Century Industries

Safety Analysis Report for the Century Industries Versa-Pac Shipping Container

Application for License
Docket No. 71-09342

Revision 3
April 09, 2010

Designed and Submitted By:

Century Industries
Bristol, Virginia

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for
Century Industries
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General Glossary of Terms and Acronyms

Annually	Once every year
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society of Nondestructive Testing
ASTM	American Society for Testing and Materials
AWS	American Welding Society
Versa-Pac	A shipping container for the transport of Type AF radioactive materials.
CFR	U.S. Code of Federal Regulations
Containment Boundary	The components of the packaging intended to retain the radioactive material during transport.
CSI	The criticality safety index as define by the dimensionless number (rounded up to the next tenth) assigned to and placed on the label of a fissile material package, to designate the degree of control of accumulated packages containing fissile material during transport.
Decay Heat	The heat resulting from radioactive decay.
Enrichment	The percentage (by weight) of U^{235} contained in the radioactive material.
FEA	Finite Element Analysis
H/X Ratio	The water-hydrogen to fissile atom ratio
(H+C)/X Ratio	The ratio of the sum of water-hydrogen atoms and the carbon atoms to the fissile atoms.
HAC	Hypothetical Accident Conditions as defined by 10 CFR 71.73.
Heterogeneous	The form of fissile material is such that discrete particles exist and the moderator material is distributed around the particles.
HEU	Highly-enriched uranium
Homogenous	The form of the fissile material is such that the moderator is mixed uniformly with it.
Hydrogenous	Containing hydrogen atoms.
ID	Inner diameter
IH	Inside Height
Insolation	Heat input by solar radiation as defined by 10 CFR 71.71.
Internal moderator	The presence of hydrogenous material in the payload vessel and mixed with the payload.
Interspersed Moderator	The presence of hydrogenous material between packages and in the payload vessel, but not mixed with the payload.
Moderation Control	Control of materials containing hydrogen.
NCT	Normal Conditions of Transport as defined by 10 CFR 71.71.
NIST	National Institute of Standards and Technology

Nominal	The design value or dimension without application of the allowable variation or tolerance.
Non-hydrogenous	Does not contain hydrogen atoms.
NRC	The U.S. Regulatory Commission
OD	Outer diameter
Package	The packaging together with its radioactive contents as presented for transport.
Packaging	The assembly of components necessary to ensure compliance with the packaging requirements of 10 CFR 71.
Plastic	A thermosetting or thermoplastic polymer
Poly	Polyethylene
Pre-packaging	Materials, not supplied as part of the Versa-Pac shipping container and not a part of the radioactive payload, that are used to limit the movement of radioactive material within the payload vessel.
RQ	Regulated Quantity
RTV	Silicone Rubber Compound
Specific Activity	The radioactivity of a radionuclide per unit mass.
Type A Package	Package used to transport a quantity of material where the aggregate radioactivity content does not exceed the Normal Form A_2 value listed in 10 CFR 71.
Type B Package	Package used to transport more than Type A quantity of material.
UC	Uranium Carbides
UH	Uranium Hydrites
U-Metal	Uranium Metal
UNX	All forms of uranyl nitrate in crystalline or solution form, including uranyl nitrate hexahydrate, uranyl nitrate dihydrate, uranyl nitrate trihydrate and uranyl nitrate solution.
UO_2	Uranium Dioxide
Uranium Compound	Any compound of uranium containing any combination of elements, referred to also as U_xO_y.
User	The person or entity shipping radioactive material in the package.
U_xO_y	Uranium compounds. Although the designation shows X atoms of uranium and Y atoms of oxygen, this designation is meant to represent any compound of uranium containing any combination of elements.

SECTION ONE
GENERAL INFORMATION

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List of Tables and Figures

SAFETY ANALYSIS REPORT
FOR MODEL VERSA-PAC
SHIPPING CONTAINER
(Revision 3, April, 2010)

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1 GENERAL INFORMATION

This Safety Analysis Report for the Versa-Pac Shipping Container is submitted in support of the Century Industries request for approval of the subject shipping container and issuance of a Type A Fissile Material Certificate of Compliance for the container in compliance with the requirements of 10 CFR 71 and IAEA Regulations for the Safe Transport of Radioactive Material, No. TS-R-1, 1996 Edition. This Safety Analysis Report for Packaging (SARP) has been prepared in accordance with U.S. Regulatory Commission (NRC), Regulatory Guide 7.9 Proposed Revision 2, March 2005.

1.1 Introduction

The Versa-Pac Shipping Containers employ an innovative design concept (Patent Pending) in combination with the familiar drum exterior packaging to provide enhanced structural protection to the payloads previously transported per 49 CFR 173.417(a)(6) during Hypothetical Accident Conditions (HAC). The Versa-Pac shipping containers, model numbers VP-55 and VP-110, have been designed to transport Type A Fissile Materials containing less than or equal to 350 grams of U-235 and has been evaluated to transport many of the products currently being transported in older shipping containers. The package has been designed and constructed so that it is acceptable under 71.43(g) for transport in non-exclusive and exclusive means of transport.

The package system includes an outer set of drum closure seals and an inner secondary flat gasket seal. The payload containment area of the 55 gallon version has an inside diameter of 15 inches and is 25-7/8 inches in length; while the 110 gallon version has an inside diameter of 21 inches and is 29-3/4 inches in length. The package has two distinct areas of insulation for thermal and impact protection.

The Criticality Safety Index (CSI) is 1.0.

1.2 Package Description

1.2.1 Packaging

Engineering Drawings are provided in Appendix 1.3.1. General notes pertaining to fabrication are provided in Appendix 1.3.2. An illustration of the packaging configuration is provided in Figure 1-1. Packaging markings are shown on the drawings provided in Appendix 1.3.1 with General Notes shown in Appendix 1.3.2.

The exterior skin of the Versa-Pac Shipping Container consists of at a minimum, a UN1A2/X400/S for the 55-gallon drum version with a 16 gauge body, bottom and cover. The drums use a 12 gauge bolted closure ring, standard carbon steel lugs, 5/8” diameter, ASTM A307 bolts and nuts, and a closed-cell EPDM gasket. The overall outer dimensions of the 55 gallon package are 23-1/16” OD x 34-3/4” in height to the top of the outer drum bolt ring. The drum cover is reinforced by a 10 gauge thick 22-3/8” OD x 18-3/8” ID plate, and four ½” bolts are provided to lend additional strength to the drum closure ring.

The 110 gallon version utilizes at a minimum a UN/1A2/Y409/S with 16 gauge body, bottom and cover. The drums use a 12 gauge bolted closure ring, standard carbon steel lugs, 5/8” diameter ASTM A307 bolts and nuts, and a closed-cell EPDM gasket. The overall outer dimensions for the 110 gallon package are 30-7/16” OD x 42-3/4” in height to the top of the outer drum bolt ring. The drum cover is reinforced by a 10 gauge thick 29-3/4” OD x 27-1/4” ID plate and eight ½” bolts are provided to lend additional strength to the drum closure ring.

