartment

Water in Fuel Compartment; 14.732 cm (5.80 inches) square; Material 3, water

Fuel Compartment; 15.2654 cm (6.01 inches) square (0.105 in. thick); Material 5, Stainless Steel

Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 2 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

Unit 10 GE 10x10 Fuel Assembly Shifted to the Upper Left in a Fuel Compartment for a 3x3 Compartment

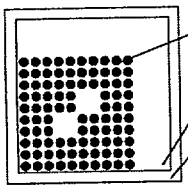


Fuel Assembly; Array 1 inside Fuel Compartment

Water in Fuel Compartment; 14.732 cm (5.80 inches) square; Material 3, water

Fuel Compartment; 15.2654 cm (6.01 inches) square (0.105 in. thick); Material 5, Stainless Steel

Unit 11 GE 10x10 Fuel Assembly Shifted to the Lower Left in a Fuel Compartment for a 2x2 Compartment

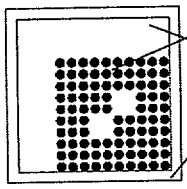


Fuel Assembly; Array 1 inside Fuel Compartment

Water in Fuel Compartment; 14.732 cm (5.80 inches) square; Material 3, water

Fuel Compartment; 15.1892 cm (5.98 inches) square (0.090 in. thick); Material 5, Stainless Steel

Unit 12 GE 10x10 Fuel Assembly Shifted to the Lower Right in a Fuel Compartment for a 2x2 Compartment

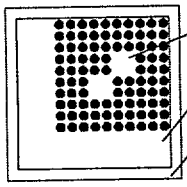


Fuel Assembly; Array 1 inside Fuel Compartment

Water in Fuel Compartment; 14.732 cm (5.80 inches) square; Material 3, water

Fuel Compartment; 15.1892 cm (5.98 inches) square (0.090 in. thick); Material 5, Stainless Steel

Unit 13 GE 10x10 Fuel Assembly Shifted to the Upper Right in a Fuel Compartment for a 2x2 Compartment

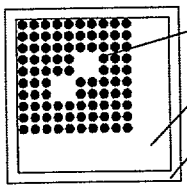


Fuel Assembly; Array 1 inside Fuel Compartment

Water in Fuel Compartment; 14.732 cm (5.80 inches) square; Material 3, water

Fuel Compartment; 15.1892 cm (5.98 inches) square (0.090 in. thick); Material 5, Stainless Steel

Unit 14 GE 10x10 Fuel Assembly Shifted to the Upper Left in a Fuel Compartment for a 2x2 Compartment



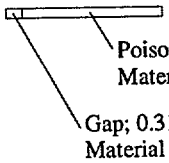
Fuel Assembly; Array 1 inside Fuel Compartment

Water in Fuel Compartment; 14.732 cm (5.80 inches) square; Material 3, water

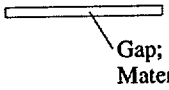
Fuel Compartment; 15.1892 cm (5.98 inches) square (0.090 in. thick); Material 5, Stainless Steel

Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 3 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

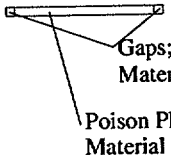
Unit 15 Poison Plate with Gap for a 3x3 Compartment



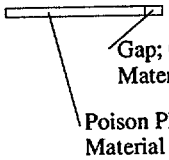
Unit 16 Gap for a 3x3 Compartment



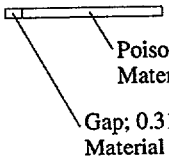
Unit 17 Poison Plate with Gap for a 3x3 Compartment



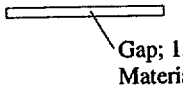
Unit 18 Poison Plate with Gap for a 3x3 Compartment



Unit 19 Poison Plate with Gap for a 2x2 Compartment



Unit 20 Gap for a 2x2 Compartment



Unit 21 Poison Plate with Gap for a 2x2 Compartment

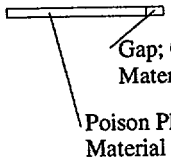
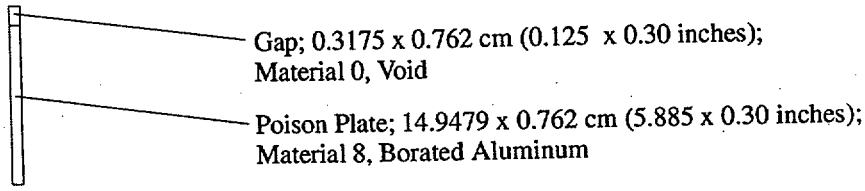
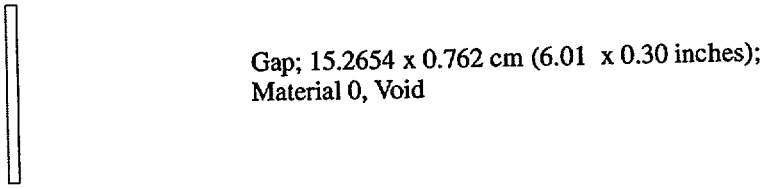


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 4 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

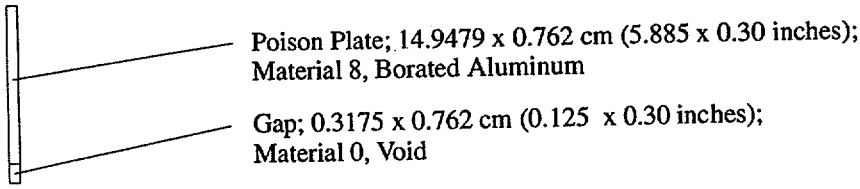
Unit 22 Poison Plate with Gap for a 3x3 Compartment



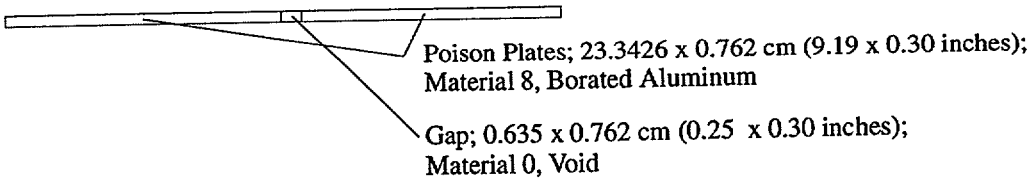
Unit 23 Gap for a 3x3 Compartment



Unit 24 Poison Plate with Gap for a 3x3 Compartment



Unit 25 Poison Plates with Gap for a 3x3 Compartment



Unit 26 Long Gap for a 3x3 Compartment

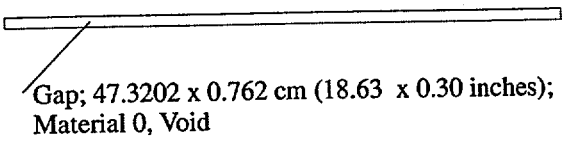
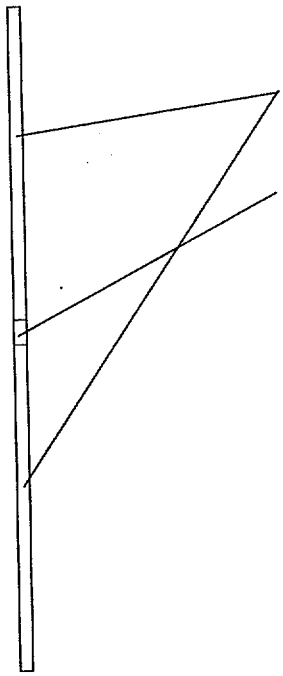


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 5 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

Unit 27 Poison Plates with Gap for a 3x3 Compartment



Unit 28 Long Gap for a 3x3 Compartment

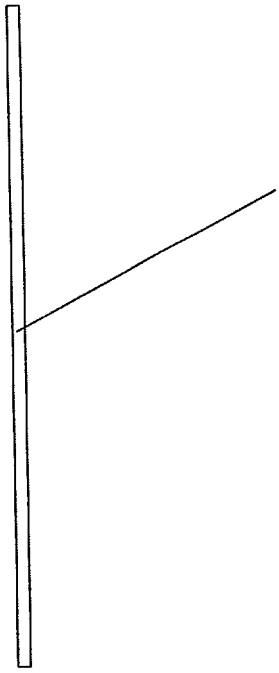
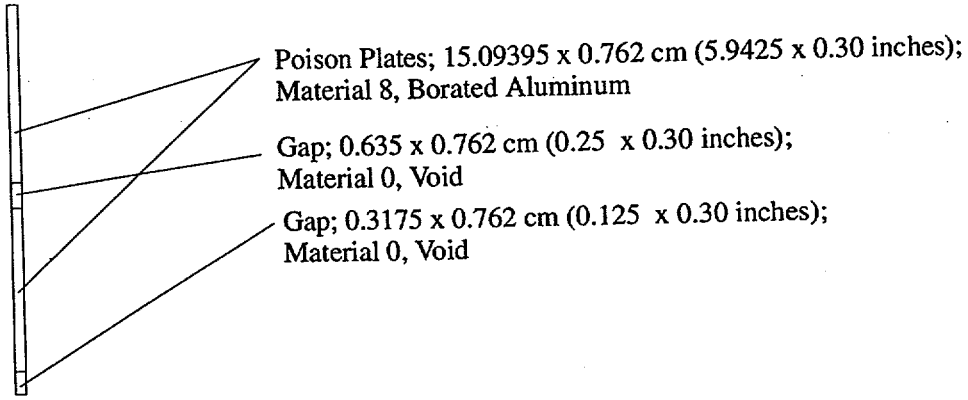
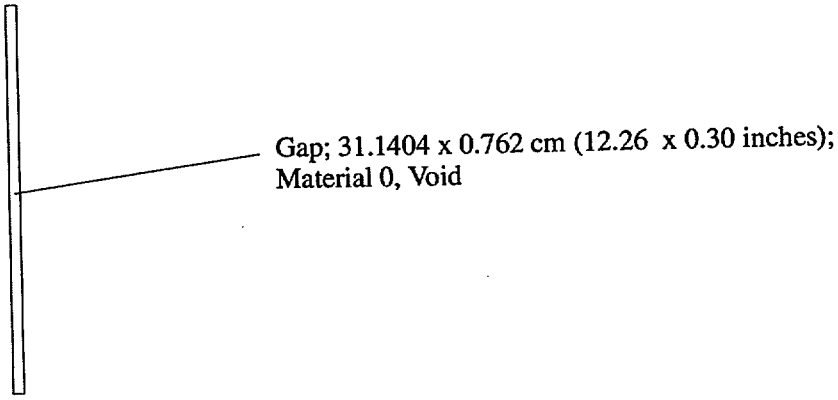


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 6 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

Unit 29 Poison Plates with Gap for a 2x2 Compartment



Unit 30 Gap for a 2x2 Compartment



Unit 31 Poison Plates with Gap for a 2x2 Compartment

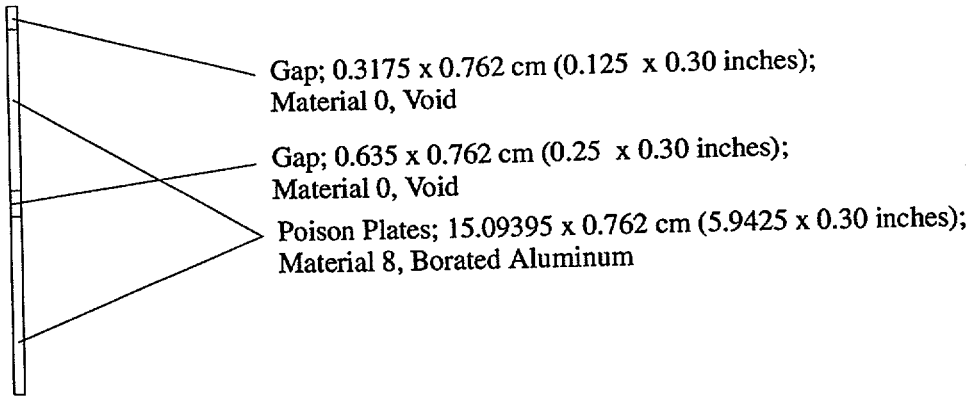
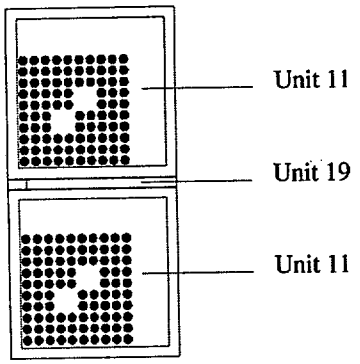
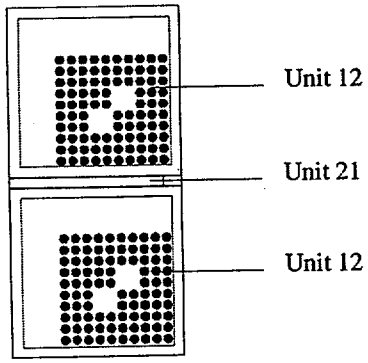


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 7 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

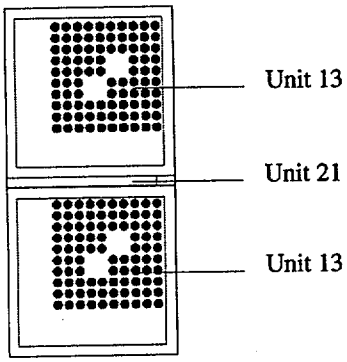
Unit 32, Array 2 - 2x2 with Poison



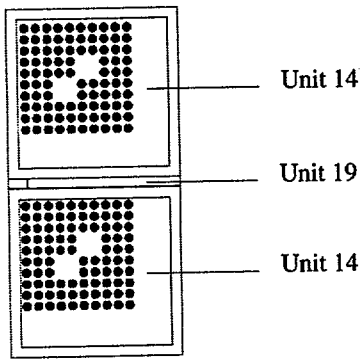
Unit 33, Array 3 - 2x2 with Poison



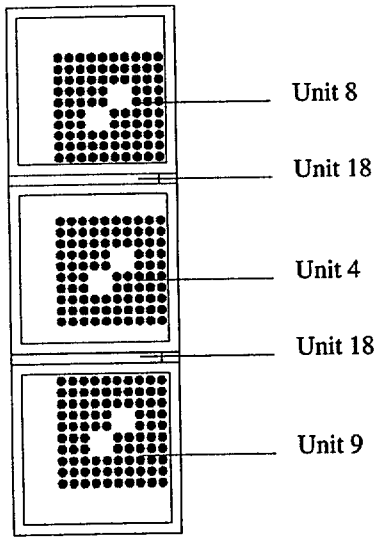
Unit 34, Array 4 - 2x2 with Poison



Unit 35, Array 5 - 2x2 with Poison



Unit 36, Array 6 - 3x3 with Poison



Unit 37, Array 7 - 3x3 with Poison

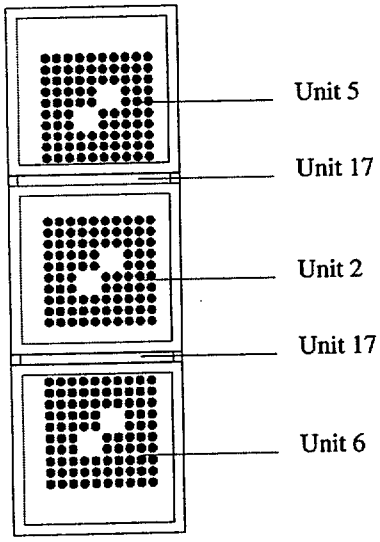
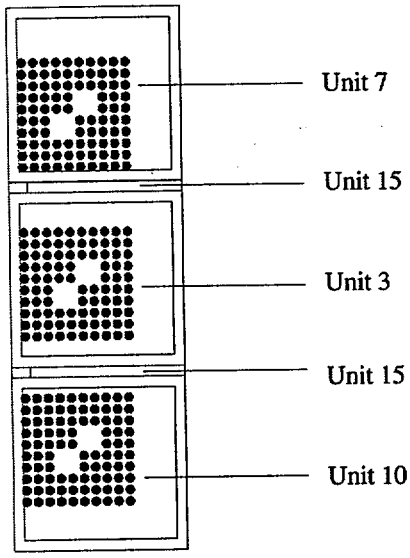
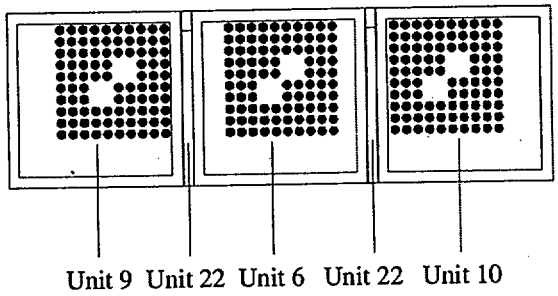


