71-9288

COLUMBIANA HI TECH LLC

Nuclear Manufacturing Excellence

March 6, 2007

Robert A. Nelson
Chief, Spent Fuel Licensing Section
Spent Fuel Project Office
United States Nuclear Regulatory Commission
Mail stop: O-13D13
Washington, DC 20555-0001

Cc: Bill Brach, Director- SFPO

Re: License Amendment request for Certificate of Compliance USA/9288/B (U) F-96, revision 7, for the model no. CHT-OP-TU Package.

Dear Mr. Nelson,

Columbiana Hi Tech, LLC submits the proposed amendment request in the form of revised Safety Analysis Report (SAR) pages to allow the use of a sleeve or insert within the nominal 8" oxide vessel for transport of heterogeneous material. With the use of a sleeve or insert within the 8" vessel, the performance requirements for use of the package as prescribed in the SAR are satisfied.

Included are proposed revisions to section 1.2.3 and a new appendix 6.8.2 which provides KENO V.a Calculations for support in the approval process for the sleeve or insert. Attachment A provides instructions for inserting the revised pages into revision 7 as supplemented, February 2006 of the SAR. Attachment B provides a listing of the changes made along with an explanation for the modification. Attachment C provides the changed and added pages.

If you have any questions concerning this request or this submittal, please feel free to contact CHT at your convenience.

Sincerely,

FOR D. W. OLSON

Donald W. Olson
President
Columbiana Hi Tech

NMSS01

1802 Fairfax Road • Greensboro, North Carolina 27407 Phone 336/852-5679

Enclosures:
Attachment A: Instructions for updating revision 7 to revision 8.
Attachment B: Explanation of changes to CHT-OP-TU SAR revision 7.
Attachment C: Revision 8 changed pages.

ATTACHMENT A

Instructions for Updating Revision 7 to Revision 8:

Title page and Table of Contents:

Remove (Revision 7):	Add (Revision 8):
Title page	Title page
Table of Contents page iv and vi	Table of Contents page iv and vi

Section 1:

Remove (Revision 7):	Add (Revision 8):
1-3	1-3
1-4	1-4

Section 2:

Remove (Revision 7):	Add (Revision 8):
No changes	

Section 3:

Remove (Revision 7):	Add (Revision 8):
No changes	

Section 4:

Remove (Revision 7):	Add (Revision 8):
No changes	

Section 5:

Remove (Revision 7):	Add (Revision 8)
No changes	

Section 6:

Remove (Revision 7):	Add (Revision 8):
6-i	6-i
6-ii	6-ii
6-35	6-36
None	6-57
None	6-58
None	6-59
None	6-60
None	6-61
None	6-62

Section 7:

Remove (Revision 7):	Add (Revision 8):
No changes	

Section 8:

Remove (Revision 7):	Add (Revision 8):
No changes	

ATTACHMENT B – Explanation of Changes

Changed page	Explanation of changes made
Title page	Updated revision status from "Revision 7 as supplemented, February 2006" to read: "Revision 8, February 2007"
Table of Contents page iv and vi	Modified pages to add 6.8.2 and table 6.8.2-1 (revision 8 changes)
1-3	Inserted new paragraph (c) allowing for use of sleeve or insert. The existing paragraphs (c), (d), and (e) have now become paragraphs (d), (e), and (f). Foot note 1 has been removed from this page and moved to page 1-4. (Revision 8 change)
1-4	Paragraphs (f), (g), (h), (i), and (j) are changed to (g), (h), (i), (j), and (k) due to the new paragraph inserted on page 1-3. Foot note 1 removed from page 1-3 has been added to page 1-4. (Revision 8 change)
6-i	Revised index to add 6.8.2 Sleeved 8"Diameter Oxide Vessel Calculations for Heterogeneous Materials. (Revised 8 change)
6-ii	Revised index to add table 6.8.2-1 Summary of Results for Sleeved 8" Oxide Vessels.
6-35	Revised page to add 6.8.2 to List of Appendices. (revised 8 change)
6-57 (new page)	Added to SAR (revision 8 change) Sleeved 8" Diameter Oxide Vessels Calculations for Heterogeneous Materials.
6-58 (new page)	Added to SAR (revision 8 change) table 6.8.2-1 Summary of Results for Sleeved 8" Oxide Vessels.
6-59 (new page)	Added to SAR (revision 8 change) Input Cases.
6-60 (new page)	Added to SAR (revision 8 change) Input Cases (continued).
6-61 (new page)	Added to SAR (revision 8 change) Input Cases (continued).
6-62 (new page)	Added to SAR (revision 8 change) Input Cases (continued).

ATTACHMENT C

Revision 8 Changed Pages

SAFETY ANALYSIS REPORT
FOR THE
MODEL CHT-OP-TU
(Revision 8, February 2007)

Submitted by:

Columbiana Hi Tech, LLC
1802 Fairfax Road
Greensboro, NC 27407

(TABLE OF CONTENTS, CONTINUED)