Both drums are further strengthened with vertical stiffeners fabricated from 1-1/4” carbon steel square tubing, two inner liners of rolled16 gauge carbon steel insulated by ceramic fiber blanket encase the vertical tubing, and a ¼” carbon steel reinforcing plate on the bottom.

The package’s interior is completely insulated with the appropriate layers of ceramic fiber blanket around the containment area with 6 pcf. rigid polyurethane foam disk on the top and on the bottom to complete the insulation of the package. Specifications for the insulation are provided in Appendix 1.3.3 and 1.3.4 for the blanket and polyurethane, respectively. The primary function of both insulations is to provide thermal protection. Although the rigid polyurethane provides some impact protection, the frame of the packaging performs the majority of the required impact protection.

A ½” thick fiberglass ring is used as a thermal break at the payload cavity flange. The thermal break is sandwiched between the steel components, with twelve 1/2 inch bolts providing the connection between the structural members through the fiberglass and effectively limits the flow of heat to the payload cavity through the steel flange components. There are no moving parts to the thermal break, and its functionality is maintained as long as it separates the steel components FB from FK (See Drawings in Appendix 1.3.1). A specification for the fiberglass material is provided in Appendix 1.3.5.

The containment boundary of the package is defined as the payload vessel with its associated welds, payload vessel high temperature heat resistant fiberglass sleeve gasket, payload vessel blind flanges, and reinforcing ring.

The payload vessel is comprised of a 10 gauge carbon steel sheet for the body and bottom. The upper end of the vessel is fitted with a ¼” inner carbon steel flange ring with a ½” thick carbon steel blind flange. The vessel has three circumferential welds (two at the flange, one at the base) and one longitudinal weld. An 1/8” high temperature resistant fiberglass sleeve gasket is used between the steel flange ring and blind flange. The payload vessel blind flange is secured with twelve ½” bolts. There are no penetrations, valves or venting devices used within the containment boundary.

The Versa-Pac meets the General Requirements for all packages as specified in 10CFR71.43.

1.2.1.1 Gross Weights

The gross weights of the Versa-Pac Shipping Container are provided in Table1-1.

1.2.1.2 Materials of Construction

The materials of construction of the Versa-Pac are provided in Tables 1-2 and 1-3 for the 55-gallon and 110-gallon versions, respectively.

1.2.1.3 Outer and Inner Protrusions

There is one outer protrusion on the Versa-Pac consisting of carbon steel fitting which contains a 1” plastic plug on the side of the package. The plug is designed to melt and allow venting of any gases that might develop in the event of a fire. The protrusion extends less than ½” from the side-wall of the outer drum and does not impede the stacking or handling of the shipping container. There are no inner protrusions on the Versa-Pac package and no outer or inner protrusion on the Versa-Pac Shipping Container.

1.2.1.4 Lifting and Tie-Down Devices

The Versa-Pac shipping container may be handled by normal industry standards for the safe movement of drums; such equipment might include specifically designed devices, forklifts, pallet jacks or other methods as determined by the User. However, the Versa-Pac package does not utilize any specific device or attachment for lifting. Additionally, there are no specific provisions for tie down of the package.

1.2.1.5 Shielding

Neutron and gamma shields are not required for the Versa-Pac payloads.

1.2.1.6 Pressure Relief Systems

There are no pressure relief systems other than the four - ½” holes, closed with vinyl push plugs on the inner liner between the insulation and containment used to vent gases that might be produced in the event of a fire. No special heat transfer mechanisms are provided or required.

1.2.1.7 Containment Features

There are three individual points of closure employed by the Versa-Pac Shipping Container. The payload ½ inch thick closure plate provides a fastening and seal using twelve ½” bolts and a 1/8” thick silicone rubber fiberglass coated flat gasket. A second closure is provided at the outer drum lid. The drum lid is secured using ½” bolts and is sealed with a 3/8” thick silicone rubber flat gasket. A standard drum ring, its EPDM gasket, and a 5/8” tensioning bolt provide the final closure. A 1/8” hole is drilled in the end of the tensioning bolt for use with a security seal.

The primary containment boundary of the Versa-Pac shipping container is defined as the inner containment body, containment end plate, inner flange ring, silicone coated fiberglass gasket, ½” blind flange, ½ bolts, washers and insert holders. Figure 1-1 further illustrates these components by text description enclosed within a text box.

1.2.1.8 Package Markings

Package marking are shown in Appendix 1.3.1 and 1.3.2.

1.2.2 Contents

All materials must be in solid form with no freestanding liquids; density is not limited. These material quantities may not exceed 350 grams U-235 in any non-pyrophoric form, enriched up to 100 Wt%. Materials that may be shipped in the Versa-Pac include uranium oxides (U_yO_x), uranium metal (U-metal), uranyl nitrate crystals (UNX), and other uranium compounds (e.g., Uranyl Fluorides and Uranyl Carbonates) enriched up to 100 Wt% U-235. The uranium compounds may also contain carbon or graphite. UNX may be in the form of uranyl nitrate hexahydrate, trihydrate or dihydrate, and must be in solid form. The payload may be in homogeneous (powder or crystalline) or non-homogeneous form. Table 1-5 identifies the limits for U-234 and U-236 as applied to the Versa-Pac Shipping Container. The A_2 values are used as stated in 10 CFR 71 and are applied to the package since the payload is limited to normal form material.

The package is evaluated assuming optimum moderation using a bounding high-density polyethylene plastic (Density = 0.98 g/cc) and supports packaging applications containing both carbon (e.g., graphite, paraffin, and polyethylene) and hydrogen based materials (e.g., water paraffin, and polyethylene). Non-fissile chemical impurities do not increase the reactivity of the system; therefore, they may be present in any quantity. The payload may be enriched in U-235 to 100 Wt%. Because the payload decay is essentially zero (approximately 11.4 W, *Section 3.4.2*); thus, there are no radiolytic decay products.

The payload material may be pre-packaged in hydrogenous or non-hydrogenous containers within the payload vessel. Hydrogenous pre-packaging materials may include polyethylene, polypropylene, and PVC. PTFE or Teflon® pre-packaging material is also allowed. Metallic pre-packaging materials such as aluminum, stainless and carbon steel are further allowed provided their total weight is controlled to within the payload allotment of the package.

The payload shall be further limited to materials with auto-ignition temperatures greater than or equal to 600^{o}F. Since many varieties of materials are used for packaging the user is required to establish that the auto-ignition temperature is a minimum of 600°F using an established method, such as the method prescribed by ASTM D2883 (Test Method for reaction threshold Temperature of Liquid and Solid Materials). Table 1-4 provides the listing of packaging materials qualified for use within the Versa-Pac shipping container; all other packaging materials must meet the 600°F minimum auto-ignition temperature described above.

No materials, excluding the minimum steel wall thickness of the package, are used as neutron absorbers or moderators.

The maximum payload capacity for the 55-gallon version is 250 pounds. The maximum payload capacity for the 110-galon version is 260 pounds.

1.2.3 Special Requirements for Plutonium

The Versa-Pac Shipping Container is not approved for the transport of Plutonium above minimum detectable quantities.