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 8 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

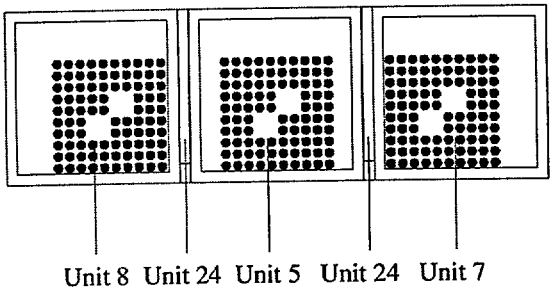
Unit 38, Array 8 - 3x3 with Poison



Unit 39, Array 9 - 3x3 with Poison



Unit 40, Array 10 - 3x3 with Poison



Unit 41, Array 11 - 3x3 with Poison

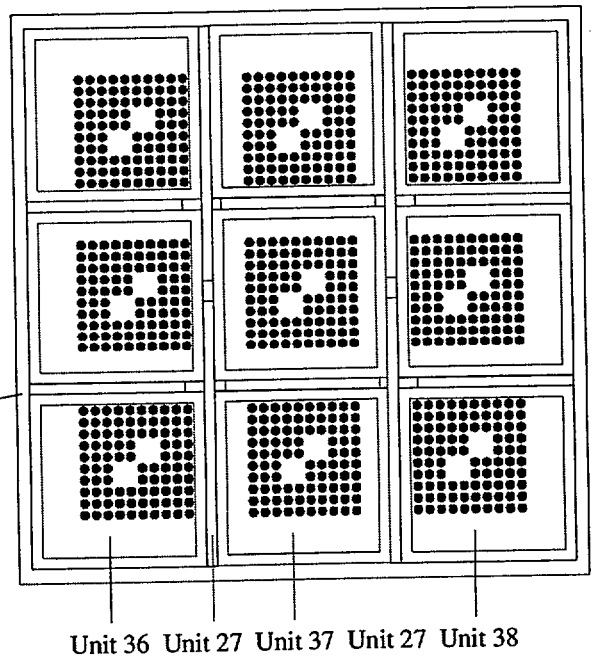
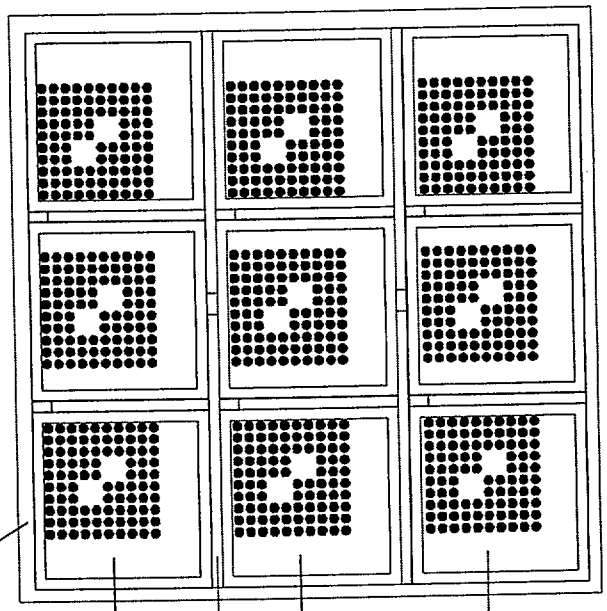


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 9 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

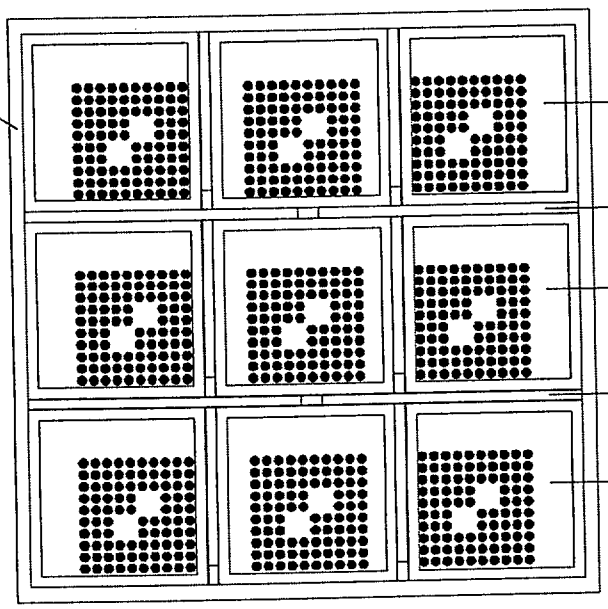
Unit 42, Array 12 - 3x3 with Poison



Unit 38 Unit 27 Unit 38 Unit 27 Unit 38

Wrapper; 47.7012 cm (18.78 inches) square
(0.075 inches thick); Material 5; Stainless Steel

Unit 43, Array 13 - 3x3 with Poison



Unit 40

Unit 25

Unit 40

Unit 25

Unit 40

Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 10 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

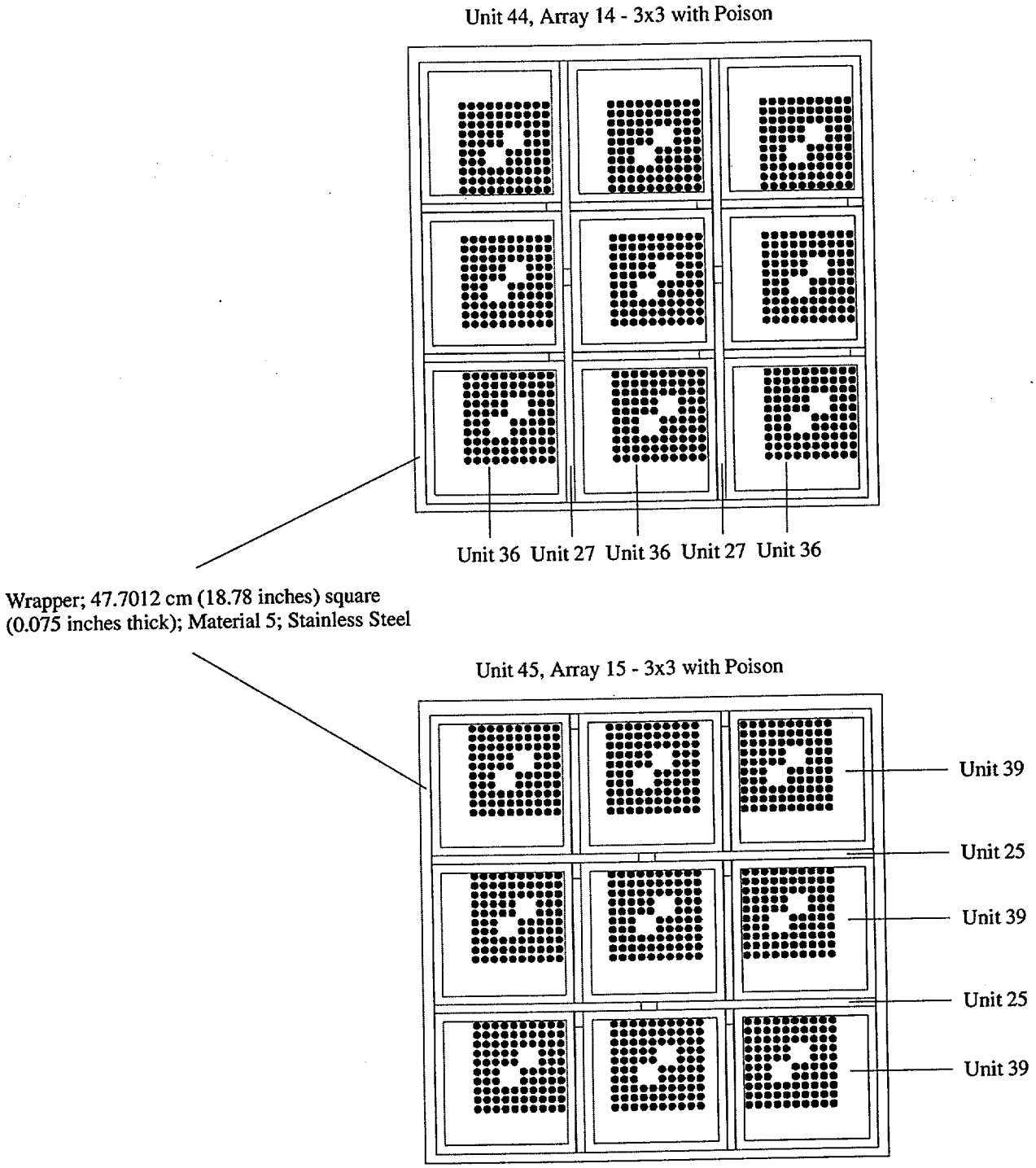


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 11 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

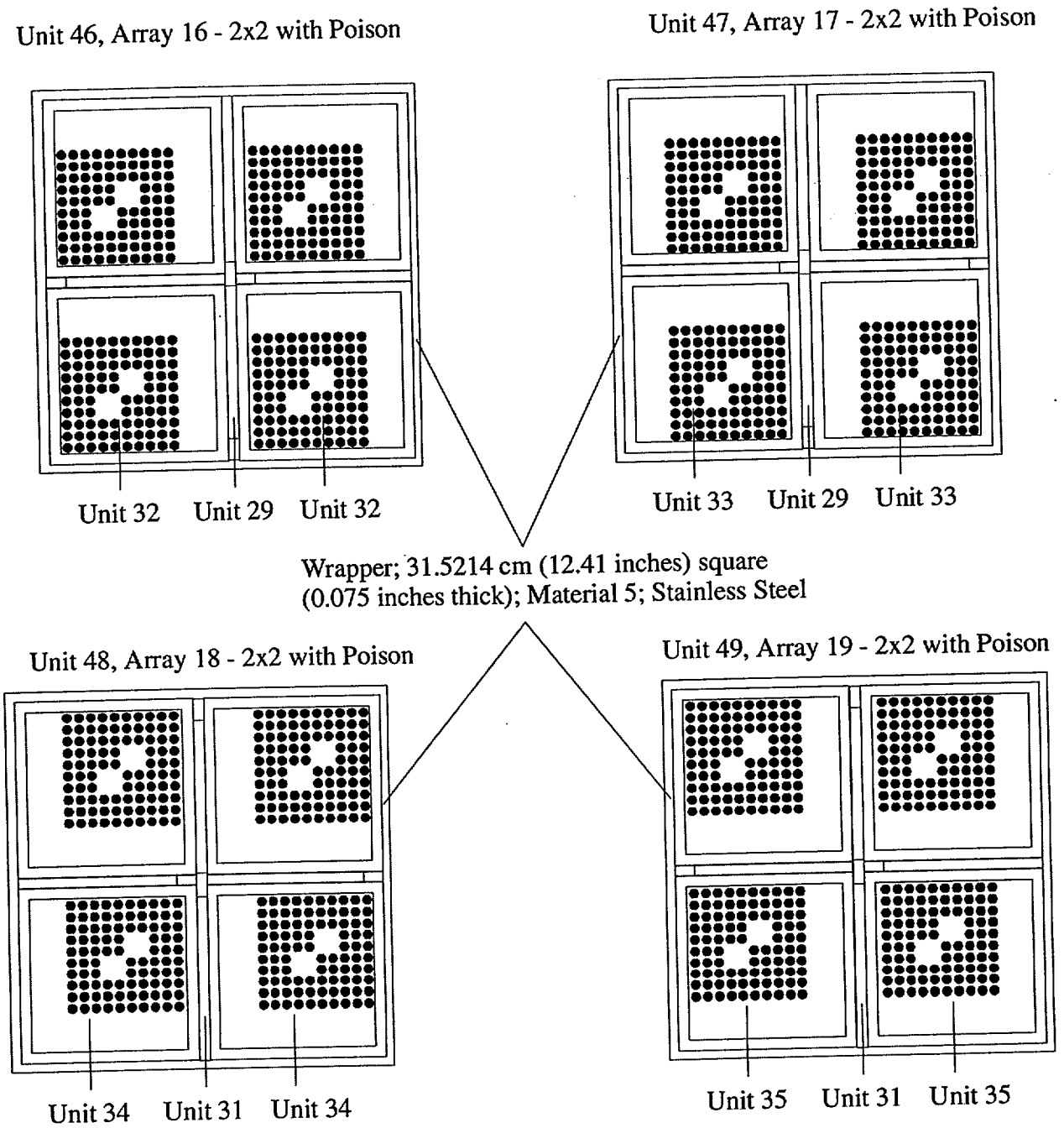
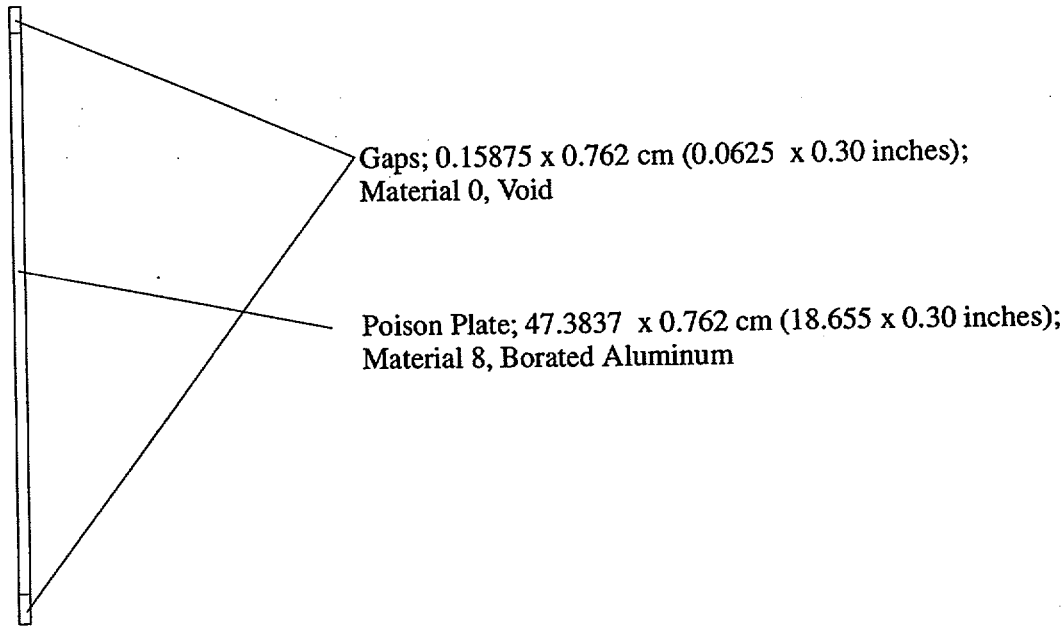