6.1.1 Normal Conditions of Transport (NCT) 6-2
6.1.2 Off-Normal Condition (ONC) 6-3
6.1.3 Hypothetical Accident Condition (HAC) 6-3
6.1.4 Discussion and Results Summary 6-4
6.2 PACKAGE FUEL LOADING 6-4
6.3 MODEL SPECIFICATION 6-4
6.3.1 Description of Calculational Model 6-4
6.4 CRITICALITY CALCULATION 6-7
6.4.1 Calculation Method 6-7
6.4.2 Loading Optimization 6-7
6.4.3 Criticality Results 6-8
6.5 CRITICAL BENCHMARK EXPERIMENTS 6-8
6.5.1 Benchmark Experiments and Applicability 6-8
6.5.2 Details of the Benchmark Calculations 6-9
6.5.3 Benchmark Results 6-9
6.6 SCALE43 INPUT DECKS - BOUNDING CASES 6-9
6.6.1 Homogeneous Cases 6-9
6.6.2 Heterogeneous Cases 6-19
6.6.3 Tilt Sensitivity Cases 6-28
6.7 REFERENCES 6-35
6.8 LIST OF APPENDICES 6-35
6.8.1 Equivalent Water Density Calculation for Rigid Foam Insulation 6-56
6.8.2 Sleeved 8" Diameter Oxide Vessel Calculations for Heterogeneous Materials 6-57

SECTION SEVEN OPERATING PROCEDURES

7 OPERATING PROCEDURES 7-1
7.1 LOADING PROCEDURES FOR A TYPE A SHIPMENT 7-1
7.1.1 Oxide Vessel Inspection 7-1
7.1.2 Transport Unit Inspection 7-1
7.1.3 Package Loading 7-2
7.2 LOADING PROCEDURES FOR A TYPE B SHIPMENT 7-3
7.2.1 Oxide Vessel Inspection 7-3
7.2.2 Transport Unit Inspection 7-3
7.2.3 Package Loading 7-4
7.3 SECURING THE PACAKAGE TO THE CONVEYANCE 7-5
7.3.1 ISO Containers 7-5
7.3.2 Tie Down Using Hold-down Bars 7-5
7.3.3 Tie Down Using Strapping (Straps, Chain or Cable) 7-6
7.3.4 Tie Down Using Other Methods 7-7
7.4 UNLOADING PROCEDURES 7-7

LIST OF TABLES AND FIGURES

Table 1-1 Allowable Content For Shipment Of Reprocessed Uranium Oxides 1-5
Table 1-2 Packaging And Payload Weights 1-5
Table 2-1 Structural Evaluation Results 2-17
Table 2-2 Mechanical Properties Of Materials 2-20
Table 3-1 Thermal Evaluation Results 3-9
Table 3-2 Thermal Properties Of Materials 3-10
Table 3-3 Package Dimensions 3-11
Table 3-4 Applied Heat Loads And Initial Conditions 3-11
Table 4-1 Package Total Maximum Radioactivity for Type B Level I Payload Specified in Table 1-1 4-7
Table 4-2 Mixture A_2 Calculation for Type B Level I Payload Specified in Table 1-1 4-8
Table 4-3 Package Total Maximum Radioactivity for Type B Level II Payload Specified in Table 1-1 4-9
Table 4-4 Mixture A_2 Calculation for Type B Level II Payload Specified in Table 1-1 4-10 4-10
Table 6-1 Quantity Of Fissile Isotopes Evaluated 6-36
Table 6-2 Summary Of Results 6-37
Table 6-3 CHT-OP-TU Evaluated Fuel Loading 6-39
Table 6-4 CHT-OP-TU Dimensions and Materials for NCT and ONC 6-40
Table 6-4a CHT-OP-TU Dimensions and Materials for HAC 6-41
Table 6-5 Package Regional Densities 6-42
Table 6.8.2-1 Summary of Results for Sleeved 8" Oxide Vessels 6-58

Figure 2.7- 1 Free Drop On Bottom 2-21
Figure 2.7- 2 Free Drop On Corner 2-21
Figure 2.7- 3 Free Drop On Edge 2-22
Figure 2.7- 4 Puncture Drop On Side 2-22
Figure 2.7- 5 Thermal Test Elevation View 2-23
Figure 2.7- 6 Thermal Test Plan View 2-23
Figure 2.7- 7 Performance Test Measurements 2-24
Figure 2.7- 8 Oxide Vessel/Sleeve Shift 2-25
Figure 6-1 NCT Homogeneous: $k_{eff} + 2\sigma$ versus Mixture Density for Dry Powder 5.0 wt% Enriched Reprocessed Uranium Oxide in a n 8" diameter Oxide Vessel 6-43
Figure 6-2 NCT Heterogeneous: $k_{eff} + 2\sigma$ versus Lattice Pitch for Dry Spherical Pellets 5.0 wt% Enriched Reprocessed Uranium Oxide in a 7.5" diameter Oxide Vessel 6-44

1.2.3 Contents of Packaging

1.2.3.1 Type and Form of Materials

The CHT-OP-TU is used for the safe transport of fissile uranium compounds. The material must be a in a chemically stable solid form up to 400°F. The CHT-OP-TU can accommodate:

(a) Homogeneous forms (powder or crystalline) may be shipped in any of the Oxide Vessels to a maximum allowable load per Oxide Vessel of 402lb (182.3kg);

(b) Heterogeneous forms (pellets, mixtures of powder and pellets, solidified materials, or dewatered materials) may be shipped in the 7.5- and 6-inch Oxide Vessels to a maximum allowable load per Oxide Vessel of 402lb (182.3kg);

(c) Heterogeneous forms (pellets, mixtures of powder and pellets, solidified materials, or dewatered materials) may be shipped in the 8-inch Oxide Vessels to a maximum allowable load per Oxide Vessel of 402lb (182.3kg) provided that the vessel is sleeved or provided with an insert that reduces the cross sectional area to less than that of a 7.5-inch vessel;

(d) All material shall meet the following criteria:

(i) The ratio of the non-fissile atoms to uranium atoms of the compound is not less than 2.0,

(ii) The theoretical density of the compound is less than that of uranium dioxide (10.96 g/cc),

(iii) U-metal, U-metal alloys, or uranium hydrites (e.g., UH) may not be shipped in the CHT-OP-TU.