1.2.4 Operational Features

The Versa-Pac Shipping Container provides for two individual closures and seals to secure the payload within the inner containment area. Connections and closures are accomplished using bolt and gasket seals.

There are no operationally complex features of the Versa-Pac Shipping packaging. All operational features are readily apparent from an inspection of the drawings provided in Appendix 1.3.1, *Packaging General Arrangement Drawings*. Operation procedures and instructions for loading, unloading, and preparing an empty Versa-Pac Shipping packaging for transport are provided in Chapter 7.0, *Operating Procedures*.

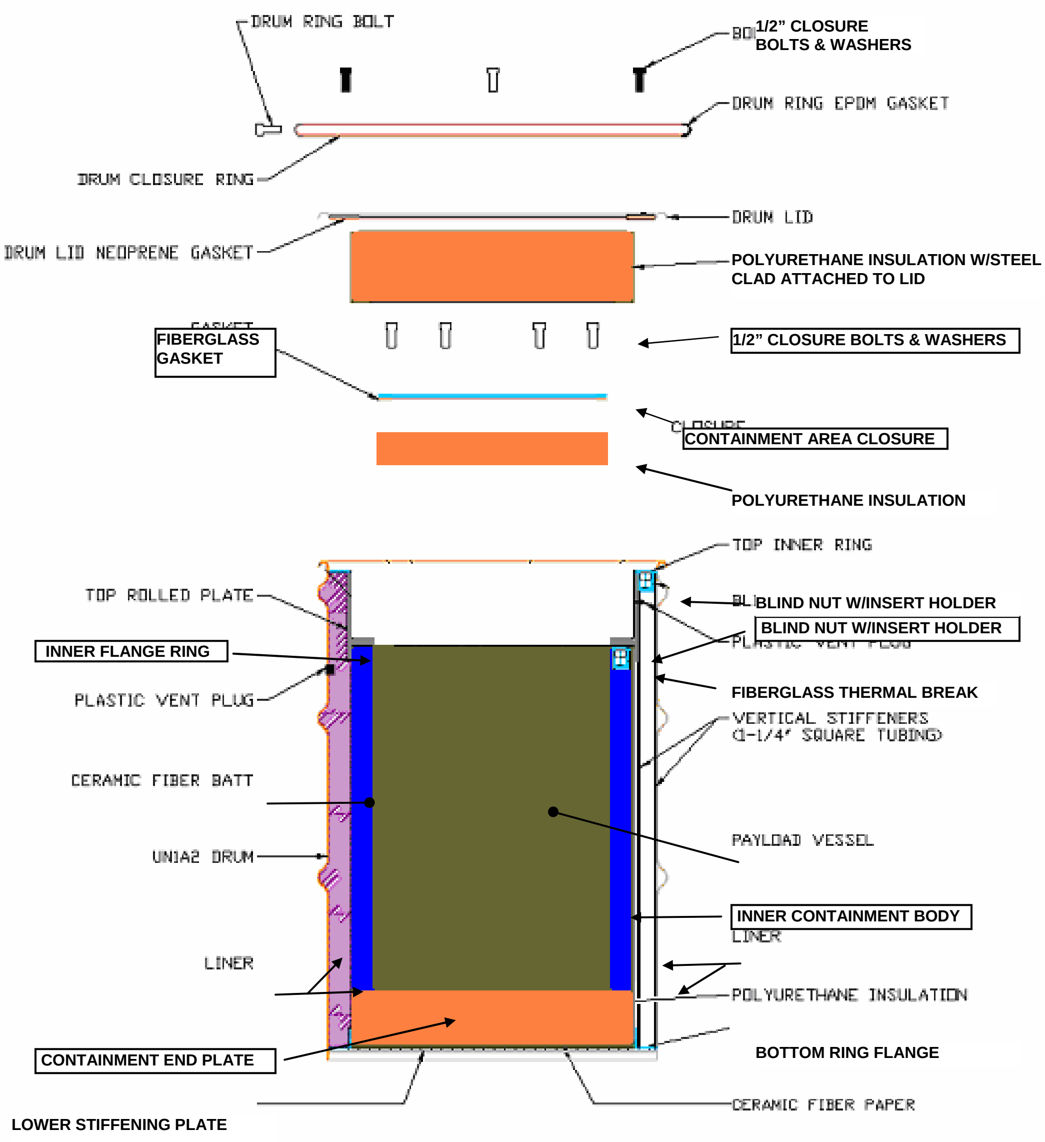

Figure 1-1 Versa-Pac Component Illustration

(Containment boundary components, as indicated in Section 1.2.1.7, are described in text boxes)

1.3 Appendices

1.3.1 Versa-Pac Shipping Container Drawings, Century Industries Drawing No.

VP-55-LD-1 & -2, VP-110-LD-1 & -2

1.3.2 General Notes

1.3.3 SOP 6.11 – Polyurethane Closed Cell Foam Specification for Century Industries Products

1.3.4 SOP 6.12 – Ceramic Fiber Insulation Specification for Century Industries Products

1.3.5 SOP 6.13 – Structural Fiberglass Component Specification for Century Industries Products

Table 1-1 Versa-Pac Shipping Container Gross Weights

55 Gallon Version – Model No. VP-55

Component	Weight (kg)	Weight (lb)
Versa-Pac Shipping Container	178	390
Maximum Payload	114	250
Maximum Gross Weight of Loaded Package	291	**640**

110 Gallon Version – Model No. VP-110

Component	Weight (kg)	Weight (lb)
Versa-Pac Shipping Container	321	705
Maximum Payload	119	260
Maximum Gross Weight of Loaded Package	439	**965**

Table 1-2 55 Gallon Versa-Pac Materials of Construction

Item	Material	Specification
55-Gallon Drum	16 Gauge, Carbon Steel	UN1A2/X400/S Design Minimum
Closure Ring	12 Gauge, Carbon Steel	UN1A2/X400/S
Drum Bolt	Carbon Steel	ASTM A307
Drum Gasket	EPDM Closed Cell	Certificate of Compliance
Inner Flat Gasket	Silicone Rubber Coated Fiberglass	ASTM-D372 , MILR 46089 Commercial ZZR 765, Class 2
Inner Flat Pads	Neoprene Sponge Rubber	ASTM D105668SCE41, ASTM 1056002C1
Inner Pads	Neoprene Rubber	ASTM D-2000, SAE J200 MIL R-33065
Sheet Materials	Carbon Steel	ASTM A1011
Plate Materials	Carbon Steel	ASTM A36
Angle	Carbon Steel	ASTM A36
Square Tubing	Carbon Steel	ASTM A500
Thread Inserts	Carbon Steel	Fastenal-EZ LOK Part No.60158 or equivalent
All Other Closure Bolts	Carbon Steel – Zinc Plated	ASTM A449 Type 1 Grade 5
Lock Washers	Carbon Steel – Zinc Plated	Clad
Insulation	Polyurethane Foam	Century SOP 6.11
Insulation	Ceramic Fiber Blanket/Paper	Century SOP 6.12
Thermal Break	Fiberglass Band/Rings	Century SOP 6.13
Nameplate	Stainless Steel	ASTM 300 Series
Paint	Industrial Primer (Inside Surfaces)	Industrial Grade
Paint	Enamel Touch Up	Industrial Grade