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 12 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

Unit 50, Poison Plates for 3x3 with Gaps - Outside



Unit 51, Short Gap for 3x3 - Outside

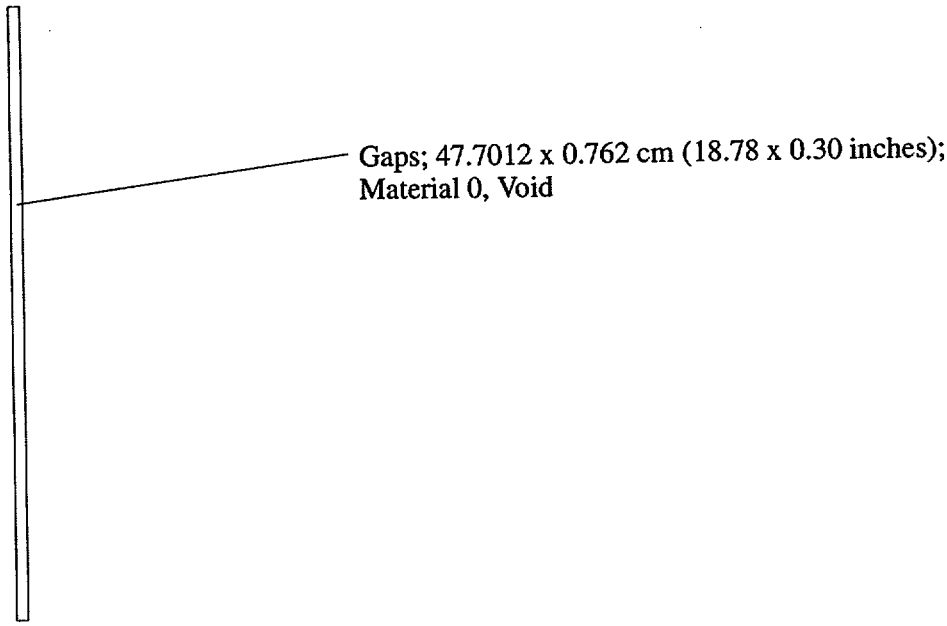
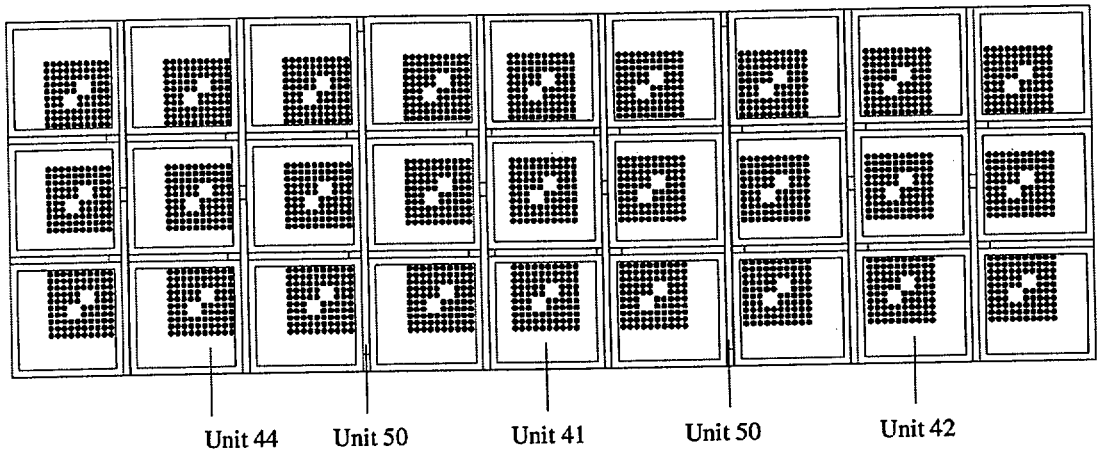
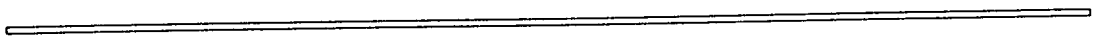


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 13 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

Unit 52, Array 20 - Row of 3x3 Compartments with Poison

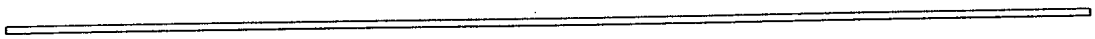


Unit 53 Long Horizontal Poison Plates



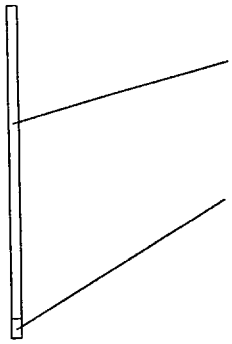
Poison Plate; 112.4204 x 0.762 cm (44.26 x 0.30 inches);
Material 8, Borated Aluminum

Unit 54 Long Horizontal Gaps



Gap; 112.4204 x 0.762 cm (44.26 x 0.30 inches);
Material 0, Void

Unit 55 Poison Plates with Gap

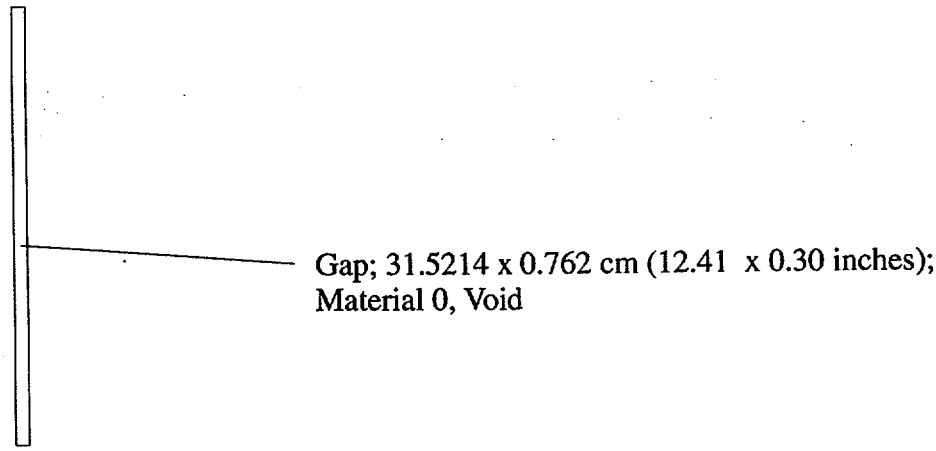


Poison Plates; 31.2039 x 0.762 cm (12.285 x 0.30 inches);
Material 8, Borated Aluminum

Gap; 0.3175 x 0.762 cm (0.125 x 0.30 inches);
Material 0, Void

Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 14 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

Unit 56 Gap



Unit 57 Poison Plates with Gap

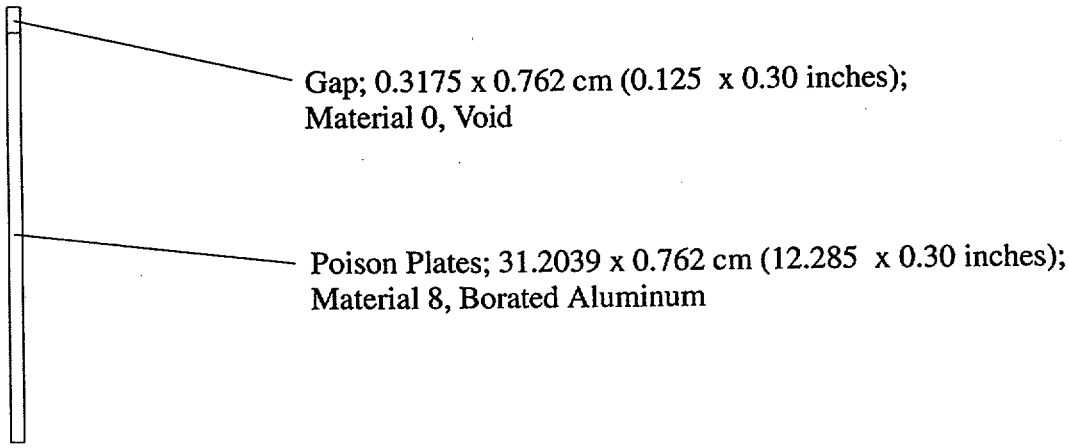


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 15 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

Unit 58 DSC/Cask Layer with Poison

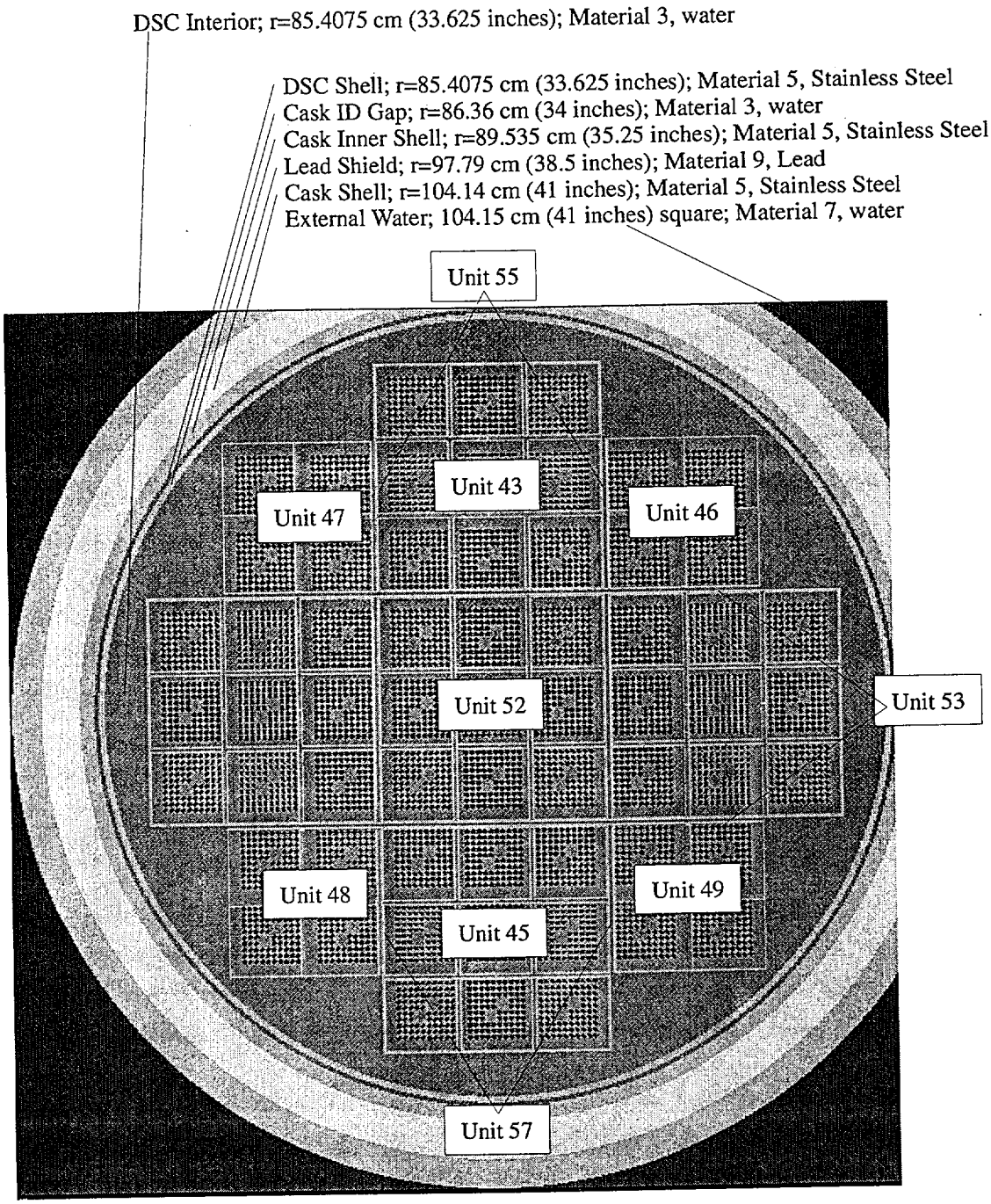


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 16 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

Unit 59 models the portion of the DSC that has poison in side the 3x3 and 2x2 compartments, but no poison between the compartments. Therefore, Unit 59 is identical to Unit 58 except: Unit 52 is replaced with Unit 60,

Unit 53 is replaced with Unit 54,
Units 55 and 57 are replaced with Unit 56

Unit 60, (Array 22) is identical to Unit 52 except that Unit 50 is replaced with Unit 51 as compared to Array 20.

Unit 61, (Array 23) is identical to Unit 32 except that Unit 19 is replaced with Unit 20 as compared to Array 2.

Unit 62, (Array 24) is identical to Unit 33 except that Unit 21 is replaced with Unit 20 as compared to Array 3.

Unit 63, (Array 25) is identical to Unit 34 except that Unit 21 is replaced with Unit 20 as compared to Array 4.

Unit 64, (Array 26) is identical to Unit 35 except that Unit 19 is replaced with Unit 20 as compared to Array 5.

Unit 65, (Array 27) is identical to Unit 36 except that Unit 18 is replaced with Unit 16 as compared to Array 6.

Unit 66, (Array 28) is identical to Unit 37 except that Unit 17 is replaced with Unit 16 as compared to Array 7.

Unit 67, (Array 29) is identical to Unit 38 except that Unit 15 is replaced with Unit 16 as compared to Array 8.

Unit 68, (Array 30) is identical to Unit 39 except that Unit 22 is replaced with Unit 23 as compared to Array 9.

Unit 69, (Array 31) is identical to Unit 40 except that Unit 24 is replaced with Unit 23 as compared to Array 10.