(e) Type B Level II materials must be packaged in an Oxide Vessel that is engraved "Type B Level II." Type B Level I materials may be packaged in an Oxide Vessel that is engraved "Type B Level I" or "Type B Level II." Type A materials may be packaged in any of the Oxide Vessels. Type and Level are designated per Table 1-1.

(f) The material may be packaged in plastic containers within the oxide vessel, provided that the total plastic per Oxide Vessel (four Oxide Vessels per package) does not exceed 1307g water-hydrogen equivalent (or 1000g. of Polyethylene)

provided the decay heat of the payload is essentially zero (less than 0.068 W/m^3)[1]. Payloads having a decay heat greater than zero may use non-hydrogen-bearing plastics such as Teflon™ (polytetrafluoroethylene or PTFE) or metallic containers.

(g) The material may contain other plastic materials (mixed with the material either homogenously or heterogeneously), provided that the total plastic per Oxide Vessel, including any plastic containers used for packaging, does not exceed 1307g water-hydrogen equivalent (or 1000 g. of Polyethylene).

(h) Excepting the allowance for plastic materials as limited by paragraphs f and g of this section, materials with a hydrogen density greater than water must be excluded.

(i) The material may be mixed with other non-fissile materials with the exception of deuterium, tritium, and beryllium.

(j) An unlimited quantity of graphite may be present within the Oxide Vessels.

(k) The heat generation rate due to radiological decay of the material is less than 10.3 W/m^3.

1.3 List of Appendices

1.3.1 CHT-OP-TU Engineering Drawings

1.3.2 Material Specifications for the CHT-OP-TU Packaging

1.3.2-A Closed-Cell Impact-Absorbing Foam Specification CHT-FOAM-001
1.3.2-B Paint Specifications

---

[1] This value is based upon the A_2 limit for ^{234}U (the bounding heat-producing isotope when combined with the A_2 limit). (0.16Ci) (2.83E-2 W/Ci) (10.96 g/cc) / (729 kg) = 0.068 W/m^3).

SECTION 6
CRITICALITY EVALUATION

TABLE OF CONTENTS

6 CRITICALITY EVALUATION 6-1

6.1 DISCUSSION AND RESULTS 6-1
6.1.1 Normal Conditions of Transport (NCT) 6-2
6.1.2 Off-Normal Condition (ONC) 6-3
6.1.3 HAC Discussion and Results 6-3
6.1.4 Discussion and Results Summary 6-4
6.2 PACKAGE FUEL LOADING 6-4
6.3 MODEL SPECIFICATION 6-4
6.3.1 Description of Calculational Model 6-4
6.4 CRITICALITY CALCULATION 6-7
6.4.1 Calculational Method 6-7
6.4.2 Loading Optimization 6-7
6.4.3 Criticality Results 6-8
6.5 CRITICAL BENCHMARK EXPERIMENTS 6-8
6.5.1 Benchmark Experiments and Applicability 6-8
6.5.2 Details of the Benchmark Calculations 6-9
6.5.3 Benchmark Results 6-9
6.6 SCALE43 INPUT DECKS - BOUNDING CASES 6-9
6.6.1 Homogeneous Cases 6-9
6.6.2 Heterogeneous Cases 6-19
6.6.3 Tilt Sensitivity Cases 6-28
6.7 REFERENCES 6-35
6.8 List of APPENDICES 6-35
6.8.1 Water Equivalent Density Calculation 6-56
6.8.2 Sleeved 8" Diameter Oxide Vessel Calculations for Heterogeneous Materials 6-57

LIST OF TABLES AND FIGURES

Table 6-1 Quantity of Fissile Isotopes Evaluated[1] 6-36

Table 6-2 Summary of Results 6-37

Table 6-3 CHT-OP-TU Fuel Loading 6-39

Table 6-4 CHT-OP-TU Dimensions and Materials for NCT and ONC 6-40

Table 6-4a CHT-OP-TU Dimensions and Materials for HAC 6-41

Table 6-5 Package Regional Densities 6-42

Table 6.8.2-1 Summary of Results for Sleeved 8" Oxide Vessels 6-58

Figure 6-1 NCT Homogeneous: $k_{eff} + 2\sigma$ versus Mixture Density for Dry Powder 5.0 wt% Enriched Reprocessed Uranium Oxide in a 8" diameter Oxide Vessel 6-43

Figure 6-2 NCT Heterogeneous: $k_{eff} + 2\sigma$ versus Lattice Pitch for Dry Spherical Pellets 5.0 wt% Enriched Reprocessed Uranium Oxide in a 7-5" diameter Oxide Vessel 6-44

Figure 6-3 Sensitivity of the Multiplication Factor to Variations in Foam Insulation Density 6-45

Figure 6-4 ONC Homogeneous: Water- and Water/Poly-Moderated Homogeneous 5wt% Enriched Reprocessed Uranium Oxide Powder in a 8" Diameter Oxide Vessel 6-46