Table 1-3 110 Gallon Versa-Pac Materials of Construction

Item	Material	Specification
110-Gallon Drum	16 Gauge, Carbon Steel	UN1A2/Y409/S Design Minimum
Closure Ring	12 Gauge, Carbon Steel	UN1A2/X400/S
Drum Bolt	Carbon Steel	ASTM A307
Drum Gasket	EPDM Closed Cell	Certificate of Compliance
Inner Flat Gasket	Silicone Rubber Coated Fiberglass	ASTM D372, MILR 46089 Commercial ZZR 765
Inner Flat Pads	Neoprene Sponge Rubber	ASTM D105668SCE41, ASTM 1056002C1
Inner Pads	Neoprene Rubber	ASTM D-2000, SAE J200 MIL R-33065
Sheet Materials	Carbon Steel/Stainless Steel	ASTM A1011
Plate Materials	Carbon Steel	ASTM A36
Angle	Carbon Steel	ASTM A36
Square Tubing	Carbon Steel	ASTM A500
Thread Inserts	Carbon Steel	Fastenal-EZ LOK Part No.60158 or equivalent
All Other Closure Bolts	Carbon Steel – Zinc Plated/S/S	ASTM A449 Type 1 Grade 5 ASTM A193 Grade B8M CL 1
Lock Washers	Carbon Steel – Zinc Plated/S/S	Clad / 18-8 or 300 series
Insulation	Polyurethane Foam	Century SN 6.11
Insulation	Ceramic Fiber Blanket/Paper	Century SN 6.12
Thermal Break	Fiberglass Band/Rings	Century SOP 6.13
Nameplate	Stainless Steel	ASTM 300 Series
Paint	Industrial Primer (Inside Surfaces)	Industrial Grade
Paint	Enamel Touch Up	Industrial Grade

Table 1-4

Melting Points & Auto-Ignition Temperatures for Selected Typical Packaging Materials for use within the Versa-Pac

Material	Ignition Temperature[1,2]		Melting Point
	(C)	(F)	(F)
Carbon Steel	N/A	N/A	2500°
Aluminum	N/A	N/A	1220°
PTFE	530°	986°	621°

Note: All other materials used for packaging within the Versa-Pac shall be individually evaluated by the user to establish acceptance to the requirements.

Note for Table 1-4

1. "Physical Constants for Investigators", http://www.tcforensic.com.au/docs/article10.html, by Tony Cafe, Reproduced from "Firepoint" magazine - Journal of Australian Fire Investigators
2. "Fuels and Chemicals - Auto Ignition Temperatures", http://www.engineeringtoolbox.com/fuels-ignition-temperatures-d_171.html

Table 1-5 Summary of Uranium Isotope Limits for U-234 and U-236

Uranium Isotope	A_2	Ci/g	Package Gram Limit (1)
U-234 (2)	2.4	6.2×10^{-3}	387
U-234 (3)	5.4×10^{-1}	6.2×10^{-3}	87
U-234 (4)	1.6×10^{-1}	6.2×10^{-3}	25
U-236 (2)	Unlimited	6.5×10^{-5}	Unlimited
U-236 (3)	5.4×10^{-1}	6.5×10^{-5}	87
U-236 (4)	1.6×10^{-1}	6.5×10^{-5}	25

1. The mixture A_2 value is calculated per 10CFR71 by the user. The payload radionuclide inventory including U-234 and U-236 shall be less than the calculated mixture A_2 value.
2. These values apply only to compounds of uranium that take the chemical for of UF_6, UO_2F_2, and $UO_2(NO_3)_2$ in both normal and accident conditions of transport.
3. These values apply only to compounds of uranium that take the chemical for of UO_3, UF_4, UCI_4 and hexavalent compounds in both normal and accident conditions of transport.
4. These values apply to all compounds of uranium other than those specified in (2) and (3) of this table.

Appendix 1.3.1

Versa-Pac Shipping Container Licensing Drawings

(4 Sheets)

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Blank Page for VP-55-LD-2 Rev. 5

Blank Page for VP-110-LD-1 Rev. 3

Blank Page for VP-110-LD-2 Rev. 4

Appendix 1.3.2 - General Notes

1. Paint all carbon steel surfaces with (2 mils.) of industrial primer in accordance with manufacturer's specifications. The drum exterior surface is to be painted with enamel top coat in accordance with the drum manufacturers' specification, touchup with spray enamel.
2. Placard as required.
3. Welding procedures and personnel shall be qualified in accordance with AWS D1.1.
4. NDT Personnel shall be qualified in accordance with ASNT-TC-1A. Visual personnel may be certified in addition or in lieu of ASNT-TC-1A as an AWS CWI or CAWI.
5. Nameplates shall be attached after painting by spot welding and paint retouched.
6. General shop tolerances of ± 1/8" apply unless noted. Material tolerances are as required under the appropriate specification.
7. Equivalent components must be approved by engineering and submitted to the NRC for approval.
8. This package shall be manufactured under a Quality Assurance Program that meets the program requirements as outlined in 10 CFR 71. Quality Assurance shall perform visual and magnetic particle inspection through the use of hold points on the Fabrication Control Records for individual packages at pre-determined points to insure that the package is produced according to specifications.
9. The nameplate shall be a minimum of 6" x 6" x 22 gauge stainless steel, ASTM A240, 300 Series. The letters shall be at least ½" high as follows:

   MFG. By: Century Industries, USA

   S/N: -----------

   Century Versa-Pac VP-(55 or 110)

   Type AF

   Tare Wgt: ------ LB

   ------KG

   Max. Gross Wgt: ----- LB

   KG

10. Gaskets and Plugs shall be installed using the appropriate material as described in Standard Operating Procedures.
11. Ceramic fiber paper/blanket/boards and polyurethane foam products shall be in accordance with Century SOP's.
12. Certifications, test reports and QA records shall be stored and maintained as required by Century Industries' Quality Assurance Program.

13. Stenciling shall be in contrasting color and be a minimum of 1" in height unless noted and shall include at a minimum the following information: Additional stenciling of the package is at the discretion of the customer.

Design ID Number:	USA/----/AF Type A (2" Letters)
Model Number:	Century Versa-Pac VP-(55 or 110)
Owners Name:	--
Owners Address:	City, State, and/or Country
	RQ, Radioactive Material, Type A
	Package, Fissile Non-Special Form

(Additional stenciling of the package is at the discretion of the customer. RQ may not be required since it is dependent on the payload contents.)

Appendix 1.3.3

Century Industries

Bristol, Virginia

Procedure Type: Standard Operating Procedure

Procedure No: SOP 6.11

Description: CI-1 Polyurethane Closed Cell Foam Specification for Century Products

This page is a record of revisions to this procedure. Each time a revision is made, only the revised pages are reissued. Remarks indicate a brief description of the revision and are not a part of the procedure.