Unit 70, (Array 32) is identical to Unit 41 except that Unit 27 is replaced with Unit 28 as compared to Array 11.

Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 17 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

Unit 71, (Array 33) is identical to Unit 42 except that Unit 27 is replaced with Unit 28 as compared to Array 12.

Unit 72, (Array 34) is identical to Unit 43 except that Unit 25 is replaced with Unit 26 as compared to Array 13.

Unit 73, (Array 35) is identical to Unit 44 except that Unit 27 is replaced with Unit 28 as compared to Array 14.

Unit 74, (Array 36) is identical to Unit 45 except that Unit 25 is replaced with Unit 26 as compared to Array 15.

Unit 75, (Array 37) is identical to Unit 46 except that
Unit 32 is replaced with Unit 61 and
Unit 29 is replaced with Unit 30 as compared to Array 16.

Unit 76, (Array 38) is identical to Unit 47 except that
Unit 33 is replaced with Unit 62 and
Unit 29 is replaced with Unit 30 as compared to Array 17.

Unit 77, (Array 39) is identical to Unit 48 except that
Unit 34 is replaced with Unit 63 and
Unit 31 is replaced with Unit 30 as compared to Array 18.

Unit 78, (Array 40) is identical to Unit 49 except that
Unit 35 is replaced with Unit 64 and
Unit 31 is replaced with Unit 30 as compared to Array 19.

Unit 79, models the portion of the DSC that has no inside the compartments, and no poison between the compartments. Therefore, Unit 79 is identical to Unit 59 except:

Unit 60 is replaced with Unit 80,
Unit 43 is replaced with Unit 72,
Unit 43 is replaced with Unit 74,
Unit 45 is replaced with Unit 74,
Unit 46 is replaced with Unit 75,
Unit 47 is replaced with Unit 76,
Unit 48 is replaced with Unit 77, and
Unit 49 is replaced with Unit 78.

Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 18 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)

Unit 80, (Array 41) is identical to Unit 60 except that:
Unit 44 is replaced with Unit 73,
Unit 41 is replaced with Unit 70, and
Unit 42 is replaced with Unit 71 as compared to Array 22.

Unit 81 GE 10x10 Water "Hole" in Fuel

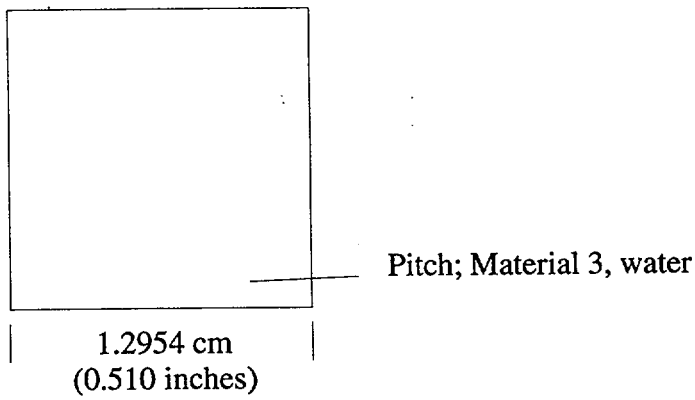
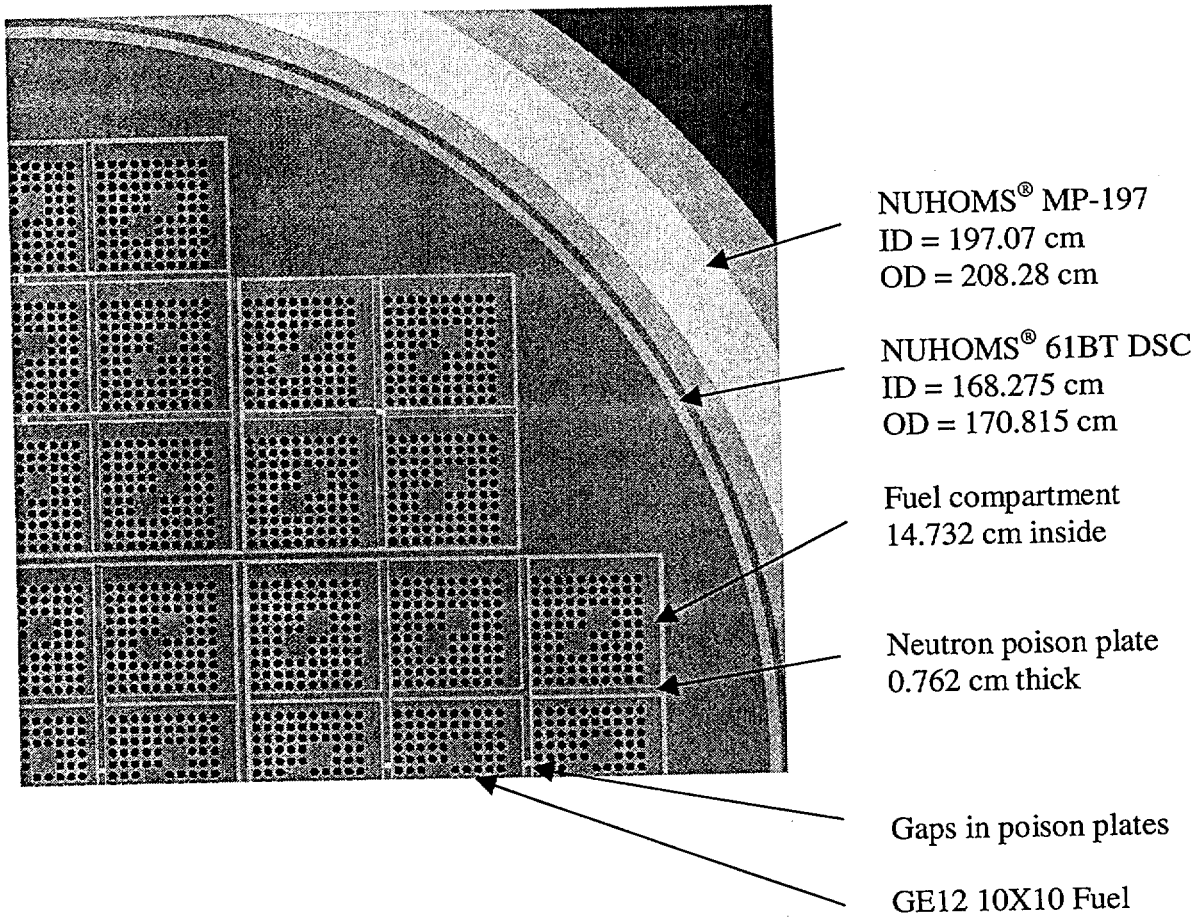


Figure 6-2
KENO V.a Units and Radial Cross Sections of the Model
PART 19 OF 19 - (ALL UNITS 0.635 CM (0.25 INCHES) HIGH)



LEGEND

VOID	
MATERIAL 1	UO2
MATERIAL 2	Ziracaloy
MATERIAL 3	water, internal
MATERIAL 5	SS 304
MATERIAL 6	water, inside fuel rod
MATERIAL 7	water, external
MATERIAL 8	B10/aluminum
MATERIAL 9	lead

Figure 6-3
KENO V.a Model Cross Section – Bounding Case

1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1
1	1	1	1	1	1	1

GE2 - 7x7 Array
1 = Fuel Rod

1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	66	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1

GE4 - 8x8 Array
1 = Fuel Rod
66 = Water Rod

1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	66	1	1	1	1
1	1	1	1	66	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1

GE5 - 8x8 Array
1 = Fuel Rod
66 = Water Rod

1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	67	66	1	1	1
1	1	1	66	67	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1

GE8 - 8x8 Array
1 = Fuel Rod
66 = Water Rod 1
67 = Water Rod 2

1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	66	66	1	1	1
1	1	1	66	66	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1

GE9 - 8x8 Array
1 = Fuel Rod
66 = Water Hole

1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	66	66	1	1	1	1
1	1	1	66	66	66	1	1	1
1	1	1	1	66	66	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1

GE11 - 9x9 Array
1 = Fuel Rod
66 = Water Hole

1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	66	66	1	1	1	1	1
1	1	1	66	66	66	1	1	1	1
1	1	1	1	66	66	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1

GE12 - 10x10 Array
1 = Fuel Rod
66 = Water Hole

Figure 6-4
Fuel Assembly Layouts

68	67	67	67	68	68	69
67	1	1	1	1	67	68
1	1	1	1	1	1	68
1	1	1	1	1	1	67
1	1	1	1	1	1	67
67	1	1	1	1	1	67
67	67	1	1	1	67	68

GE2 - 7x7 Array
(Case GE2var)
1 = Fuel Rod w/ 5.15 wt%
67 = Fuel Rod w/3.41 wt%
68 = Fuel Rod w/2.97 wt%
69 = Fuel Rod w/2.34 wt%

67	68	68	68	68	68	67	1
68	69	69	69	69	69	68	67
69	69	69	69	69	69	69	68
69	69	69	w	69	69	69	68
69	69	69	69	w	69	69	68
69	69	69	69	69	69	69	68
69	69	69	69	69	69	69	68
68	69	69	69	69	69	68	67

GE5 - 8x8 Array
(Case GE5var)
1 = Fuel Rod w/ 2.33 wt%
67 = Fuel Rod w/3.01 wt%
68 = Fuel Rod w/3.57 wt%
69 = Fuel Rod w/4.85 wt%
w = Water Rod

71	70	69	69	69	68	74	1
69	72	70	72	72	71	69	74
72	69	72	72	72	72	71	68
72	72	73	w	w	72	72	69
72	69	72	w	w	72	72	69
72	72	72	72	73	72	70	69
69	69	72	69	72	69	72	70
71	69	72	72	72	72	69	71

GE9 - 8x8 Array
(Case GE9var)
1 = Fuel Rod w/ 2.02 wt%
68 = Fuel Rod w/4.03 wt%
69 = Fuel Rod w/4.29 wt%
70= Fuel Rod w/ 3.78 wt%
71 = Fuel Rod w/3.03 wt%
72 = Fuel Rod w/4.98 wt%
73 = Fuel Rod w/4.54 wt%
74 = Fuel Rod w/3.28 wt%
w = Water Rod

Figure 6-5
Variable Enrichment Fuel Assembly Layouts

NUHOMS®-MP197 TRANSPORT PACKAGING

CHAPTER 7

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CHAPTER 7

OPERATING PROCEDURES

This chapter contains NUHOMS-MP197 loading and unloading procedures that are intended to show the general approach to cask operational activities. A separate Operations Manual (OM) will be prepared for the NUHOMS-MP197 to describe the operational steps in greater detail. The OM, along with the information in this chapter, will be used to prepare the site-specific procedures that will address the particular operational considerations related to the cask.

7.1 Procedures for Loading the Package

The NUHOMS®-MP197 Cask will be used to transport fuel off-site. This mode of use requires (1) preparation of the cask for use; (2) verification that the fuel assemblies to be loaded meet the criteria set forth in this document; and (3) installation of a DSC and fuel assemblies into the cask.

Offsite transport involves (1) preparation of the cask for transport; (2) assembly verification leakage-rate testing of the package containment boundary; (3) placement of the cask onto a transportation vehicle; and (4) installation of the impact limiters.

During shipment, the packaging contains up to 61BWR spent fuel assemblies in the NUHOMS-61BT DSC. Procedures are provided in this section for transport of (1) the cask/DSC directly from the spent plant fuel pool and (2) transport of a NUHOMS 61BT DSC after storage in a NUHOMS® Horizontal Storage Module (HSM). A glossary of terms used in this section is provided in Section 7.1.6.

7.1.1 Preparation of the NUHOMS®-MP197 Cask for Use

Procedures for preparing the cask for use after receipt at the site are provided in this section.

a. Remove the impact limiter attachment bolts from each impact limiter and remove the impact limiters from the cask.

b. Anytime prior to removing the lid, sample the cask cavity atmosphere through the vent port. Flush the cask interior gases to the site radwaste systems if necessary.

c. Remove the transportation skid tie down straps.

d. Take contamination smears on the outside surfaces of the cask. If necessary, decontaminate the cask until smearable contamination is at an acceptable level.

e. Inspect the cask hardware (including vent/drain/test port plugs) for damage which may have occurred during transportation. Repair or replace as required.

f. Install the front and rear trunnions. Lubricate, install and preload the trunnion bolts and torque them to 250 ft-lbs in the first pass and to 520 - 540 ft-lbs in the final pass following the torquing sequence shown in Figure 7-1.

g. Place suitable slings around the cask front and rear trunnions, lift cask and place on the onsite transfer trailer.

h. Remove the slings from the cask.

i. Install the onsite transfer trailer trunnion block covers.

7.1.2 Wet Loading the NUHOMS®-MP197 Cask and 61BT DSC

The procedure for wet loading the cask and 61BT DSC is summarized in this section. This procedure is intended to describe the type and quality of work performed to load and seal a DSC. Actual DSC loading procedures may vary slightly from tasks described below. The NUHOMS®-MP197 Cask is designed to transport one NUHOMS-61BT DSC containing 61 BWR fuel assemblies. All fuel assembly locations are to be loaded with design basis fuel assemblies. Verification that the burnup, enrichment, and cooling time of the assemblies are all within acceptable ranges will be performed by site personnel, prior to shipment, as discussed below.

7.1.2.1 Preparation of the Transport Cask and DSC

a. Verify that the fuel assemblies to be placed in the DSC meet the maximum burnup, maximum initial enrichment, minimum cooling time, and maximum decay heat limits for fuel assemblies as specified in Section 1.2.3 of this document.

b. Using a suitable prime mover, position the cask and onsite transfer trailer below the plant crane.

c. Remove the onsite transfer trailer trunnion block covers.

d. Engage the cask front trunnions with the lifting yoke using the plant crane, rotate the cask to a vertical orientation, lift the cask from the onsite transfer trailer, and place the cask in the plant decon area.

e. Place scaffolding around the cask so that the top closure lid and surface of the cask are easily accessible to personnel.

f. Remove the top closure lid and examine the cask cavity for any physical damage and ready the cask for service.

g. Examine the DSC for any physical damage which might have occurred since the receipt inspection was performed. The DSC is to be cleaned and any loose debris removed.

h. Using a crane, lower the DSC into the cask cavity by the internal lifting lugs and rotate the DSC to match the cask and DSC alignment marks.

i. Fill the cask-DSC annulus with clean, demineralized water. Place the inflatable seal into the upper cask liner recess and seal the cask-DSC annulus by pressurizing the seal with compressed air.

j. Fill the DSC cavity with water from the fuel pool or an equivalent source. For BWR fuel, demineralized water may be used.