Figure 6-5 ONC Heterogeneous: Water- and Water/Poly-Moderated Heterogeneous 5wt% Enriched Spherical Pellets of Reprocessed Uranium Oxide in a 7.5"Diameter Oxide Vessel 6-47

Figure 6-6 Illustration of KENO Model of a single CHT-OP-TU for the Normal Condition (front corner removed) 6-48

Figure 6-7 Front and Side View of SCALE Model of a single CHT-OP-TU with Tilted Oxide Vessels for Hypothetical Accident Conditions Sensitivity Study 6-49

Figure 6-7a Section View of SCALE Model of CHT-OP-TU for HAC (untilted model) 6-50

Figure 6-7b Sensitivity of the HAC System to Oxide Vessel Tilt, up to the Maximum Tilt Measured 6-51

Figure 6-8 Arrangement of Packages Analyzed for Hypothetical Accident Conditions (Shown at the bottom plane of the Oxide Vessels) 6-52

Figure 6-9 NCT, Graphite-moderation with Both Powder and Pellets (8" and 7.5" vessel, respectively) 6-53

Figure 6-10 K_{eff} as a Function of Interspersed Moderator (water) Density 6-54

Figure 6-11 Illustration of the Relative Multiplication Factors for Various Arrays Sizes 6-55

```
UNIT 70
ARRAY  6  3*0.0
REPLICATE   3 1  5R0.3048 0.635  1
REPLICATE   0 1  5R0 10.16  1
UNIT 80
ARRAY  7  3*0.0
REPLICATE   3 1  5R0.3048 0.635  1
REPLICATE   0 1  5R0 10.16  1
UNIT 90
ARRAY  8  3*0.0
REPLICATE   3 1  5R0.3048 0.635  1
REPLICATE   0 1  5R0 10.16  1
UNIT 95
ARRAY  9  3*0.0
REPLICATE   3 1  5R0.3048 0.635  1
REPLICATE   0 1  5R0 10.16  1
GLOBAL
UNIT 110
ARRAY  10  3*0.0
REPLICATE   5 1  6R30.48  1
END GEOM
READ ARRAY
ARA=1  NUX=1  NUY=1  NUZ=6  FILL 15 14 13 12 11
10  END FILL
ARA=2  NUX=1  NUY=1  NUZ=6  FILL 25 24 23 22 21 20
END FILL
ARA=3  NUX=1  NUY=1  NUZ=6  FILL 35 34 33 32 31 30
END FILL
ARA=4  NUX=1  NUY=1  NUZ=6  FILL 45 44 43 42 41 40
END FILL
ARA=5  NUX=2  NUY=2  NUZ=1  FILL  F6  END FILL
ARA=6  NUX=2  NUY=2  NUZ=1  FILL  F7  END FILL
ARA=7  NUX=2  NUY=2  NUZ=1  FILL  F8  END FILL
ARA=8  NUX=2  NUY=2  NUZ=1  FILL  F9  END FILL
ARA=9  NUX=2  NUY=2  NUZ=1  FILL  F5  END FILL
'ARA=10 NUX=1  NUY=1  NUZ=1  FILL  60  END FILL
ARA=10  NUX=4  NUY=4  NUZ=4  FILL
60 70 60 70 90 60 70 80 60 90 80 70 90 80 90 80
2Q16
95 95 95 95 95 60 95 95 95 95 80 95 95 95 95 95 END
FILL
END ARRAY
READ BOUNDS
ALL=VOID
END BOUNDS
END DATA
END
```

6.7 References

[6-1] Montgomery, Rosemary A. *Validation of SCALE-PC for Uranium Systems with Enrichments between 0.72 and 10.0 wt% U-235*, MTS985, Rev. 2, 7/30/01.

6.8 List of Appendices

6.8.1 Water Equivalent Density Calculation

6.8.2 Sleeved 8" Diameter Oxide Vessel Calculation for Heterogeneous Materials

Sleeved 8" Diameter Oxide Vessel Calculations For Heterogeneous Materials

Calculations documented in Table 6-2 indicated that the nominal 8" diameter (allowed vessel diameters ranging from 7.8" to 8.2") oxide vessel is too large for accommodation of heterogeneous materials (pellets). As a result, calculations for a nominal 7.5" diameter (allowed vessel diameters ranging from 7.3" to 7.7") oxide vessel were document in Table 6-2 to provide an acceptable means for the transport of heterogeneous materials. However, as documented in this Appendix, the use of metallic inserts within the 8" diameter oxide vessel to reduce the cross sectional area of the vessel to that of a 7.5" vessel provides an acceptable arrangement for packaging and transport of heterogeneous materials in the 8" oxide vessel. As further presented in this Appendix, a sleeved 8" diameter vessel of equivalent cross sectional area to that of a nominal 7.5" vessel will not exceed the USL of 0.9473 as previously established in Section 6.

Calculations were performed to justify the use of a sleeve for an 8" vessel. Preliminary calculations suggest that the sleeve must be metallic. For weight consideration, further calculations presented will involve the use of an Aluminum sleeve. Calculations with a full length Aluminum sleeve that reduces an 8.2" maximum sleeve (with a minimum wall thickness of 0.22") diameter to a maximum 7.7" sleeve diameter were initially performed. The calculated results assuming optimum moderated heterogeneous materials in a 4 x 4 x 3 + 2 damaged package array, with each vessel containing 1.0 kg of plastic with an additional modeling bias of 0.0053 as prescribed in Section 6 is 0.9435 ($k_{eff} + 2\sigma$ + bias and uncertainty). If the sleeve is provided with a 1" gap at both the top and bottom of the vessel with heterogeneous material filling the gaps then the calculated result increases to 0.9458. Both results are within the USL of 0.9473.