REVISION	**DATE**	**AFFECTED PAGE (S)**	**REMARKS**
0	01/01/04	All	Original
1	04/11/05	All	Update for Panels
2	01/02/09	All	General Update
3	01-01-10	6	Adjustment to Paragraphs 7.2.1 & 7.2.2

APPROVALS

3			
REV	QA MANAGER	OPERATIONS MGR	PRODUCTION MGR

1.0 PURPOSE

1.1 The purpose of this procedure is to describe the methods of installing CI-1 polyurethane foam in Century Industries products.

2.0 SCOPE

2.1 The scope of this specification shall cover material requirements of the installation of closed cell urethane foam with a density range of 5.0 to 11.0 pounds per cubic foot (PCF) for all shipping containers manufactured by Century Industries.

3.0 ELEMENTAL COMPOUNDS

3.1 The closed cell urethane foam shall have the following elemental percentages, each with a tolerance of ± 10%.

Hydrogen	6.7%
Carbon	61.7%
Oxygen	26.1%
Nitrogen	5.2%
Other	0.3%

4.0 BASIC PHYSICAL PROPERTIES

4.1 Density

Density measurements of test samples shall be performed in accordance with ASTM D-1622. Density measurement of the urethane foam as installed will be by simple calculation of the foam weight divided by the package cavity volume during the normal production runs.

4.2 Compressive Strength

Compressive strength shall be tested in accordance with ASTM D-1621, Compressive Properties of Rigid Cellular Plastics or ASTM D695, Compressive Properties of Rigid Plastics. Density of the foam shall range between 5.0 and 11.0 pcf, with compressive strength between 80 and 300 psi dependant upon the foam strength required by the product specifications.

4.3 Thermal Conductivity

Thermal conductivity shall meet the requirements of and be performed in accordance with ASTM C518. Based upon previous test results the thermal conductivity of the foam K Factor = 4.05 Btu-in/ (h-sq ft-°F.

4.4 Flame Retardancy

Testing was performed in accordance with ASTM E84 and meet the minimum requirements.

4.5 Water Absorption and Moisture Content

Testing for Water Absorption shall be in accordance with ASTM D579.

4.6 Chloride Content

Leachable chloride content shall be less than 100 ppm.

5.0 Storage Requirements

Urethane foam resins and urethane foam and other raw materials and processing chemicals should be stored at room temperature.

6.0 Operating Procedure

6.1 Raw Materials

6.1.1 The urethane foam will be two component; rigid polyurethane system that produces a hard foam with a nominal, free rinse core density of 5 to 11 pcf. The system should be a water blown foam formula with a polymeric MDI as the “A” component. It should be formulated to combine the following desirable combination of processing and foam properties:

6.1.2 The flame retardant should be either a carbon intumescent or mono-penta-erythritol based material.

6.2 Foam In Place Procedure

6.2.1 Calculate the amount of foam required for volume and add 10%.

6.2.2 Weigh container to be foamed – Record reading.

6.2.3 Weigh raw materials for a 7% flame retardant formulation.

6.2.4 Adjust temperature of container to be foamed.

6.2.5 Pre-mix flame retardant and Part A of urethane system in container that will hold al of the components.

6.2.6 Add Part R and mix.

6.2.7 Pour into container cavity.

6.2.8 Watch foam rise for any abnormalities.

6.2.9 When the rise is complete, allow foam to cure before cutting.

6.2.10 Trim excess foam form container.

6.2.11 Weigh foamed container.

6.2.12 Calculate density of the foam in the container based on container void volume and net weight of the foam installed.

6.3 Mold Fabrication Foam Procedure

6.3.1 This procedure is to used for foaming molds, blocks or buns of material to be cut to a particular finished component part to be used in the final container.

6.3.2 Calculate the amount of foam required for the mold.

6.3.3 Adjust the mold temperature.

6.3.4 Weigh out the raw materials.

6.3.5 Pre-mix flame retardant and Part A of the urethane system in a container that will hold all components.

6.3.6 Add Part R and mix.

6.3.7 Pour evenly into mold.

6.3.8 Watch for abnormalities.

6.3.9 Once the rise is complete, record total rise height.

6.3.10 Once the foam has cured, cut to specified shape.

6.3.11 As required take sample and calculate pcf.

6.3.12 A specific bun number (Pour No.) is assigned to the bun and spray painted on the top.

6.4 Mold Fabrication Foam Procedure – Cutting

6.4.1 Cutting: After curing, each bun will be cut on the wire saw to the required foam panel shape per the instructions provided by the Production Supervisor. Each individual panel shape and orientation will have a unique letter identification assigned to it such as TR (Top Right), TL (Top Left), ET (End Top), EB (End Bottom) and SRB (Side Right Bottom), Etc.

6.4.2 Each shape that is cut will be marked with the Bun Number and the Shape ID.

6.4.3 A sample of left over foam from each bun will be collected and labeled for pcf calculation.

7.0 Quality Assurance

7.1 Production

Prior to production of each product utilizing the closed cell urethane foam, Quality Assurance shall establish the correct weight of the foam materials required to produce the correct density.

7.2 Records

7.2.1 Foam in Place

A foaming record must be completed for each foam installation in each individual package and it shall become a part of the final QA record. This record shall include as a minimum: foam components, weight of the container before and after the foaming and trimming and have proper QA verifications.

The foam fabricator shall supply records from the resin manufacturer for each urethane resin batch. They shall also supply from an independent laboratory, results to verify that the leachable chloride content taken from foam samples of each resin batch, meet the leachable chloride content requirement of less than 100 ppm.

7.2.2 Foam Panels

A foaming record must be completed for each foam panel bun produced and it shall become a part of the final QA record. This record shall include as a minimum: foam components, weight of raw materials charged, the dimensions of the foamed bun and have proper QA verifications.

The density of the representative foam panel material from each bun shall be calculated and recorded in the Panel Foam Density Record.

The foam fabricator shall supply records from the resin manufacturer for each urethane resin batch. They shall also supply from an independent laboratory, results to verify that the leachable chloride content taken from foam samples of each resin batch, meet the leachable chloride content requirement of less than 100 ppm.

8.0 Attachments

8.1 Production Foam Record

8.2 Panel Foam Density Record

Century Industries UF-1 Production Foam Record

Date: ______________________ Time: ________________ Pour No: __________________

Mold Room Temperature: _______________ Type of Pour: In-Place _____ Mold ____

Chemical	LBS	Grams	Description
“A” System			
“R” System			
Flame Retardant			
Total			

Foam in Place Density Data

Containers Empty Weight	
Trimmed Foam Container Weight	
Volume of Container Cavity Foamed	
Density of Container Foam	

Mold Foam Density

Mold size in Inches	
Height of Foam in Mold	
Weight of Foam Charge	
Density of Foam Component	

Foaming Information

	Plan	Actual
Start Temp. – Resin “A”		
Start Temp. – Resin “R”		
Mixer RPM		
Mixer Type		
Chem. Mix Time in Sec.		
Cream Time in Sec.		
Foam Time in Sec.		
Tack Free Time in Sec.		
Foam Height in Mold (In.)		