Note: A Cask/DSC annulus pressurization tank filled with clear demineralized water is connected to the top vent port of the cask via a hose to provide a positive head above the

level of water in the Cask/DSC annulus. This is an optional arrangement, which provides additional assurance that contaminated water from the fuel pool will not enter the Cask/DSC annulus, provided the positive head is maintained at all times.

k. Place the top shield plug onto the DSC. Examine the top shield plug to ensure a proper fit.

l. Position the cask lifting yoke and engage the cask lifting trunnions and the rigging cables to the DSC top shield plug. Adjust the rigging cables as necessary to obtain even cable tension.

m. Visually inspect the yoke lifting hooks to insure that they are properly positioned and engaged on the cask lifting trunnions.

n. Move the scaffolding away from the cask as necessary.

o. Lift the cask just far enough to allow the weight of the cask to be distributed onto the yoke lifting hooks. Reinspect the lifting hooks to insure that they are properly positioned on the cask trunnions.

p. Optionally, secure a sheet of suitable material to the bottom of the transportr cask to minimize the potential for ground-in contamination. This may also be done prior to initial placement of the cask in the decon area.

q. Prior to the cask being lifted into the fuel pool, the water level in the pool should be adjusted as necessary to accommodate the Cask/DSC volume. If the water placed in the DSC cavity was obtained from the fuel pool, a level adjustment may not be necessary.

7.1.2.2 DSC Fuel Loading

a. Lift the Cask/DSC and position it over the cask loading area of the spent fuel pool in accordance with the plant's 10CFR50 cask handling procedures.

b. Lower the cask into the fuel pool until the bottom of the cask is at the height of the fuel pool surface. As the cask is lowered into the pool, spray the exterior surface of the cask with demineralized water.

c. Place the cask in the location of the fuel pool designated as the cask loading area.

d. Disengage the lifting yoke from the cask lifting trunnions and move the yoke and the top shield plug clear of the cask. Spray the lifting yoke and top shield plug with clean demineralized water if it is raised out of the fuel pool.

e. Move a candidate fuel assembly from a fuel rack in accordance with the plant's 10CFR50 fuel handling procedures.

f. Prior to insertion of a spent fuel assembly into the DSC, the identity of the assembly is to be verified by two individuals using an underwater video camera or other means. Read and record the fuel assembly identification number from the fuel assembly and check this identification number against the DSC loading plan which indicates which fuel assemblies are acceptable for transport.

g. Position the fuel assembly for insertion into the selected DSC storage cell and load the fuel assembly. Repeat Steps e through g for each SFA loaded into the DSC. After the DSC has been fully loaded, check and record the identity and location of each fuel assembly in the DSC.

h. After all the SFAs have been placed into the DSC and their identities verified, place the hold down ring and position the lifting yoke and the top shield plug and lower the shield plug onto the DSC.

i. Visually verify that the top shield plug is properly seated onto the DSC.

j. Position the lifting yoke with the cask trunnions and verify that it is properly engaged.

k. Raise the transport cask to the pool surface. Prior to raising the top of the cask above the water surface, stop vertical movement.

l. Inspect the top shield plug to verify that it is properly seated onto the DSC. If not, lower the cask and reposition the top shield plug. Repeat Steps k and l as necessary.

m. Continue to raise the cask from the pool and spray the exposed portion of the cask with demineralized water until the top region of the cask is accessible.

n. Drain any excess water from the top of the DSC shield plug back to the fuel pool.

o. Check the radiation levels at the center of the top shield plug and around the perimeter of the cask.

p. Drain approximately 1100 gallons of water (as indicated on the rotometer) from the DSC back into the fuel pool or other suitable location using the VDS or optional liquid pump.

q. Lift the cask from the fuel pool. As the cask is raised from the pool, continue to spray the cask with demineralized water.

r. Move the transport cask with loaded DSC to the cask decon area.

s. Replace the approximate 1100 gallons of water removed (as indicated on the rotometer) from the DSC with demineralized water or spent fuel pool water.

7.1.2.3 DSC Drying and Backfilling

a. Check the radiation levels along the perimeter of the cask. The cask exterior surface should be decontaminated as required. Temporary shielding may be installed as necessary to minimize personnel exposure.

b. Place scaffolding around the cask so that any point on the surface of the cask is easily accessible to personnel.

c. Disengage the rigging cables from the top shield plug and remove the eyebolts. Disengage the lifting yoke from the trunnions and position it clear of the cask.

d. Decontaminate the exposed surfaces of the DSC shell perimeter and remove the inflatable cask/DSC annulus seal.

e. Connect the cask drain line to the cask, open the cask cavity drain port and allow water from the annulus to drain out until the water level is approximately twelve inches below the top edge of the DSC shell. Take swipes around the outer surface of the DSC shell and check for smearable contamination as required.

f. Drain approximately 1100 gallons of water (as indicated on a rotometer) from the DSC back into the fuel pool or other suitable location using the VDS or an optional liquid pump.

g. Disconnect hose from the DSC siphon port.

h. Install the automatic welding machine onto the inner top cover plate and place the inner top cover plate with the automatic welding machine onto the DSC. Verify proper fit-up of the inner top cover plate with the DSC shell.

i. Check radiation levels along surface of the inner top cover plate. Temporary shielding may be installed as necessary to minimize personnel exposure.

j. CAUTION: Insert a ¼ inch tygon tubing of sufficient length through the vent port such that it terminates just below the DSC shield plug. Connect the tygon tubing to a hydrogen monitor to allow continuous monitoring of the hydrogen atmosphere in the DSC cavity during welding of the inner cover plate.

k. Cover the cask/DSC annulus to prevent debris and weld splatter from entering the annulus.

l. Ready the automatic welding machine and tack weld the inner top cover plate to the DSC shell. Install the inner top cover plate weldment and remove the automatic welding machine.

CAUTION: Continuously monitor the hydrogen concentration in the DSC cavity using the tygon tube arrangement described in step j during the inner top cover plate cutting/welding operations. Verify that the measured hydrogen concentration does not exceed a safety limit of 2.4%. If this limit is exceeded, stop all welding operations and purge the DSC cavity with 2-3 psig helium (or any other inert medium) via the ¼ inch tygon tubing to reduce the hydrogen concentration safely below the 2.4% limit.

m. Perform dye penetrant weld examination of the inner top cover plate weld.

n. Place the strongback so that it sits on the inner top cover plate and is oriented such that:

- the DSC siphon and vent ports are accessible
- the strongback stud holes line up with the cask lid bolt holes.

o. Lubricate the studs and, using a crossing pattern, adjust the strongback studs to snug tight ensuring approximately even pressure on the cover plate.

p. Connect the VDS to the DSC siphon and vent ports.

q. Install temporary shielding to minimize personnel exposure throughout the subsequent welding operations as required.

r. Engage the compressed air, nitrogen or helium supply and open the valve on the vent port and allow compressed gas to force the water from the DSC cavity through the siphon port.

s. Once the water stops flowing from the DSC, close the DSC siphon port and disengage the gas source.

t. Connect the hose from the vent port and the siphon port to the intake of the vacuum pump. Connect a hose from the discharge side of the VDS to the plant's radioactive waste system or spent fuel pool. Connect the VDS to a helium source.

u. Open the valve on the suction side of the pump, start the VDS and draw a vacuum on the DSC cavity. The cavity pressure should be reduced in steps of approximately 100 mm Hg, 50 mm Hg, 25 mm Hg, 15 mm Hg, 10 mm Hg, 5 mm Hg, and 3 mm Hg. After pumping down to each level, the pump is valved off and the cavity pressure monitored. The cavity pressure will rise as water and other volatiles in the cavity evaporate. When the cavity pressure stabilizes, the pump is valved in to complete the vacuum drying process. It may be necessary to repeat some steps, depending on the rate and extent of the pressure increase. Vacuum drying is complete when the pressure stabilizes for a minimum of 30 minutes at 3 mm Hg or less.

v. Open the valve to the vent port and allow the helium to flow into the DSC cavity.

w. Pressurize the DSC with helium to about 24 psia not to exceed 34 psia.

x. Helium leak test the inner top cover plate weld for leakage in accordance with ANSI N14.5 to a sensitivity of 1×10^{-5} atm cm^3/sec.

y. If a leak is found, repair the weld, repressurize the DSC and repeat the helium leak test.

z. Once no leaks are detected, depressurize the DSC cavity by releasing the helium through the VDS to the plant's spent fuel pool or radioactive waste system.

aa. Re-evacuate the DSC cavity using the VDS. The cavity pressure should be reduced in steps of approximately 10 mm Hg, 5 mm Hg, and 3 mm Hg. After pumping down to each level, the pump is valved off and the cavity pressure is monitored. When the cavity pressure stabilizes, the pump is valved in to continue the vacuum drying process. Vacuum drying is complete when the pressure stabilizes for a minimum of 30 minutes at 3 mm Hg or less.

bb. Open the valve on the vent port and allow helium to flow into the DSC cavity to pressurize the DSC to about 17.2 psia.

cc. Close the valves on the helium source.

dd. Remove the strongback, decontaminate as necessary, and store.

7.1.2.4 DSC Sealing Operations

a. Disconnect the VDS from the DSC. Seal weld the prefabricated plugs over the vent and siphon ports and perform a dye penetrant weld examination.

b. Install the automatic welding machine onto the outer top cover plate and place the outer top cover plate with the automatic welding system onto the DSC. Verify proper fit up of the outer top cover plate with the DSC shell.

c. Tack weld the outer top cover plate to the DSC shell. Place the outer top cover plate weld root pass.

d. Helium leak test the inner top cover plate and vent/siphon port plate welds using the leak test port in the outer top cover plate.

e. If a leak is found, remove the outer cover plate root pass, the vent and siphon port plugs and repair the inner cover plate welds. Then install the strongback and repeat procedure steps from section 7.1.2.3 step v.

f. Perform dye penetrant examination of the root pass weld. Weld out the outer top cover plate to the DSC shell and perform dye penetrant examination on the weld surface.

g. Seal weld the prefaricated plug over the outer cover plate test port and perform dye penetrant weld examinations.

h. Remove the automatic welding machine from the DSC.

i. Remove the cask drain port screw and drain the Cask/DSC annulus.

j. Install the drain port screw and tighten it to 65 ft-lbs. Install and tighten the drain port plug.

k. Install the cask lid. Lubricate, install and preload the lid bolts and torque them to 200 ft-lbs. Follow the torquing sequence shown in Figure 7-1. Repeat the torquing process following the sequence of Figure 7-1. Torque to 600 ft-lbs in second pass, 1000 ft-lbs in third pass and between 1440 and 1510 ft-lbs in the final pass. A circular pattern of torquing may be used, to eliminate further bolt movement.

7.1.2.5 Transport Cask Downending

a. Re-attach the transport cask lifting yoke to the crane hook, as necessary. Ready the transport trailer and cask support skid for service.

b. Move the scaffolding away from the cask as necessary. Engage the lifting yoke and lift the cask over the cask support skid on the transport trailer.

c. The transport trailer should be positioned so that cask support skid is accessible to the crane with the trailer supported on the vertical jacks.

d. Position the cask rear trunnions onto the transfer trailer support skid pillow blocks.

e. Move the crane forward while simultaneously lowering the cask until the cask front trunnions are just above the support skid upper trunnion pillow blocks.

f. Inspect the positioning of the cask to insure that the cask and trunnion pillow blocks are properly aligned.

g. Lower the cask onto the skid until the weight of the cask is distributed to the trunnion pillow blocks.

h. Inspect the trunnions to insure that they are properly seated onto the skid and install the trunnion tower closure plates.

i. Preparing the cask for transportation in accordance with the procedure described in Section 7.1.4.

7.1.3 Loading the DSC into the Cask from an HSM

The procedure for loading a DSC into the cask from a NUHOMS® Horizontal Storage Module (HSM) is summarized in this section. Depending on the most recent use of the cask, several of the initial steps listed below may not be necessary.

a. Using a suitable prime mover, bring the onsite transfer trailer (and cask) to the ISFSI site and back the trailer in front of the module face.

b. Remove the ram closure plate and the lid.

c. Install the ram trunnion support assembly.

d. Remove the HSM door and the DSC seismic restraint assembly from the HSM.

e. Use the trailer skid positioning system and optical surveying transits to align and dock the cask with the HSM.

f. Install the cask/HSM restraints.

g. Install and align the hydraulic ram cylinder in the ram trunnion support assembly.

h. Extend the ram hydraulic cylinder until the grapple contacts the DSC bottom cover.

i. Engage the DSC grapple ring with the ram grapple.

j. Retract the ram hydraulic cylinder until the DSC is fully seated in the cask.

k. Disengage the grapple from the DSC.

l. Remove the hydraulic ram and ram trunnion support assembly from the cask.

m. Install the cask ram closure plate with new o-rings. Lubricate, install and preload the ram closure bolts and torque them to 65 ft-lbs in the first pass and to 100 – 125 ft-lbs in the final pass follow the torquing sequence shown in Figure 7-1.

n. Remove the cask/HSM restraints.

o. Using the skid positioning system, move the cask to the transfer position and secure the onsite support skid to the onsite transfer trailer.

a. Verify that the lid O-ring seals are new. Discard any seals that have previously been installed in the cask.

b. If necessary, apply vacuum grease to the seals and the adjoining sealing surfaces on the cask lid.

c. Install the cask lid. Lubricate, install and preload the lid bolts and torque them to 200 ft-lbs. Follow the torquing sequence shown in Figure 7-1. Repeat the torquing process following the sequence of Figure 7-1. Torque to 600 ft-lbs in second pass, 1000 ft-lbs in third pass and between 1440 and 1510 ft-lbs in the final pass. A circular pattern of torquing may be used, to eliminate further bolt movement.

p. Preparing the cask for transportation in accordance with the procedure described in Section 7.1.4.

7.1.4 Preparing the Cask for Transportation

Once a loaded DSC has been placed inside the NUHOMS®-MP197 Cask, the following tasks are performed to prepare the cask for transportation. The cask is assumed to be seated horizontally in the onsite support skid.

a. Verify that the fuel assemblies meet the burnup, initial enrichment, cooling time, and decay heat criteria set forth in Section 1.2.3.

b. Verify that the cask surface removable contamination levels meet the requirements of 49 CFR 173.443 [2] and 10 CFR 71.87 [3].

c. Perform the assembly verification leakage rate testing specified in Section 7.4. This test must be performed within 12 months prior to the shipment. This test includes drawing a vacuum in the cavity between the cask and DSC, which ensures that any water has been removed.

7.1.5 Placing the Cask onto the Railcar

The procedure for placement of the cask on the railcar.

a. Using a suitable prime mover, bring the cask and onsite transfer trailer to the transportation railcar.

b. Remove the onsite transfer trailer trunnion block covers.

c. Install suitable slings around the cask front and rear trunnions.

d. Lift the cask from the onsite transfer trailer.

e. Place the cask onto the railcar transportation skid.

f. Remove the lifting slings from the cask.

g. Remove the cask front and rear trunnions and install the trunnion plugs.

h. Install the skid tie down strap.

i. Install the front and rear impact limiters onto the cask. Lubricate the attachment bolts with Nuclear Grade Neolube or equivalent and torque to 100 ft-lbs, diametrically in the first pass, and between 140 – 160 ft-lbs in the final pass.

j. Install the cask tamperproof device.

k. Monitor the cask radiation levels per 49 CFR 173.441 [2] and 10 CFR 71.47 [3] requirements.