Additional calculations were performed to indicate that the sleeve geometry can vary significantly. The cross sectional area of the nominal 8" vessel (assuming a maximum diameter of 8.2") is 340-cm^2 while the nominal 7.5" vessel (assuming a maximum diameter of 7.7") is 300-cm^2. Therefore, a metallic sleeve with a cross sectional area of at least 40-cm^2 would allow transport of heterogeneous materials in the 8" vessel within the USL. Assuming the sleeve is a lumped cylinder would equate to a 3.58-cm radius rod. Two additional calculations were performed with a centrally and edge located rod of 3.58-cm radius. Both were modeled with 1" gaps at the top and bottom of the vessel. The calculated results were 0.9036 for the centrally located rod and 0.9281 for the edge located rod. Both results are within the USL of 0.9473.

Based on the above results, a sleeve that is dispersed and further placed contiguous to the vessel wall would lead to the higher calculated result. An insert that would reduce the cross sectional area of the vessel and placed centrally within the vessel would lead to lower calculated results.

Table 6.8.2-1 Summary of Results for Sleeved 8" Oxide Vessels

Transport Case	Number of packages	Array Size	Nominal Oxide Vessel Diameter	Form	Close Water Reflection	Interspersed Moderation (g/cc H_20)	Fuel Moderator	H/X Ratio (Water-to-Fuel Volume Ratio)	K_{eff}	σ	$K_{eff} + 2\sigma$	Applicable USL
HAC	50	4x4x3 + 2	8" Aluminum Sleeved (7.5")	Heterogeneous	Yes	0.0001	Water/poly	(3.0)	0.9334 + 0.0053	0.0024	0.9435	0.9473
HAC	50	4x4x3 + 2	8" Aluminum Sleeved (7.5"), 1-in gaps	Heterogeneous	Yes	0.0001	Water/poly	(3.0)	0.9365 + 0.0053	0.0020	0.9458	0.9473
HAC	50	4x4x3 + 2	3.58-cm centrally located rod, 1" gaps	Heterogeneous	Yes	0.0001	Water/poly	(3.0)	0.8937 + 0.0053	0.0023	0.9036	0.9473
HAC	50	4x4x3 + 2	3.58-cm edge located rod, 1" gaps	Heterogeneous	Yes	0.0001	Water/poly	(3.0)	0.9184 + 0.0053	0.0022	0.9281	0.9473