Person Responsible for Formulation: ____

Person Responsible for Production: ____

QA Review By: ____ Date: ______________

Appendix 1.3.4

Century Industries

Bristol, Virginia

Procedure Type: Standard Operating Procedure

Procedure No: SOP 6.12

Description: CI-1 Ceramic Fiber Insulation Specification for Century Products

This page is a record of revisions to this procedure. Each time a revision is made, only the revised pages are reissued. Remarks indicate a brief description of the revision and are not a part of the procedure.

REVISION	**DATE**	**AFFECTED PAGE (S)**	**REMARKS**
0	01/01/04	ALL	Original
1	07/03/08	2	Density and Thickness
2	06/15/09	2	Addition of Higher Density Materials
3	12/12/09	2, 3 & 4	Adjustment to Text and Record Adjustment

APPROVALS

3			
REV	QA MANAGER	OPERATIONS MGR	PRODUCTION MGR

1.0 PURPOSE

1.1 The purpose of this procedure is to describe the ceramic fiber materials used in Century Industries products

2.0 SCOPE

2.1 The scope of this specification shall cover material requirements for the installation of both ceramic fiber paper and blanket insulation products in Century Industries products.

3.0 BASIC PHYSICAL PROPERTIES

3.1 Paper

Density = 8-10 lbs/ft^3

Thickness = 1/8 in.

Thermal Conductivity = Btu-in/hr/ft^2 °F (ASTM C 201)

3.2 Blanket

Density = 6, 8 & 12 lb/ft^3

Thickness = 0.5 to 3 in.

Thermal Conductivity = Btu-in./hr./ft^2/°F (ASTM C 201)

4.0 Storage Requirements

4.1 Store the Ceramic Fiber paper and blanket insulation in an area with relatively low humidity at ambient temperature.

5.0 Quality Assurance

5.1 Production

Quality Assurance shall verify that the density and thickness of the ceramic fiber insulation is correct when received and prior to installation.

5.2 Records

A ceramic fiber insulation record must be completed for each individual package and it shall become a part of the final QA record. This record shall include as a minimum: verification of density and thickness and serial number of the package in which the insulation was installed.

6.0 Attachments

6.1 Ceramic Fiber Installation Record

Century Industries CI-1

Ceramic Fiber Installation Record

Ceramic Fiber Paper

Package Serial Number	Density	Thickness	Manufacturer/Product	Lot/Batch No.

Ceramic Fiber Blanket

Package Serial Number	Density	Thickness	Manufacturer/Product	Lot/Batch No.

Production Signature: ______________________________ Date: _____________

QA Signature: _____________________________________ Date: _____________

Appendix 1.3.5

Century Industries

Bristol, Virginia

Procedure Type: Standard Operating Procedure

Procedure No: SOP 6.13

Description: Structural Fiberglass Component Specification for Century Products

This page is a record of revisions to this procedure. Each time a revision is made, only the revised pages are reissued. Remarks indicate a brief description of the revision and are not a part of the procedure.

REVISION	**DATE**	**AFFECTED PAGE (S)**	**REMARKS**
0	11/10/08	ALL	Original
1	12/12/09	4, Paragraph 4.1	Storage Requirement Completion

APPROVALS

1			
REV	QA MANAGER	OPERATIONS MGR	PRODUCTION MGR

1.0 PURPOSE

1.1 The purpose of this procedure is to describe the structural fiberglass component materials used in Century Industries products

2.0 SCOPE

2.1 The scope of this specification shall cover material requirements for the structural fiberglass components utilized in Century Industries products.

3.0 BASIC PHYSICAL PROPERTIES

3.1

Property	Value	ASTM Test
Mechanical		
Tensile Stress, LW	30,000 psi	D638
Tensile Stress, CW	7,000 psi	D638
Compressive Stress, LW	30,000 psi	D695
Compressive Stress, CW	15,000 psi	D695
Flexural Stress, LW	30,000 psi	D790
Flexural Stress, CW	10,000 psi	D790
Modulus of Elasticity[1]	2.6 x 10^6 psi	Full Section
Modulus of Elasticity >4"[1]	2.5 x 10^6 psi	Full Section
Physical		
Barcol Hardness	45	D2583
24 Hour Water Absorption	0.6% Maximum	D570
Density	.062 - .070 lbs/in^3	D792
Thermal Conductivity	4-BTU-in/ft^2/hr/°F	C177
Electrical		
Arc Resistance, LW	120 Seconds	D495
Flammability		
Tunnel Test	25 Maximum	E84
Flammability	Self Extinguishing	D635

LW – Lengthwise CW – Crosswise

Note:

1. This value is to be determined from full section simple beam bending of structural shapes.

2. All test requirements are minimum ultimate coupon properties of structural shapes per the referenced ASTM Specification, unless otherwise noted.

3.2 Description of Tests

Tensile Strength (ASTM D638)

The tensile strength is determined by pulling ends of a test specimen until failure.

Compressive Strength (ASTM D695)

The ultimate compressive strength of a material is a force required to rupture the test specimen when a load is applied such that the specimen is crushed.

Flexural Properties (ASTM D790)

The flexural strength is determined by placing a test specimen between two supports and applying a load to the center.

Modulus of Elasticity (Full Section)

This test is conducted by loading a prescribed length of the full shape (not a coupon) with a support at each end and applying a center load.

Barcol Hardness (ASTM D2583)

The barcol hardness is a measurement of the resistance of the surface of a test specimen to penetration by a needle probe which is spring driven. The barcol hardness is generally an average of multiple measurements on the same part and is an approximate measure of the materials completeness of cure.

Water Absorption (ASTM D570)

The specimens are immersed in water for a period of 24 hours and the change in weight is measured.

Density (ASTM D792)

The density is the ratio of the mass (weight) of a specimen to the volume of the specimen.

Thermal Conductivity (C177)

This test establishes the criteria for the laboratory measurement of the steady-state heat flux through flat, homogeneous specimens when the surface is in contact with solid, parallel boundaries held at constant temperature using a guarded hot plate apparatus.

Arc Resistance (ASTM D495)

This test is performed by placing two probes on a test specimen at a distance of ¼”. A high voltage, low current, arc is passed between the probes with a specified on/off cycle for the arc. The time taken for the arc to completely burn a path through the composite is measured.

Tunnel Test (ASTM E84)

In the 25 foot tunnel test, a smoke generation value and the rate of flame spread are determined.

Flammability (ASTM D635)

The specimen is held horizontally with one end subjected to a flame for 30 seconds.

4.0 Storage Requirements

4.1 All fiberglass products shall be stored in a dry area at ambient temperatures. Fiberglass products may be stored either vertically or horizontally and should be properly supported to reduce the possibility of damage.

5.0 Quality Assurance

5.1 Production

Quality Assurance shall verify that the materials are free from damage and that the certificate of compliance for the product is correct and that it meets the requirements of this procedure when received and prior to installation.

5.2 Records

A Certificate of Compliance from the manufacturer must be reviewed for compliance with this procedure and it shall become a part of the final QA record.