Note: The procedure outlined above may also be used to transfer the cask directly from the fuel pool to a rail car, without using the transfer trailer, should appropriate facilities be available for such a transfer. The procedures outlined in Section 7.1.5 would also be applicable to such a scenario.

7.1.6 Glossary

The following terms, used in the above procedures, are defined below.

a.	Horizontal Storage Module (HSM):	Concrete shielded structure used for onsite storage of DSCs.
b.	Onsite Transfer Trailer:	A hydraulically supported trailer used for onsite movements of the cask.
c.	Onsite Support Skid:	Skid present on the onsite transfer trailer used to support the cask during onsite movements.
d.	Cask/DSC Annulus Seal:	Pneumatic seal placed between the cask and DSC during operations in the fuel pool.
e.	Cask Lifting Yoke:	Passive, open hook lifting yoke used for vertical lifts of the cask.

f.	Ram Trunnion Support Assembly:	Frame attached to the cask bottom which provides an anchor for the hydraulic ram during DSC insertion and retrieval.
g.	Skid Positioning System:	Hydraulically operated alignment system that provides the interface between the onsite transfer trailer and the onsite support skid.
h.	Hydraulic Ram:	Hydraulic cylinder used to insert/withdraw DSCs to/from HSMs.
i.	Cask/HSM Restraints:	Provides the load path between the cask and HSM during DSC transfer operations.

7.2 Procedures for Unloading the Cask

Unloading the NUHOMS®-MP197 Cask after transport involves removing the cask from the railcar and removing the canister from the cask. The cask is designed to allow the canister to be unloaded from the cask into a NUHOMS® staging module, or hot cell, and provisions exist to allow wet unloading into a fuel pool. The necessary procedures for these tasks are essentially the reverse of those described in Section 7.1.

7.2.1 Receipt of the Loaded NUHOMS®-MP197 Cask

Procedures for receiving the loaded cask after shipment are described in this section. Procedures for receiving an empty cask are provided in Section 7.1.1.

a. Verify that the tamperproof device is intact.

b. Remove the tamperproof device.

c. Remove the impact limiter attachment bolts from each impact limiter and remove the impact limiters from the cask.

d. Remove the transportation skid tie down strap.

e. Take contamination smears on the outside surfaces of the cask. If necessary, decontaminate the cask until smearable contamination is at an acceptable level.

d. Install the front and rear trunnions. Lubricate, install and preload the trunnion bolts and torque them to 250 ft-lbs in the first pass and to 520 -540 ft-lbs in the final pass follow the torquing sequence shown in Figure 7-1.

f. Place suitable slings around the cask front and rear trunnions.

g. Using a suitable crane, lift the cask from the railcar. Place cask onto the onsite transfer trailer. Remove the slings from the cask.

h. Install the onsite support skid pillow block covers.

i. Transfer the cask to a staging module, fuel pool, or dry cell and unload using the procedures described in the following sections.

7.2.2 Unloading the NUHOMS®-MP197 Cask to a Staging Module

The procedure for unloading a DSC from the cask into an HSM is summarized in this section. This procedure is typical of NUHOMS® ISFSIs and some of the steps listed below may be performed in a different order.

a. Position the onsite transfer trailer in front of the module face.

b. Sample the cask cavity atmosphere through the vent port. Flush the cask interior gases to the site radwaste systems if necessary.

c. Remove the cask ram closure plate. Discard the ram closure seals.

d. Install the ram trunnion support assembly.

e. Remove the HSM door.

f. Use the skid positioning system and optical surveying transits to align the cask with the HSM.

g. Remove the cask lid. Discard the lid seals.

h. Dock the cask with the HSM and install the cask/HSM restraints.

i. Install and align the hydraulic ram cylinder in the ram trunnion support assembly.

j. Extend the ram hydraulic cylinder until the grapple contacts the DSC bottom cover.

k. Engage the DSC grapple ring with the ram grapple.

l. Extend the ram hydraulic cylinder until the DSC is fully inserted in the HSM.

m. Disengage the grapple from the DSC.

n. Remove the hydraulic ram from the cask.

o. Remove the cask from the HSM.

p. Install the HSM door and DSC seismic restraint.

q. Move the onsite transfer trailer and cask to a low-dose maintenance area.

r. Inspect the cask hardware (including vent/drain/test port plugs) for damage that may have occurred during transportation. Repair or replace as necessary.

7.2.3 Unloading the NUHOMS®-MP197 Cask to a Fuel Pool

The procedure for unloading the cask and DSC into a fuel pool is summarized in this section. This procedure is intended to describe the type and quality of work performed to unload a DSC. Actual DSC unloading procedures may vary slightly from the tasks described below.

a. Tow the onsite transfer trailer to the fuel receiving area.

b. Remove the onsite support skid pillow block covers.

c. Using the cask lifting yoke, engage the front trunnions, rotate the cask to a vertical orientation, lift the cask from the onsite support skid, and place the cask in the decon pit.

d. Sample the cask cavity atmosphere through the vent port. Flush the cask interior gases to the site radwaste systems if necessary.

e. Remove the bolts from the cask lid and lift the lid from the cask.

f. Remove and discard the cask lid seals.

g. Locate the DSC siphon and vent ports using the indications on the DSC outer top cover plate.

h. Drill a hole in the DSC outer top cover plate and remove the siphon closure plug to expose the siphon port quick connect.

i. Drill a hole in the DSC outer top cover plate and remove the vent closure plug to expose the vent port quick connect.

j. Sample the DSC cavity atmosphere. If necessary, flush the DSC cavity gases to the site radwaste systems.

k. Fill the DSC with demineralized water through the siphon port with the vent port open and routed to the plant's off-gas system.

Note: The DSC cavity may optionally be filled with borated water.

l. Install a debris shield over the cask/DSC annulus.

m. Use plasma arc-gouging, a mechanical cutting system, or other suitable means remove the closure weld from the outer top cover plate.

CAUTION: Monitor the hydrogen concentration in the DSC cavity during this step to ensure that it does not exceed 2.4%.

n. Remove the DSC outer top cover plate.

o. Remove the closure weld from the DSC inner top cover plate.

p. Remove the DSC inner top cover plate.

q. Fill the cask/DSC annulus with demineralized water and install the cask/DSC annulus seal.

r. Remove excess material on the DSC inside shell surface which will interfere with top shield plug removal.

s. Clean the cask surface of dirt and debris that may have accumulated during transportation or weld removal.

t. Engage the cask lifting yoke to the front trunnions and install the shield plug cables between the yoke and the DSC top shield plug.

u. Lower the cask into the fuel pool.

v. Disengage the lifting yoke from the cask trunnions and remove the top shield plug.

w. Remove the fuel assemblies from the DSC.

x. Engage the lifting yoke to the cask front trunnions, remove the cask from the pool, and place it in the decon area.

y. Remove the water from the DSC cavity and DSC/Cask annulus.

z. Remove the DSC from the cask and handle in accordance with low-level waste procedures.

aa. Decontaminate the cask inner and outer surfaces as necessary.

bb. Inspect the cask hardware for damage that may have occurred during transportation. Repair or replace as necessary.

7.2.4 Unloading the NUHOMS®-MP197 Cask to a Dry Cell

The procedure for handling a DSC in a dry cell is highly dependent on the design of the dry cell and on the intended future use of the DSC. The procedure described below is intended to show the type of operations that will be performed and is not intended to be limiting.

a. Tow the onsite transfer trailer to the hot cell area.

b. Remove the onsite support skid pillow block covers.

c. Using the cask lifting yoke, engage the front trunnions, rotate the cask to a vertical orientation, lift the cask from the onsite support skid, and place the cask in the appropriate handling area.

d. Sample the cask cavity atmosphere through the vent port. Flush the cask interior gases to the site radwaste systems if necessary.

e. Remove the bolts from the cask lid and lift the lid from the cask.

f. Remove and discard the cask lid seals.

g. Transfer the cask into the hot cell using suitable handling equipment.

h. Remove the DSC from the cask and handle according to appropriate procedures.

i. Remove the cask from the hot cell.

j. Decontaminate the cask inner and outer surfaces as necessary.

k. Inspect the cask hardware for damage that may have occurred during transportation. Repair or replace as necessary.

7.3 Preparation of an Empty Cask for Transport

Previously used and empty NUHOMS®-MP197 casks shall be prepared for transport per the requirements of 49 CFR 173.427 [2].

7.4 Leakage rate Testing of the containment Boundary

The procedure for leak testing the cask containment boundary prior to shipment is given in this section. Assembly verification leak testing shall conform to the requirements of Section 6.5 and Section A3.5 of ANSI N14.5-1987, "American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment [1]". The order in which the leak tests of the various seals are performed may vary. If more than one leak detector is available then more than one seal may be tested at a time. Assembly verification leak test flow chart is presented in Figure 7-2.

a. Remove the cask vent port plug.

b. Install the cask port tool in the cask vent port. (The port tool is designed to replace the vent/drain and test port plugs and provide a means for loosening the vent/drain and test port screw in a controlled volume. This volume can be isolated from the cask volume by an externally accessible valve to ensure personell protection during cask venting operations.)

c. Turn the cask port tool handle to open the cask vent port.

d. Attach a suitable vacuum pump to the cask port tool.

e. Reduce the cask cavity pressure to below 1.0 psia.

f. Attach a source of helium to the cask port tool.

g. Fill the cask cavity with helium to atmospheric pressure.

h. Close the vent port screw by turning the cask port tool handle. Tighten the vent port screw to 65 ft-lbs.

i. Remove the helium saturated cask port tool and install a clean (helium free) cask port tool.

j. Connect a mass spectrometer leak detector capable of detecting a leak of $5x10^{-8}$ standard cubic centimeters per second to the cask port tool.

k. Evacuate the vent port until the vacuum is sufficient to operate the leak detection equipment per the manufacturer's recommendations.

l. Perform the leak test. If the leakage rate is greater than $1x10^{-7}$ standard cubic centimeters per second repair or replace the vent port screw and/or seal as required and retest.

Note: Upon removing the vent port screw, it will be necessary to reduce the cask cavity pressure below 1.0 psia and refill with helium through the vent port.

m. Remove the leak detection equipment from the cask vent port.

n. Remove the cask port tool from the vent port and replace the vent port plug.

o. Remove the top test port plug.

p. Install the cask port tool in the top test port.

q. Turn the cask port tool handle to open the top test port screw.

r. Connect the vacuum pump to the cask port tool.

s. Connect the leak detector to the cask port tool.

t. Evacuate the top test port until the vacuum is sufficient to operate the leak detection equipment per the manufacturer's recommendations. Perform a pressure rise leak test to confirm leakage past the outer seal is less than $7x10^{-3}$ std-cc/sec of air.

u. Perform the helium leak test. If the leakage rate is greater than $1x10^{-7}$ standard cubic centimeters per second repair or replace the cask top lid O-ring seals as required and retest.

Note: Upon removing and reinstalling the cask top closure, it will be necessary to reduce the cask cavity pressure below 1.0 psia and refill with helium through the vent port. The vent port assembly verification test must also be retested as described above.

v. Remove the leak detection equipment from the top test port.

w. Tighten the top test port screw to 65 ft-lbs. Remove the cask port tool from the top test port and replace the top test port plug.

x. Remove the cask drain port plug.

y. Install the cask port tool in the cask drain port.

z. Turn the cask port tool handle to verify that the cask drain port is closed.

aa. Connect the vacuum pump to the cask port tool.

bb. Connect the leak detector to the cask port tool.

cc. Evacuate the drain port until the vacuum is sufficient to operate the leak detection equipment per the manufacturer's recommendations.

dd. Perform the leak test. If the leakage rate is greater than $1x10^{-7}$ standard cubic centimeters per second repair or replace the drain port screw and/or seal as required and retest.

Note: Upon removing the drain port screw, it will be necessary to reduce the cask cavity pressure below 1.0 psia and refill with helium through the vent port. The vent port assembly verification test must also be retested as described above.

ee. Remove the leak detection equipment from the drain port.

ff. Tighten the drain port screw to 65 ft-lbs. Remove the cask port tool from the cask drain port and replace the drain port plug.

gg. Remove the bottom test port plug.

hh. Install the cask port tool in the bottom test port.

ii. Turn the cask port tool handle to open the bottom test port screw.

jj. Connect the vacuum pump to the cask port tool.

kk. Connect the leak detector to the cask port tool.

ll. Evacuate the bottom test port until the vacuum is sufficient to operate the leak detection equipment per the manufacturer's recommendations. Perform a pressure rise leak test to confirm leakage past the outer seal is less than $7x10^{-3}$ std-cc/sec of air.

mm. Perform the helium leak test. If the leakage rate is greater than $1x10^{-7}$ standard cubic centimeters per second repair or replace the cask ram closure O-ring seals as required and retest.

Note: Upon removing the cask ram closure, it will be necessary to reduce the cask cavity pressure below 1.0 psia and refill with helium through the vent port. The vent port assembly verification test must also be retested as described above.

nn. Remove the leak detection equipment from the bottom test port.

oo. Tighten the bottom test port screw to 65 ft-lbs. Remove the cask port tool from the bottom test port and replace the bottom test port plug.

This concludes the assembly verification leak test procedure.

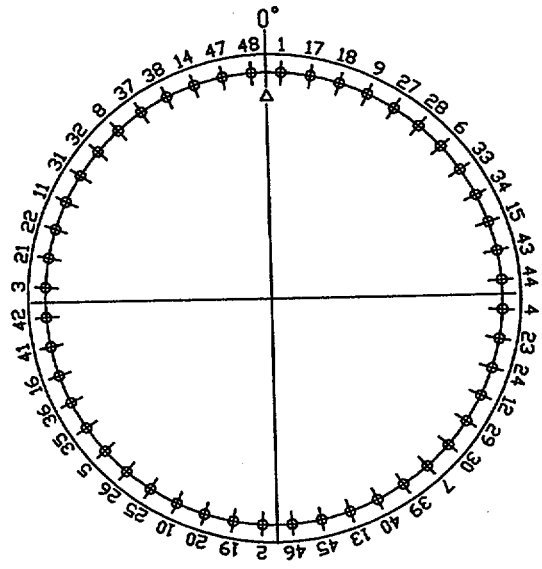
7.5 References

1. ANSI N14.5-1987, "American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment," American National Standards Institute, Inc., New York, 1987.

2. Title 49, Code of Federal Regulations, Part 173 (49 CFR 173), "Shippers - General Requirements for Shipments and Packaging."

3. Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), "Packaging and Transportation of Radioactive Material."