8" Vessel with Aluminum Sleeve

```
=CSAS2x        parm=size=800000
HAC polyethylene OPTIMUM MODERATED
REPROCESSED UO2 AT 3.25G/CC AND 5WT%
'Burnt Foam Model
44GR     LATT
'Reprocessed UO2
UO2          1 0.9999 294.0 92232 0.000002
92233 0.005
                              92235 5.0 92238
94.994998  END
PU           1 2.2437e-6 294.0 94239 100 END
H2O          2 0.9655 294.0  END
POLYETHYLENE 2 0.0345  294.0 END
'Interspersed moderator
H2O           8 0.0001  294.0  END
'Package steel
CARBONSTEEL  3 1.0  294.0  END
SS304        4 1.0  294.0  END
'Reflector
H2O          5 1.0   294.0  END
'6.45pcf foam insulation with min H
H2O          6 0.06011 294.0 END
'18 pcf foam insulation with min H
H2O          7 0.16776 294.0 END
Al           9 1.0   294.0 END
END COMP
SPHTRIANGP  1.44525 1.0 1 2 END
MORE DATA   IIM=500 ICM=500 END MORE
HAC NO POLY WITH PELLETS
READ PARM  NUB=YES GEN=305 NPG=600 NSK=5
TME=60 TBA=60 RND=012187
END PARM
READ GEOM

UNIT 1
'fuel region based on max OD of 8.2"
CYLINDER   500 1  9.779   102.641  2.54
CYLINDER     9 1  10.414  102.641  2.54
CYLINDER   500 1  10.414  105.181  0.0
'oxide vessel walls and bottom, minimum
thickness
REPLICATE   4 1  0.5588  0.00  0.635  1
' gap between oxide vessel and sleeve
REPLICATE   8 1  2.949   0.0  0.0  1
'transport unit sleeve thickness
REPLICATE   4 1  0.366  0.0  0.635  1
'Foam next to tube below lid diameter
REPLICATE   6 1  3.17476   0.00  0.00  1
'combined Oxide vessel flange and lid
REPLICATE   4 1  0.00    2.923   0.00 1
'foam insulation
CUBOID      6 1  28.4960 -19.8600  19.8600 -
28.4960 108.104 -1.270
replicate   7 1   5R0.0  6.477 1
CUBOID      0 1  4P28.49600  108.104 -7.747
'Burnt away section
replicate   0 1   5R0.0  4.318 1

UNIT 2
'fuel region based on max OD of 8.2"
CYLINDER   500 1  9.779   102.641  2.54
CYLINDER     9 1  10.414  102.641  2.54
CYLINDER   500 1  10.414  105.181  0.0
'oxide vessel walls, lid and bottom, minimum
thickness
REPLICATE   4 1  0.5588  0.00  0.635  1
' gap between oxide vessel and sleeve
REPLICATE   8 1  2.949   0.0  0.0  1
'transport unit sleeve thickness
REPLICATE   4 1  0.366  0.0  0.635  1
'Foam next to tube below lid diameter
REPLICATE   6 1  3.17476   0.00  0.00  1
'combined Oxide vessel flange and lid
REPLICATE   4 1  0.00    2.923   0.00 1
'foam insulation
CUBOID      6 1  19.8600 -28.4960 19.8600 -
28.4960 108.104 -1.270
replicate   7 1   5R0.0  6.477 1
CUBOID      0 1  4P28.49600  108.104 -7.747
'Burnt away section
replicate   0 1   5R0.0  4.318 1

UNIT 3
'fuel region based on max OD of 8.2"
CYLINDER   500 1  9.779   102.641  2.54
CYLINDER     9 1  10.414  102.641  2.54
CYLINDER   500 1  10.414  105.181  0.0
'oxide vessel walls, lid and bottom, minimum
thickness
REPLICATE   4 1  0.5588  0.00  0.635  1
' gap between oxide vessel and sleeve
REPLICATE   8 1  2.949   0.0  0.0  1
'transport unit sleeve thickness
REPLICATE   4 1  0.366  0.0  0.635  1
'Foam next to tube below lid diameter
REPLICATE   6 1  3.17476   0.00  0.00  1
'combined Oxide vessel flange and lid
REPLICATE   4 1  0.00    2.923   0.00 1
'foam insulation
CUBOID      6 1  19.8600 -28.4960 28.4960 -
19.8600 108.104 -1.270
replicate   7 1   5R0.0  6.477 1
CUBOID      0 1  4P28.49600  108.104 -7.747
'Burnt away section
replicate   0 1   5R0.0  4.318 1

UNIT 4
'fuel region based on max OD of 8.2"
CYLINDER   500 1  9.779   102.641  2.54
CYLINDER     9 1  10.414  102.641  2.54
CYLINDER   500 1  10.414  105.181  0.0
'oxide vessel walls, lid and bottom, minimum
thickness
REPLICATE   4 1  0.5588  0.00  0.635  1
' gap between oxide vessel and sleeve
REPLICATE   8 1  2.949   0.0  0.0  1
'transport unit sleeve thickness
REPLICATE   4 1  0.366  0.0  0.635  1
'Foam next to tube below lid diameter
REPLICATE   6 1  3.17476   0.00  0.00  1
'combined Oxide vessel flange and lid
REPLICATE   4 1  0.00    2.923   0.00 1
'foam insulation
CUBOID      6 1  28.4960 -19.8600  28.4960 -
19.8600 108.104 -1.270
replicate   7 1   5R0.0  6.477 1
```

```
CUBOID      0 1  4P28.49600  108.104 -7.747
'Burnt away section
replicate   0 1   5R0.0  4.318 1

UNIT 11
'GASKETS
CYLINDER    8 1  16.8275  1.74625    0.0
'Outer lid bottom
REPLICATE   4 1  0.000    0.3048    0.00  1
'Outer lid foam plug
REPLICATE   6 1  0.000    7.556    0.00  1
REPLICATE   4 1  0.608   0.00      0.00  1
CUBOID      6 1  28.4960 -19.8600  19.8600 -
28.4960 9.60705  0.00
CUBOID      0 1  4P28.4960 9.60705  0.00

unit 111
'Burnt section of outer lid
CYLINDER    0 1  16.8275  8.636    0.0
'Outer lid sides and sleeve sides
REPLICATE   4 1  0.608   0.00      0.00  1
'Outer lid minus thickness of 11 gauge
REPLICATE   4 1  0.00   0.965     0.00  1
'foam insulation
CUBOID      0 1  4P28.49600  9.601  0.00

UNIT 12
'GASKETS
CYLINDER    8 1  16.8275  1.74625    0.0
'Outer lid bottom
REPLICATE   4 1  0.000    0.3048    0.00  1
'Outer lid foam plug
REPLICATE   6 1  0.000    7.556    0.00  1
'Outer lid sides and sleeve sides
REPLICATE   4 1  0.608   0.00      0.00  1
'foam insulation
CUBOID      6 1  19.8600 -28.4960 19.8600 -
28.4960 9.60705  0.00
CUBOID      0 1  4P28.49600  9.60705  0.00

UNIT 13
'GASKETS
CYLINDER    8 1  16.8275  1.74625    0.0
'Outer lid bottom
REPLICATE   4 1  0.000    0.3048    0.00  1
'Outer lid foam plug
REPLICATE   6 1  0.000    7.556    0.00  1
'Outer lid sides and sleeve sides
REPLICATE   4 1  0.608   0.00      0.00  1
'foam insulation
CUBOID      6 1  19.8600 -28.4960 28.4960 -
19.8600 9.60705  0.00
CUBOID      0 1  4P28.49600  9.60705  0.00

UNIT 14
'GASKETS
CYLINDER    8 1  16.8275  1.74625    0.0
'Outer lid bottom
REPLICATE   4 1  0.000    0.3048    0.00  1
'Outer lid foam plug
REPLICATE   6 1  0.000    7.556    0.00  1
'Outer lid sides and sleeve sides
REPLICATE   4 1  0.608   0.00      0.00  1
'foam insulation
CUBOID      6 1  28.4960 -19.8600  28.4960 -
19.8600 9.60705  0.00
CUBOID      0 1  4P28.49600  9.60705  0.00

UNIT 95
'BLANK
CUBOID      0 1 4P56.992 127.31205 -12.065
REPLICATE   0 1  5R0.3048 0.635  1
'REPLICATE   0 1  5R0 2.54  1

UNIT 30
ARRAY  1  3*0.0
UNIT 40
ARRAY  2  3*0.0
'Transport unit outer walls
REPLICATE   3 1  5R0.3048 0.635  1
'Transport unit feet
'REPLICATE   8 1  5R0 2.54  1

GLOBAL
UNIT 50
ARRAY  3  3*0.0
'full reflection
REPLICATE   5 1  6R30.48  1
END GEOM
READ ARRAY
ARA=1  NUX=2  NUY=2  NUZ=3  FILL  4 3 1 2 14
13 11 12 111 111 111 111   END FILL
ARA=2  NUX=1  NUY=1  NUZ=1  FILL  30 END
FILL
ARA=3  NUX=4  NUY=4  NUZ=4  FILL
40 40 40 40 40 40 40 40 40 40 40 40 40 40 40
40
2Q16
95 95 95 95 95 40 95 95 95 40 95 95 95 95 95
95 END FILL
END ARRAY
READ BOUNDS
ALL=VOID
END BOUNDS
END DATA
END
```