SECTION THREE
THERMAL EVALUATION

Table of Contents

List of Tables and Figures

3 THERMAL EVALUATION

The Century Industries Versa-Pac is designed to maintain the temperatures of the payload and containment boundary within specified limits during normal transportation and hypothetical accident conditions. This section presents an evaluation of the thermal performance of the packaging.

3.1 Description of the Thermal Design

3.1.1 Design Features

The 55-gallon Versa-Pac consists of a 15” ID x 25-7/8” inside height payload cavity centered within an insulated 55-gallon drum. Drawings of the 55-gallon version Versa-Pac are provided in Appendix 1.3.1. An illustration of the packaging is provided in Figure 1-1.

The overall nominal dimensions of the 55-gallon Versa-Pac shipping container are 23-1/16” OD x 34-1/2” in height to the top of the outer drum lid without the bolt ring in place. The payload cavity is protected from water intrusion with a gasketed lid that is closed with twelve ½” diameter bolts. Exterior to the payload cavity lid, the 55-gallon drum lid is modified with a 20ga steel encapsulated polyurethane insulation plug. The gasketed drum lid is closed with four ½” diameter bolts and a standard drum ring. A gasket at the drum lid’s stiffening ring provides a third barrier against water in-leakage. The 55-gallon drum is strengthened with four longitudinal stiffeners fabricated from 1-1/4” carbon steel square tubing equally spaced around the circumference of the drum. A 16ga outer liner and a 16ga inner liner provide additional radial stiffness to the drum. A ½” thick fiberglass ring is used as a thermal break at the payload cavity flange. The thermal break is sandwiched between the steel components and effectively limits the flow of heat to the payload cavity through the steel flange components. The volume between the inner liner and the 10ga containment body is filled with ceramic fiber insulation (see Appendix 1.3.4).

The 110-gallon Versa-Pac consists of a 21” ID x 29-3/4” payload cavity centered within an insulated 110-gallon drum. Drawings of the 110-gallon version Versa-Pac are provided in Appendix 1.4.1. An illustration of the packaging is provided in Figure 1-2. The overall nominal dimensions of the package are 30-7/16” OD x 42-1/2” in height to the top of the outer drum lid without the bolt ring in place. The basic design of the 110-gallon Versa-Pac is identical to that of the 55-gallon Versa-Pac, except for the larger exterior diameter and payload cavity diameter. The thickness of the walls and insulation remain the same.

3.1.2 Contents Decay Heat

The decay heat for the payload is limited to 11.4 W total for the 55-gallon and 110-gallon models, with no single item having a decay heat greater than 20 W/m^3.

3.1.3 Summary Tables of Temperatures

Table 3-1 provides a summary of the Normal and HAC temperatures for the Versa-Pac. The maximum peak content temperature occurs for the HAC fire event 22 minutes into the cool-down sequence and is 552^{o}F at the top of payload cavity.

3.1.4 Summary Tables of Maximum Pressures

Since the Versa-Pac is not a sealed system, the maximum normal and HAC operating pressure is near atmospheric pressure. Thus, the Versa-Pac meets the requirements of 10CFR71. However, assuming a sealed system, the maximum HAC operating pressure is less than 9.8 psig (Section 2.6.1.1)

3.2 Material Properties and Component Specifications

3.2.1 Material Properties

Thermal material properties are provided in Table 3.5.1-3. Mechanical material properties, including the linear thermal expansion coefficient, are provided in Table 2-2.

The payload is a stable solid that does not undergo any physical state changes (solid to liquid or solid to gas) below 600°F. Additionally, the melting point temperature of the contents must be greater than 600°F. Water moisture may be present (standing water is not permitted); however, during the fire it is converted to steam and is allowed to escape via the package closure gaskets. Payloads that are unstable or decompose at temperatures below 600°F that further pressurize the containment shall not be shipped in the Versa-Pac. The payload is a stable solid with both the auto-ignition temperature and the melting point greater than 600°F. The allowable temperature limits for the payload of the Versa-Pac packages are 500°F for NCT and 600°F for HAC.

3.2.2 Component Specifications

The Versa-Pac is insulated to protect the containment boundary during Hypothetical Accident Conditions (HAC). The volume between the drum and the liner is filled with ceramic fiber insulation. The volume between the liner and the payload canister is also filled with ceramic fiber insulation. A fiberglass thermal break is used to limit the flow of heat to the payload cavity through the steel flange components. The relevant thermal material properties and specifications are provided in Table 3.5.1-2. These insulators have been shown by the manufacturers to perform adequately over extended periods of time, with no shrinkage, settling, or loss of insulating properties. Additionally, these insulators do not burn. The melting point of the ceramic fiber insulation and the fiberglass thermal break are well above the temperature of the 1475°F fire specified by 10CFR71.73. These insulation products are provided as fire-protection and are sacrificial components during a fire event. Steel components are serviceable to 800°F per the ASME Code, and have a melting point of about 2500°F.

The payload cavity gaskets are rated for operating temperatures between -40°F and 1800°F; however, the Versa-Pac isn't designed as a sealed system and the function of the gaskets is to prevent dispersal of the contents only. Since the system is not sealed, the internal pressure is maintained near atmospheric conditions during all conditions of transport. The nominal payload vessel internal pressure is 0 psig. As a conservative comparison and demonstration, the maximum allowable external and internal working pressure for a sealed cylinder having 0.14” walls and ends is evaluated as 15 psig, with the maximum stresses occurring at the juncture of the lid and base with the sides of the cylinder[1]. Thus, the Versa-Pac is capable of sustaining the working pressures expected without collapse.

The fiberglass thermal break is fabricated to the specification provided in Appendix 1.3.5. The fiberglass is serviceable to a temperature of 160°F and maintains its thermal properties to 525°F

3.3 Thermal Evaluation for Normal Conditions of Transport (NCT)

The Versa-Pac is designed to meet the requirements specified by the United States Code of Federal Regulations (Title 10 and 49) and IAEA Safety Standards (TS-R-1). The package was evaluated for all conditions of transport utilizing a transient quarter-symmetric finite element model as described in Appendix 3.5.1. Material properties used in the analyses are provided in Appendix 3.5.1. Table 3-2 provides a summary of the parameters analyzed for each scenario examined, including initial conditions and heat loads.

3.3.1 Heat and Cold

The absorptivity of the outer shell is conservatively assumed to be 1.0. The convection heat transfer coefficient is conservatively assumed to be 1.0 Btu/hr-F-ft^2. The decay heat is assumed to be at the maximum for normal hot conditions. The maximum temperatures for Normal Conditions of Transport occur when the conditions specified by 10CFR71.71(c)(1) are applied. The specified insolation rate of 800 g-cal/cm^2 per 12-hour period is applied to the top surface of the packaging and an insolation rate of 400 g-cal/cm^2 per 12-hour period is applied to the curved sides of the packaging. Insolation is not applied to the base of the packaging.

With these insolation rates applied for 12-hours and alternated with 12-hours without insolation, the peak daytime temperature at the external surface of the package for the normal condition of transport is 140°F (60°C) at the drum lid as illustrated in Figures 3-1 and 3-2. The peak temperature of the contents for the normal condition is 144°F (62°C), as shown in Figure 3-3.