Figure 7-1
Torquing Patterns



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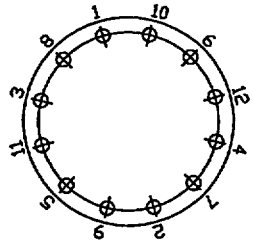
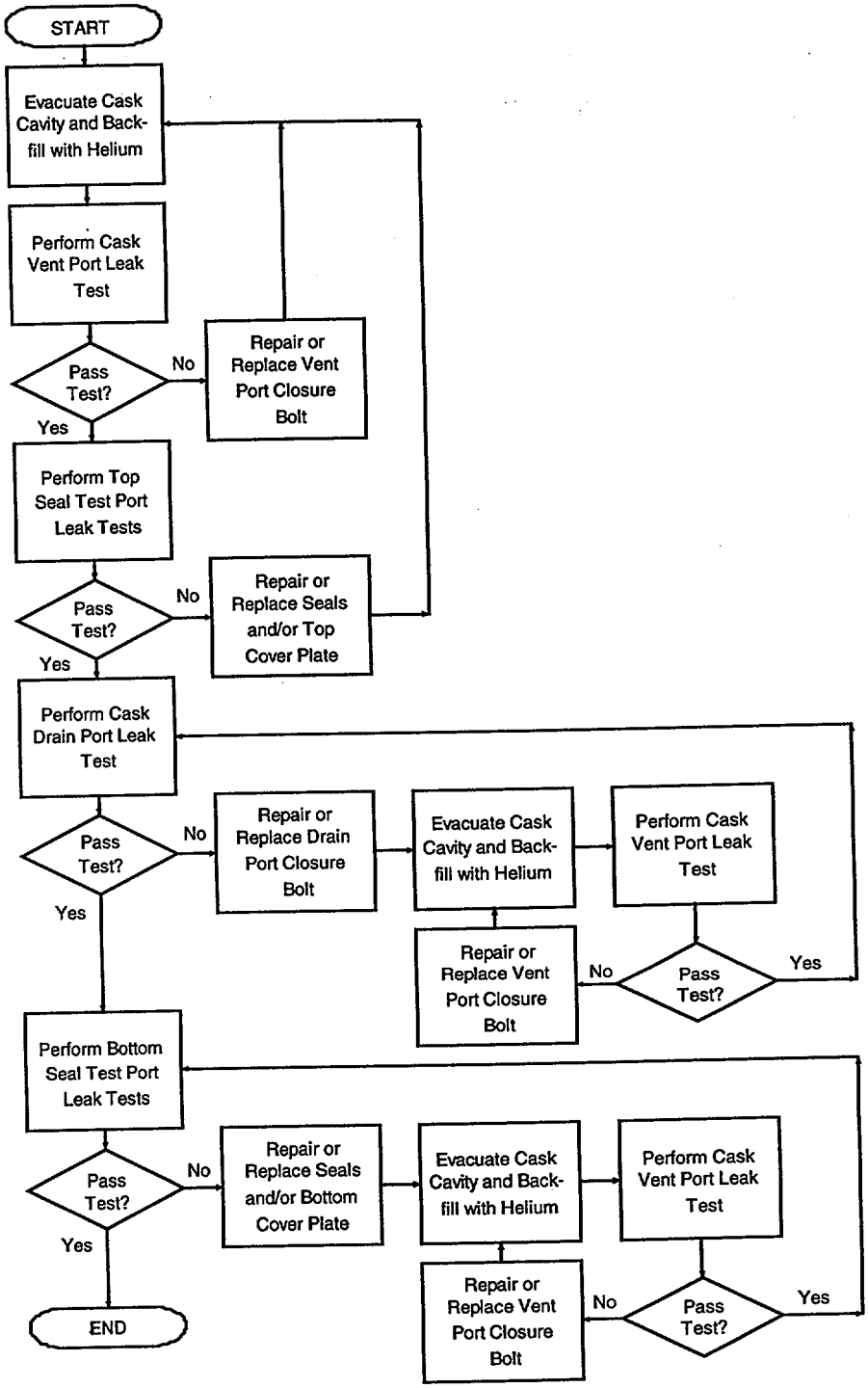


TRUNNION AND RAM CLOSURE PLATE

Figure 7-2
Assembly Verification Leak Test Flow Chart



NUHOMS[0]-MP197 TRANSPORT PACKAGING

CHAPTER 8

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CHAPTER 8

ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

The following reviews, inspections, and tests shall be performed on the NUHOMS®-MP197 packaging prior to initial transport. Many of these tests will be performed at the Fabricator's facility prior to delivery of the Cask/DSC to the utility for use. Tests will be performed in accordance with written procedures.

8.1.1 Visual Inspection

Visual inspections are performed at the Fabricator's facility to ensure that the packaging conforms to the drawings and specifications. The visual Inspections Include:

A. Cleanliness Inspections
B. Visual Weld Inspections as Required by ASME Code
C. Inspection of Sealing Surface Finish
D. Dimensional Inspections for Conformance with Chapter 1 Drawings

8.1.2 Structural and Pressure Tests

The structural analyses performed on the packaging are presented in Chapter 2. To ensure that the packaging can perform its design function, the structural materials are chemically and physically tested to confirm that the required properties are met. All welding is performed using qualified processes and qualified personnel, according to the ASME Boiler and the Pressure Vessel Code[1]. Base materials and welds are examined in accordance with the ASME Boiler and Pressure Vessel code requirements. NDE requirements for welds are specified on the drawings provided in Chapter 1. All NDE is performed in accordance with written procedures. The inspection personnel are qualified in accordance with SNT-TC-1A[2].

The NUHOMS®-MP197 containment welds, and the NUHOMS®-61BT DSC (canister) are designed, fabricated, tested and inspected, in accordance with ASME B&PV Code Subsection NB. The NUHOMS®-61BT fuel basket is designed, fabricated, and inspected in accordance with the ASME B&PV Code Subsection NG. Exceptions to the code are described in Chapter 2, Section 2.11. Welds of the noncontainment structure are inspected as per the NDE acceptance criteria of ASME B&PV Code, Subsection NF.

The impact limiter attachment bolt material shall be Charpy tested to show absorbed energy is at least 20 ft-lb at -20°F.

8.1.2.1 Pressure Tests

A pressure test is performed on the NUHOMS®-MP197 packaging assembly (with or without the DSC in place) at a pressure of 62.5 psig. This is well above 1.5 times the maximum normal operating pressure of 5.4 psig (Chapter 4). The test pressure is held for a minimum of 10 minutes. The test is performed in accordance with ASME B&PV Code, Section III, Subsection NB, Paragraph NB-6200 or NB-6300. All visible joints/surfaces are visually examined for possible leakage after application of the pressure.

In addition, a bubble leak test is performed on the resin enclosure. The purpose of this test is to identify any potential leak passages in the enclosure welds.

8.1.2.2 Load Tests

Two sets of trunnions are provided for the NUHOMS®-MP197 transport package lifting. One set of trunnions has double shoulders (non-single failure proof). The other set of trunnions has a single shoulder (single failure proof). Only one set of trunnions is used depending on site and transfer operation requirements. The trunnions are fabricated and tested in accordance with ANSI N14.6 [3]. A load test of three times the design lift load (for single failure proof trunnions) or 1 ½ times the design lift load (for non-single failure proof trunnions) is applied to the trunnions for a period of ten minutes, to ensure that the trunnions can perform satisfactorily.

A force equal to 1.5 times the impact limiter weight will be applied to the hoist rings of each limiter for a period of ten (10) minutes. At the conclusion of the test, the impact limiter hoist rings will be visually examined for defects and permanent deformations.

8.1.3 Leak Tests

8.1.3.1 NUHOMS®-MP197 Cask

Leakage tests are performed on the containment boundary prior to first use, typically at the Fabricator's facility. The fabrication verification leak test can be separated into the following five tests: 1) cask leakage integrity, 2) cask vent port closure bolt seal integrity, 3) cask drain port closure bolt seal integrity, 4) cask top closure (lid) seal integrity, and 5) ram closure plate seal integrity. These tests are usually performed using the helium mass spectrometer method. Alternative methods are acceptable, provided that the required sensitivity is achieved. The leak test is performed in accordance with ANSI N14.5 [4]. The personnel performing the leakage test are qualified in accordance with SNT-TC-1A [2].

Testing the Cask Leakage Integrity

Prior to lead pour and final machining of the inner shell, the cylindrical portion of the containment boundary including the bottom end closure will be leak tested in accordance with the requirements of ANSI N14.5, using temporary closures and seals for the ram and top closure

plates. Because the inner shell will not be accessible for leak testing after lead is poured, leak testing will be performed during the fabrication process, as permitted by ANSI N 14.5 Table 1. As one means of performing this test, the interior of the cask cavity may be flooded with a helium atmosphere while vacuum is drawn on the lead cavity to determine the leak rate. If a leak is discovered the source will be determined, repaired and the shells retested to ensure that the measured leak rate is less than $1x10^{-7}$ ref cm^3/s.

The test will be performed in conjunction with the non-destructive examination of the inner shell welds in accordance with ASME BPVC, Section III, Subsection NB, a PT examination of every weld layer in the shell to top forging closure weld, and a PT examination of all final machined weld surfaces of the inner shell per the ASME Code.

Fabrication Leak Test

The fabrication leak tests include the following:

- Testing the Cask Vent Port Closure seal Integrity
- Testing the Cask Drain Port Closure seal Integrity
- Testing the Cask top Closure Plate (Lid) seal Integrity
- Testing the Cask Ram Closure seal Integrity

In accordance with the ANSI N 14.5, section 7.1, the acceptance criteria is that each component must be individually leaktight, that is, the leak rate must be less than $1x10^{-7}$ ref cm^3/s.

8.1.3.2 NUHOMS®-61BT DSC

The NUHOMS®-61BT DSC containment is leak tested to verify it is leaktight in accordance with ANSI N14.5.

The leak tests are typically performed using the helium mass spectrometer method. Alternative methods are acceptable, provided that the required sensitivity is achieved.

8.1.4 Components Tests

8.1.4.1 Valves, Rupture Discs, and Fluid Transport Devices

There are no valves or couplings in the NUHOMS®-MP197 packaging.

8.1.4.2 Gaskets

The lid and all the other containment penetrations are sealed using double elastomer seals. The inner seal forms part of the containment boundary. Leak testing of the seals is described in section 8.1.3.

8.1.4.3 Impact Limiter Leakage Test

The following test will be performed, after all the seal welds are completed on the impact limiter, to verify that the impact limiter wood has been protected from any moisture exchange with the environment.

Pressurize each impact limiter container to a pressure of approximately 3 psig. Test all the weld seams and surfaces for leakage using a soap bubble test.

8.1.4.4 Functional Tests

The following functional tests will be performed prior to first use of the cask. Generally these tests will be performed at the fabrication facility.

a. Installation and removal of the lid, penetration covers, and other fittings will be observed. Each component will be checked for difficulties in installation and removal. After removal, each component will be visually examined for damage. Any defects will be corrected prior to acceptance of the cask.

b. After installation of the fuel basket into the DSC, each basket compartment will be checked by gauge to demonstrate that the fuel assemblies will fit in the basket.

8.1.5 Shielding Tests

Chapter 5 presents the analyses performed to ensure that the NUHOM®-MP197 package shielding integrity is adequate.

8.1.5.1 Neutron Shield Tests

The radial neutron shield is protected from damage or loss by the aluminum and steel enclosure. The neutron shield material is a proprietary, borated, reinforced polymer.

The primary function of the resin is to shield against neutrons, which is performed primarily by the hydrogen content in the resin. The sole function of the boron is to suppress n-γ reactions with hydrogen. The resin also provides some gamma shielding, which is a function of the overall resin density, and is not sensitive to composition.

The shielding performance of the resin can be verified adequately by chemical analysis and verification of density. Uniformity is assured by installation process control.

The following are acceptance values for density and chemical composition for the resin. The values used in the shielding calculations of Chapter 5 are included for comparison.

Chapter 5 values		Acceptance Testing Values		
Element	Nominal wt %	Element	wt %	acceptance range (wt %)
H	5.05	H	5.05	-10 / +20
B	1.05	B	1.05	± 20

The minimum resin density in acceptance testing is 1.547 g/cm^3. Resin composition or density test results which fall outside of this range will be evaluated to ensure that the shielding regulatory dose limits are not exceeded.

Density testing will be performed on every mixed batch of resin. Chemical analysis will be made on the first batch mixed with a given set of components, and thereafter whenever a new lot of one of the major components is introduced. Major components are aluminum oxide, zinc borate and the polyester resin, which combined make up 92% of the resin by weight.

Qualification tests of the personnel and procedure used for mixing and pouring the polyester resin used for radial neutron shielding are performed. Qualification testing includes verification that the chemical composition and density are achieved, and that the process is performed in such a manner as to prevent voids.

Tests are performed at loading to ensure that the radiation dose limits are not exceeded for each cask.

8.1.5.2 Gamma Shield Test

The NUHOMS®-MP-197 cask body poured lead shielding integrity will be confirmed via gamma scanning prior to installation of the neutron shield.

The outer cask surface is gridded and a chart is made to reflect the gridded surface. The gamma scan will be performed using a detector with a detection area enveloping the grid minimum area (e.g., for a 6" × 6" grid, the detector will encompass a 6" × 6" square). The acceptance criterion is determined by utilizing a test block made up from minimum thickness less 5% for the lead and steel sheets. The source is placed behind the test block assembly and the dose rate is measured. The dose rate measured on this test block is then used as the maximum acceptable reading for the inspected cask.

The source/detector distance used in the inspection shall be the same as that used in establishing the minimum dose rate in the mockup. Dose rates for minimum cask shell thickness shall be at least three times the background dose rate.

8.1.6 Neutron Absorber Tests

Functional Requirements of Poison Plates

The poison plates only serve as a neutron absorber for criticality control and as a heat conduction path; the NUHOMS®-MP197 safety analyses do not rely upon their mechanical strength. The basket structural components surround the plates on all sides. The radiation and temperature environment in the cask is not sufficiently severe to damage the aluminum matrix that retains the boron-containing particles. To assure performance of the plates' Important-to-Safety function, the only critical variables that need to be verified are thermal conductivity and B10 areal density as discussed in the following paragraphs.

Thermal Conductivity Testing

The poison plate material will be qualification tested to verify that the thermal conductivity equals or exceeds the values listed in Section 3.3. Acceptance testing of the material in production may be done at only one temperature in that range to verify that the conductivity equals or exceeds the corresponding value in Section 3.3.

Testing may be by ASTM E1225 [5], ASTM E1461 [6] , or equivalent method. Acceptance testing shall be performed on specimens removed from coupons adjacent to the final plates.

B10 Areal Density Testing

There are three types of NUHOMS®-61BT DSC baskets (Type A, B, and C), each identical with the exception of the minimum B10 content in the poison plates, as described in Chapter 1. Only one type of poison plate is used in a specific NUHOMS®-61BT DSC, based on the maximum enrichment of the fuel that will be placed in the NUHOMS®-61BT DSC. There are three acceptable poison materials, Boral®, Borated Aluminum and Boron Carbide/Aluminum Metal Matrix Composite (MMC). All materials shall be subject to thermal conductivity, dimensional, and visual acceptance testing. The B10 areal density and uniformity of the poison plates shall be verified using approved procedures as follows.