8" Vessel with 3.58" Diameter Aluminum Insert

```
=CSAS2x       parm=size=800000
HAC polyethylene OPTIMUM MODERATED
REPROCESSED UO2 AT 3.25G/CC AND 5WT%
'Burnt Foam Model
44GR     LATT
'Reprocessed UO2
UO2          1 0.9999 294.0 92232 0.000002
92233 0.005
                              92235 5.0 92238
94.994998  END
PU           1 2.2437e-6 294.0 94239 100 END
H2O          2 0.9655 294.0  END
POLYETHYLENE 2 0.0345  294.0 END
'Interspersed moderator
H2O           8 0.0001  294.0  END
'Package steel
CARBONSTEEL  3 1.0  294.0  END
SS304        4 1.0  294.0  END
'Reflector
H2O          5 1.0   294.0  END
'6.45pcf foam insulation with min H
H2O          6 0.06011 294.0 END
'18 pcf foam insulation with min H
```

```
H2O          7 0.16776 294.0 END
Al           9 1.0   294.0 END
END COMP
SPHTRIANGP  1.44525 1.0 1 2 END
MORE DATA   IIM=500 ICM=500 END MORE
HAC NO POLY WITH PELLETS
READ PARM  NUB=YES GEN=305 NPG=600 NSK=5
TME=60 TBA=60 RND=012187
END PARM
READ GEOM

UNIT 1
'fuel region based on max OD of 8.2"
CYLINDER   500 1  10.414  105.181  0.0
hole  100 6.8 0.0 0.0
'hole  100 0.0 0.0 0.0
'oxide vessel walls and bottom, minimum
thickness
REPLICATE   4 1  0.5588  0.00  0.635  1
' gap between oxide vessel and sleeve
REPLICATE   8 1  2.949   0.0  0.0  1
'transport unit sleeve thickness
REPLICATE   4 1  0.366  0.0  0.635  1
'Foam next to tube below lid diameter
REPLICATE   6 1  3.17476   0.00  0.00  1
'combined Oxide vessel flange and lid
REPLICATE   4 1  0.00    2.923   0.00 1
'foam insulation
CUBOID      6 1  28.4960 -19.8600  19.8600 -
28.4960 108.104 -1.270
replicate   7 1   5R0.0  6.477 1
CUBOID      0 1  4P28.49600  108.104 -7.747
'Burnt away section
replicate   0 1   5R0.0  4.318 1

UNIT 2
'fuel region based on max OD of 8.2"
CYLINDER   500 1  10.414  105.181  0.0
hole  100 6.8 0.0 0.0
'hole  100 0.0 0.0 0.0
'oxide vessel walls, lid and bottom, minimum
thickness
REPLICATE   4 1  0.5588  0.00  0.635  1
' gap between oxide vessel and sleeve
REPLICATE   8 1  2.949   0.0  0.0  1
'transport unit sleeve thickness
REPLICATE   4 1  0.366  0.0  0.635  1
'Foam next to tube below lid diameter
REPLICATE   6 1  3.17476   0.00  0.00  1
'combined Oxide vessel flange and lid
REPLICATE   4 1  0.00    2.923   0.00 1
'foam insulation
CUBOID      6 1  19.8600 -28.4960 19.8600 -
28.4960 108.104 -1.270
replicate   7 1   5R0.0  6.477 1
CUBOID      0 1  4P28.49600  108.104 -7.747
'Burnt away section
replicate   0 1   5R0.0  4.318 1

UNIT 3
'fuel region based on max OD of 8.2"
CYLINDER   500 1  10.414  105.181  0.0
hole  100 6.8 0.0 0.0
'hole  100 0.0 0.0 0.0
'oxide vessel walls, lid and bottom, minimum
thickness
REPLICATE   4 1  0.5588  0.00  0.635  1
' gap between oxide vessel and sleeve
REPLICATE   8 1  2.949   0.0  0.0  1
'transport unit sleeve thickness
REPLICATE   4 1  0.366  0.0  0.635  1
'Foam next to tube below lid diameter
REPLICATE   6 1  3.17476   0.00  0.00  1
'combined Oxide vessel flange and lid
REPLICATE   4 1  0.00    2.923   0.00 1
'foam insulation
CUBOID      6 1  19.8600 -28.4960 28.4960 -
19.8600 108.104 -1.270
replicate   7 1   5R0.0  6.477 1
CUBOID      0 1  4P28.49600  108.104 -7.747
'Burnt away section
replicate   0 1   5R0.0  4.318 1

UNIT 4
'fuel region based on max OD of 8.2"
CYLINDER   500 1  10.414  105.181  0.0
hole  100 6.8 0.0 0.0
'hole  100 0.0 0.0 0.0
'oxide vessel walls, lid and bottom, minimum
thickness
REPLICATE   4 1  0.5588  0.00  0.635  1
' gap between oxide vessel and sleeve
REPLICATE   8 1  2.949   0.0  0.0  1
'transport unit sleeve thickness
REPLICATE   4 1  0.366  0.0  0.635  1
'Foam next to tube below lid diameter
REPLICATE   6 1  3.17476   0.00  0.00  1
'combined Oxide vessel flange and lid
REPLICATE   4 1  0.00    2.923   0.00 1
'foam insulation
CUBOID      6 1  28.4960 -19.8600  28.4960 -
19.8600 108.104 -1.270
replicate   7 1   5R0.0  6.477 1
CUBOID      0 1  4P28.49600  108.104 -7.747
'Burnt away section
replicate   0 1   5R0.0  4.318 1

UNIT 11
'GASKETS
CYLINDER    8 1  16.8275  1.74625    0.0
'Outer lid bottom
REPLICATE   4 1  0.000    0.3048    0.00  1
'Outer lid foam plug
REPLICATE   6 1  0.000    7.556    0.00  1
REPLICATE   4 1  0.608   0.00      0.00  1
CUBOID      6 1  28.4960 -19.8600  19.8600 -
28.4960 9.60705  0.00
CUBOID      0 1  4P28.4960 9.60705  0.00

unit 111
'Burnt section of outer lid
CYLINDER    0 1  16.8275  8.636    0.0
'Outer lid sides and sleeve sides
REPLICATE   4 1  0.608   0.00      0.00  1
'Outer lid minus thickness of 11 gauge
REPLICATE   4 1  0.00   0.965     0.00  1
'foam insulation
CUBOID      0 1  4P28.49600  9.601  0.00

UNIT 12
'GASKETS
CYLINDER    8 1  16.8275  1.74625    0.0
'Outer lid bottom
REPLICATE   4 1  0.000    0.3048    0.00  1
```

```
'Outer lid foam plug
REPLICATE   6 1  0.000    7.556    0.00  1
'Outer lid sides and sleeve sides
REPLICATE   4 1  0.608   0.00      0.00  1
'foam insulation
CUBOID      6 1  19.8600 -28.4960 19.8600 -
28.4960 9.60705  0.00
CUBOID      0 1  4P28.49600  9.60705  0.00

UNIT 13
'GASKETS
CYLINDER    8 1  16.8275  1.74625    0.0
'Outer lid bottom
REPLICATE   4 1  0.000    0.3048    0.00  1
'Outer lid foam plug
REPLICATE   6 1  0.000    7.556    0.00  1
'Outer lid sides and sleeve sides
REPLICATE   4 1  0.608   0.00      0.00  1
'foam insulation
CUBOID      6 1  19.8600 -28.4960 28.4960 -
19.8600 9.60705  0.00
CUBOID      0 1  4P28.49600  9.60705  0.00

UNIT 14
'GASKETS
CYLINDER    8 1  16.8275  1.74625    0.0
'Outer lid bottom
REPLICATE   4 1  0.000    0.3048    0.00  1
'Outer lid foam plug
REPLICATE   6 1  0.000    7.556    0.00  1
'Outer lid sides and sleeve sides
REPLICATE   4 1  0.608   0.00      0.00  1
'foam insulation
CUBOID      6 1  28.4960 -19.8600  28.4960 -
19.8600 9.60705  0.00
CUBOID      0 1  4P28.49600  9.60705  0.00

UNIT 95
'BLANK
CUBOID      0 1 4P56.992 127.31205 -12.065
REPLICATE   0 1  5R0.3048 0.635  1
'REPLICATE   0 1  5R0 2.54  1

UNIT 30
ARRAY  1  3*0.0
UNIT 40
ARRAY  2  3*0.0
'Transport unit outer walls
REPLICATE   3 1  5R0.3048 0.635  1
'Transport unit feet
'REPLICATE   8 1  5R0 2.54  1

Unit 100
'bottom pellet box with aluminum bottom and
sides with top gap
CYLINDER    9 1  3.58  102.641 2.54

GLOBAL
UNIT 50
ARRAY  3  3*0.0
'full reflection
REPLICATE   5 1  6R30.48  1
END GEOM
READ ARRAY
ARA=1  NUX=2  NUY=2  NUZ=3  FILL  4 3 1 2 14
13 11 12 111 111 111 111   END FILL
ARA=2  NUX=1  NUY=1  NUZ=1  FILL  30 END
FILL
ARA=3  NUX=4  NUY=4  NUZ=4  FILL
40 40 40 40 40 40 40 40 40 40 40 40 40 40 40
40
2Q16
95 95 95 95 95 40 95 95 95 40 95 95 95 95 95
95 END FILL
END ARRAY
READ BOUNDS
ALL=VOID
END BOUNDS
END DATA
END
```