A. Borated Aluminum Using Enriched Boron, 90% B10 Credit

Material Description

The poison consists of borated aluminum containing boron which is isotopically enriched to 95 wt. % B10. Because of the negligibly low solubility of boron in solid aluminum, the boron appears entirely as discrete second phase particles of AlB_2 in the aluminum matrix. The matrix is limited to any 1000 series aluminum, aluminum alloy 6063, or aluminum alloy 6351 so that no boron-containing phases other than AlB_2 are formed. Titanium may also be added to form TiB_2 particles, which are finer. The effect on the properties of the matrix aluminum alloy are those typically associated with a uniform fine (1-10 micron) dispersion of an inert equiaxed second phase.

The cast ingot may be rolled, extruded, or both to the final plate dimensions.

The minimum boron 10 areal density for the three DSC types is given in Table 8-1 in the 90% credit column. As an example of the correspondence between areal density and the weight percent of boron in the alloy, 2.1 wt. % boron converts to slightly more than 40 mg B10/cm^2 as follows: (2.69 g BAl/cm^3)(2.1 wt. % B)(95 wt. % B10)(0.305 inch)(2.54 cm/inch) = 0.0416 g B10/cm^2. If thinner poison sheets are paired with aluminum sheets (see drawing NUH-61B-1065), the boron content is proportionately higher, up to that needed to maintain the minimum required B10 areal density.

Test Coupons

The poison plates are manufactured in a variety of sizes. Coupons will be removed between every other plate or at the end of the plate so that there is at least one coupon contiguous with each plate. Coupons will generally be the full width of the plate. Thermal conductivity coupons may be removed from the full width coupon. The minimum dimension of the coupon shall be as required for acceptance test specimens; 1 to 2 inches is generally adequate.

Acceptance Testing, Neutronic

Boron-10 areal density will be verified by neutron transmission testing of the coupons. The transmission through the coupons is compared with transmission through calibrated standards composed of a homogeneous boron compound without other significant poisons, for example zirconium diboride or titanium diboride. These standards are paired with aluminum shims sized to match the scattering by aluminum in the poison plates. Uniform but non-homogeneous materials such as metal matrix composites may be used for standards, provided that testing shows them to be equivalent to a homogeneous standard. The effective boron-10 content of each coupon, minus 3σ based on the number of neutrons counted for that coupon, must be greater than or equal to the minimum specified, for the DSC type A, B, or C, using the 90% credit column in Table 8-1.

The area of the collimated neutron beam used for neutron transmission testing is approximately 1 cm^2.

In the event that a coupon fails the neutron transmission measurement, the associated plate is rejected. As an alternate basis for accepting that plate, four additional measurements may be made at separate locations on the plate itself, or on coupons cut from the four corners of the plate. For each of the additional measurements, the value of areal density less 3σ based on the number of neutrons counted must be greater than or equal to the specified minimum in order to accept the plate.

If any of those four fails, the plate associated with the measurements will be rejected, but the average of the five measurements made is used as a datum in the statistical analysis of the lot (see below).

Macroscopic uniformity of boron-10 distribution will be verified by neutron radioscopy or radiography of the coupons. The acceptance criterion is that there be uniform luminance across the coupon. This inspection shall cover the entire coupon.

For every lot, initial sampling of coupons for neutron transmission measurements and radiography/radioscopy shall be 100%, which shall be considered normal sampling. Rejection of a given coupon shall result in rejection of its associated plate.

Reduced sampling (50%) may be introduced based upon acceptance of all coupons in the first 25% randomly sampled from the lot. A rejection during reduced inspection will require a return to 100% inspection of the lot. A lot is defined as all the plates produced from a single ingot.

A statistical analysis of the neutron transmission results for each lot shall be used to demonstrate that applying the one-sided tolerance factors for a 95% probability / 95% confidence level results in a minimum areal density greater than or equal to the minimum specified. The analysis shall be based on full data set for the lot, except that any data from materials which are rejected based on physical examination of the materials are not to be used in the statistical analysis. For example, a rejection based on dimensional or surface finish inspection is ground for excluding the datum associated with that plate. Failure of this statistical analysis shall result in rejection of the entire lot. Individual pieces in that lot may be accepted based on the determination of an alternate minimum thickness as follows.

All areal densities determined by neutron transmission for that lot may be converted to volume density by dividing by the thickness of the corresponding coupon. The one sided lower tolerance limit of volume density with 95% probability and 95% confidence may then be determined. Finally, the minimum specified value of B10 areal density may be divided by the 95/95 lower tolerance limit of B10 volume density to arrive at a minimum plate thickness. Then, all plates which have any location (other than local pits) thinner than this minimum shall be rejected, and those equal to or thicker may be accepted.

B. Boralyn®, Metamic® or equivalent Metal Matrix Composites, 90% B10 credit

Material Description

The poison plates consist of a composite of aluminum with boron carbide particulate reinforcement. The material is formed into a billet by powder metallurgical processes and either extruded, rolled, or both to final dimensions. The finished product has near-theoretical density and metallurgical bonding of the aluminum matrix particles. It is "uniform" blend of powder particles from face to face, i.e.; it is not a "sandwich" panel.

The specified minimum boron 10 areal density, depending on the NUHOMS®-61BT DSC Type, is given in Table 8-1 in the 90% credit column. As an example of the relation between boron 10 areal density and volume % boron carbide, 15 volume % boron carbide corresponds to slightly more than 40 mg B10/cm^2 as follows: 0.15(2.52 g/cm^3 B_4C)(0.782 gB/gB_4C)(0.185 g B10/gB)(0.305 in)(2.54 cm/in) = 0.0424 g B10/cm^2.

The process specifications for the material shall be subject to qualification testing to demonstrate that the process results in a material that:

- has a uniform distribution of boron carbide particles in an aluminum alloy with few or none of the following: voids, oxide-coated aluminum particles, B_4C fracturing, or B_4C/aluminum reaction products,
- meets the requirements for B10 areal density and thermal conductivity, and
- will be capable of performing its Important-to-Safety functions under the thermal and radiological environment of the NUHOMS®-61BT DSC over its 40-year lifetime.

The production of plates for use in the NUHOMS®-61BT DSC is consistent with the process used to produce the qualification test material. Processing changes may be incorporated into the production process, only if they are reviewed and approved by the holder of an NRC-approved QA plan who is supervising fabrication. The basis for acceptance shall be that the changes do not have an adverse effect on either the microstructure or the uniformity of the boron carbide distribution, because these are the characteristics that determine the durability and neutron absorption effectiveness of the material. The evaluation may consist of an engineering review, or it may consist of additional testing. In general, changes in key billet forming variables such as the temperature or pressure would require testing, while changes in mechanical processing variables, such as extrusion speed, would not have to be evaluated. Increasing the boron carbide content would require testing, while decreasing it would not.

Typical processing consists of:

- blending of boron carbide powder with aluminum alloy powder,
- billet formed by vacuum hot pressing (Boralyn® process) or by cold isostatic pressing followed by vacuum sintering (Metamic® process),
- billet extruded to intermediate or to final size,
- hot roll, cold roll and flatten as required, and
- anneal (optional)

Test Coupons

Test coupon removal will be the same as that for borated aluminum, as described in Section 8.1.6A.

Acceptance Testing, B10 Density

Acceptance testing will be the same as that for borated aluminum, as described in Section 8.1.6A.

C. Justification for Use of 90% Boron 10 Credit in Borated Aluminum and Metal Matrix Composites

According to NUREG/CR-5661 [7]

"Limiting added poison material credit to 75% without comprehensive tests is based on concerns for potential 'streaming' of neutrons due to nonuniformities. It has been shown that boron carbide granules embedded in aluminum permit channeling of a beam of neutrons between the grains and reduce the effectiveness for neutron absorption."

Furthermore

"A percentage of poison material greater than 75% may be considered in the analysis only if comprehensive tests, capable of verifying the presence *and uniformity* of the poison, are implemented."

The calculations in Chapter 6 use boron areal densities that are 90% of the minimum values specified here for these materials. This is justified by the following considerations.

a) The coupons for neutronic inspection are removed adjacent to the finished plates. As such, they are taken from locations that are representative of the finished product.

b) Neutron radiography/radioscopy of coupons will detect macroscopic non-uniformities in the B10 distribution such as could be introduced by the fabrication process.

c) Neutron transmission measures effective B10 content directly. The term "effective" is used here because if there are any of the effects noted in NUREG/CR-5661, the neutron transmission technique will measure not the physical B10 areal density, but a lower value. Thus, this technique by its nature screens out the microscopic non-uniformities which have been the source of the recommended 75% credit for B10 in criticality evaluations.

d) The use of neutron transmission and radiography/radioscopy satisfies the "and uniformity" requirement emphasized in NUREG/CR-5661 on both the microscopic and macroscopic scales.

e) Statistical analysis of the neutron transmission results will verify with 95% confidence and 95% certainty that the boron 10 areal density is 100% or more of the minimum specified value at any location in the lot.

f) The recommendations of NUREG/CR-5661 are based upon testing of a poison with boron carbide particles averaging 85 microns. The boride particles in these materials are finer: borated aluminum approximately 5-10 microns and metal matrix composites 1-25 microns. For a given degree of uniformity, fine particles will be less subject to neutron streaming than coarse particles.

g) Because the material reviewed in the NUREG was a sandwich panel, the thickness of the boron carbide-containing center could not be directly verified by thickness measurement. The alloy and MMC specified here are uniform throughout their thickness.

D. Boral®, 75% B10 Credit

Material Description, Boral®

Boral® consists of a core of mechanically bonded aluminum and boron carbide powders sandwiched between two outer layers of aluminum 1100, which is mechanically bonded to the core. The boron carbide particles average approximately 85 microns in diameter. The sheet is formed by filling an aluminum 1100 box with the boron carbide/aluminum powder mixture, and then hot-rolling the box. The walls of the box form the cladding, while the powder mixture forms the core of the Boral®. Additional information on the fabrication, specification, and performance of Boral® may be found in references [8]and [9].

Acceptance Testing, Neutronic

Boral® will be procured in accordance with AAR Manufacturing Inc.'s Standard Specification for Boral® Composite Sheet [8]. In accordance with Section 7.3 of that specification, B 10 areal density will be verified by chemical analysis or by neutron attenuation testing, using a sampling plan that will verify that the coupon meets the specified minimum values of with 95% probability at the 95% confidence level.

Boral® has been used in dry storage, wet storage, and research reactor control blades for over 25 years. Because the standard 75% credit is being used for boron 10, it is not necessary to impose requirements in addition to those in the manufacturer's standard specification.

8.2 Maintenance Program

8.2.1 Structural and Pressure Tests

Within 14 months prior to any lift of a NUHOMS®-MP197 transport package, the lifting (top) trunnions shall be subject to either of the following:

1. A test load equal to 300% of the maximum service load per ANSI N14.6 [3], paragraph 7.3.1(a) for single failure proof trunnions or a test load equal to 150% of the maximum service load per ANSI N14.6, paragraph 7.3.1(b) for non-single failure proof trunnions. After sustaining the test load for a period of not less than 10 minutes, critical areas shall be subjected to visual inspection for defects, and all components shall be inspected for permanent deformation.

2. Dimensional testing, visual inspection and nondestructive examination of critical areas of the trunnions including the bearing surfaces in accordance with Paragraph 6.3.1 of ANSI N14.6. The examination will be performed for subsequent shipments.

8.2.2 Leak Tests

The following containment boundary components shall be subject to periodic maintenance, and preshipment leak testing in accordance with ANSI N14.5:

Vent Port
Drain Port
Top Closure Plate
Ram Port

Test	Frequency	Acceptance Criteria	Typical Method (ANSI N14.5 TABLE A-1)
Periodic	within 12 months Prior to shipment	Each component individually $\leq 1\times10^{-7}$ ref cm^3/s	(He) A.5.3 A.5.4
Pre-shipment	Before each shipment, after the contents are loaded and the package is closed	No detected leakage, sensitivity of 10^{-3} ref cm^3/s or better	A.5.1 A.5.2 A.5.8 A.5.9
Maintenance	After maintenance repair or replacement of containment by components. Including inner seals	Each component individually $\leq 1\times10^{-7}$ ref cm^3/s	(He) A.5.3 A.5.4

No leak tests are required prior to shipment of an empty NUHOMS®-MP197 packaging.

8.2.3 Subsystem Maintenance

8.2.3.1 Fasteners

The lid bolts, ram cover bolts, vent plug, drain plug, and test plugs shall be inspected after each use, and annually, for deformed or stripped threads. Damaged parts shall be evaluated for continued use and replace as required.

8.2.3.2 Impact Limiters

A visual examination of the impact limiters before each shipment will be performed to ensure that the impact limiters have not been degraded between leak test intervals. If there is no evidence of weld cracking or other damage which could result in water in-leakage, the wood will not be degraded. If there is visual damage, the impact limiter will be removed from service, repaired, if possible, and inspected for degradation of the wood. Impact limiters will be leak tested once every five years to ensure that water has not entered the impact limiters. If the leak test indicates that the impact limiters have a leak, a humidity test will be performed to verify that there is no free water in the impact limiters.

8.2.4 Valves, Rupture Discs, and Gaskets on Containment Vessel

If a ram cover or the lid is removed, the seals are replaced prior to spent fuel transport. The seals will be leak tested after retorquing the bolts in accordance with Section 7.4.

The elastomer seals may be reused for transport of an empty NUHOMS®-MP197 packaging.

There are no valves or rupture discs on the NUHOMS®-MP197 packaging containment.

8.2.5 Shielding

There are no periodic tests or inspections required for the NUHOMS®-MP197 shielding. Radiation surveys will be performed on the package exterior to ensure that the limits specified in 10 CFR 71.47 are met prior to each shipment.

8.2.6 Thermal

There are no periodic tests or inspections required for the NUHOMS®-MP197 package heat transfer components.

8.3 References

1. ASME Boiler and Pressure Vessel Code, Section III, 1998 Edition including 1999 addenda.

2. SNT-TC-1A, "American Society for Nondestructive Testing, Personnel Qualification and Certification in Nondestructive Testing," 1992.

3. ANSI N14.6-1993, "American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More for Nuclear Materials," New York

4. ANSI N14.5-1997, "American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials"

5. ASTM E1225, "Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique."

6. ASTM E1461, "Thermal Diffusivity of Solids by the Flash Method."

7. NUREG/CR-5661, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages," 1997.

8. AAR Advanced Structures, "Boral®, The Proven Neutron Absorber".

9. AAR Advanced Structures, Boral® Product Performance Report 624.

Table 8-1
Specified Boron 10 Content

NUHOMS-61BT® DSC Type	Chapter 6 Analysis B10 Areal Density (g/cm^2)	Specified Minimum B10 Areal Density (g/cm^2)	
		90% B10 Credit Materials (note 1)	75% B10 Credit Materials (note 2)
A	0.019	0.021	0.025
B	0.029	0.032	0.038
C	0.036	0.040	0.048

Notes:
1. Borated aluminum, Boralyn®, Metamic®, or equivalent metal matrix composites
2. Boral®