Under normal cold conditions as specified by 10CFR71.71(c)(2), the minimum temperature of the packaging and payload, assuming zero decay heat, is -40°F. This temperature is within the limits specified in Section 3.1.

---

[1] Classical equations for thin-walled cylinders with a uniformly distributed interior pressure are used, including junction discontinuity stresses at the connection between the ends and sides of the cylinder, and considering an allowable stress of 30 ksi.

3.3.2 Maximum Normal Operating Pressure

Since the Versa-Pac is not a sealed system, the maximum normal operating pressure is near atmospheric pressure.

3.4 Thermal Evaluation for Hypothetical Accident Conditions (HAC)

The Versa-Pac was evaluated for HAC using the finite element models described in Appendix 3.5.1 and under the conditions listed in Table 3-2. The maximum temperature recorded at the payload cavity during the fire event was 552^{o}F at the top of payload cavity, just below the polyurethane plug, as shown in Figure 3.1. This temperature is well below the maximum HAC allowable temperature of 600^{o}F.

3.4.1 Initial Conditions

The model imposes an initial condition of 100^{o}F on all nodes at the start of the thermal event. Damage from the mechanical tests was not simulated; however, local reductions in wall thickness were shown in the drop tests to be limited to the outer 1-1/2” of the package. Since this portion of the package quickly attains the temperature of the fire, a local reduction isn’t expected to influence the temperature of the contents.

3.4.2 Fire Test Conditions

For the fire analysis, the external surface nodes were constrained to a temperature of 1475^{o}F for the 30-minute event. For the 55-gallon version, the contents are modeled with a decay heat load of 0.022 in-lb$_f$/s / in^3, for a conservative total package heat load of 11.4 W. The decay heat load of the 110-gallon version modeled is 0.0085 for a total of 11.4 W.

3.4.3 Cool-down Conditions

The cool-down sequence is initialized with the temperatures recorded for each node at the end of the 30 minute fire sequence. Insolation is applied using the insolation rates and 12-hours on, 12-hours off application described for the NCT evaluation. The ambient temperature is 100^{o}F. Surface temperature dependant external surface natural convection coefficients are applied at the outer surfaces of the package, with the exception of the base, which is assumed to be adiabatic[2]. The remainder of the model and specifications are identical to those used during the fire sequence. The cool-down sequence was run for a 2-hour cool-down period, with the peak payload temperatures occurring within the first hour after cessation of the fire.

---

[2] An *adiabatic process* is a thermodynamic process in which there is no heat transfer into or out of the system. In this case, the surface that the package is sitting on is assumed to be a perfect insulator, and no heat can be removed from the base unless it moves through the sides of the package. This is considered to be the conservative orientation for the package during cool-down conditions.

3.4.4 Maximum HAC Temperatures and Pressures

3.4.4.1 HAC Temperatures

The maximum temperature recorded at the payload cavity during the fire event was 552^{o}F at the top of payload cavity, just below the polyurethane plug, for the 55-gallon package as shown in Figure 3.4. The temperature distributions of the various package components are shown in Figures 3.4 through 3.14. A time dependent graph of the peak temperature locations on the payload cavity is provided in Figure 3.15. The 110-gallon package performance is bounded by that of the 55-gallon package.

3.4.4.2 HAC Pressures

Since the Versa-Pac is not a sealed system, the maximum normal operating pressure is near atmospheric pressure.

3.4.5 Maximum Thermal Stresses

The performance of the Versa-Pac with respect to thermal stresses is demonstrated through the fire tests performed for similar packages. A summary of one such test is provided in Appendix 3.5.3. The flexible construction of the connection between the payload cavity and the flange assures that thermal gradients do not impose excessive stress on the package joints. Appendix 3.5.5 provides a thermal stress evaluation of the polyurethane plug insert.

3.4.6 Accident Conditions for Fissile Material Packages for Air Transport

This section is not applicable.

3.5 List of Appendices

3.5.1. Description of the Thermal Model

3.5.2. Excerpted from ALGOR Non-Linear Thermal Transient Heat Transfer Analysis Manual, Emulation of body-to-body radiation as temperature dependent conduction

3.5.3. Excerpted from Safety Analysis Report for the Century Champion Type B Package Thermal Test

3.5.4. Schematic of Thermal Evaluation Conditions

3.5.5. Thermal Stress Evaluation of the Polyurethane Plug Insert

3.6 References

3.6.1. MatWeb material database, a division of Automation Creations, Inc. (ACI) of Blacksburg, Virginia.

3.6.2. ALGOR FEMPRO FEA Software by Autodesk, Pittsburgh, PA, version 18.1.

3.6.3. Incropera & DeWitt, *Fundamentals of Heat and Mass Transfer 3rd Edition*, John Wiley & Sons, New York, 1990.

Table 3-1 Evaluation Results

Evaluation	**Component**	**Evaluation Result**	**Evaluation Criteria**	**Margin of Safety** Note 1
Normal Hot Maximum Temperature	External surface	140°F	800°F	660°F
	Payload cavity gasket	130°F	1800°F	1670°F
	Payload	144°F	500°F	356°F
Normal Cold Minimum Temperature	External surface	-40°F	N/A	N/A
	Payload cavity gasket	-40°F	-40°F	0°F
	Payload	-40°F	N/A	N/A
Normal Maximum internal pressure	Payload cavity	0 psig	15 psig	15 psig
HAC Maximum Temperature	External surface	1475°F	2500°F	1025°F
	Payload cavity gasket	623°F	1800°F	1177°F
	Payload	552°F	600°F	48°F
HAC Maximum Internal Pressure	Payload cavity	0 psig	15 psig	15 psig
HAC Thermal Stress	package	Demonstrated by test as acceptable	No failure due to fire event temperature distribution	N/A

Notes on Table 3-1

1. The margin of safety is (allowable – actual)
2. Results shown are for the 55-gallon package. The 110-gallon package performance is bounded by that of the 55-gallon package.

Table 3-2 Applied Heat Loads, Heat Transfer Coefficients and Initial Conditions

Parameter	**Normal Transport Hot**	**Normal Transport Cold**	**HAC Transport**
Ambient Temperature, °F	100.00	-40.00	1475 for 30min, 100.00 until peak temperatures are identified
Top surface insolation, BTU/hr-ft^2, 12 hours on, 12 hours off	246.00	0.00	N/A during the fire, 246.00 during cool-down
Curved surface insolation, BTU/hr-ft^2, 12 hours on, 12 hours off	123.0	0.00	N/A during the fire, 123.00 during cool-down
Base surface insolation, BTU/hr-ft^2, 12 hours on, 12 hours off	0.00	0.00	N/A during the fire, 0.00 during cool-down
Radiological Decay Heat, 55 gal / 110 gal, W	11.4 / 11.4	0.00	11.4 / 11.4
Analysis performed	Transient	N/A	Transient
Initial Package/Content Temperature	100.00	N/A	100ºF
External surface absorptivity/emissivity	1.0	N/A	1.0
External surface convection coefficient, Btu/hr-F-ft^2	1.0	N/A	During fire transient, N/A During cool-down, see Table 3.5.1-5

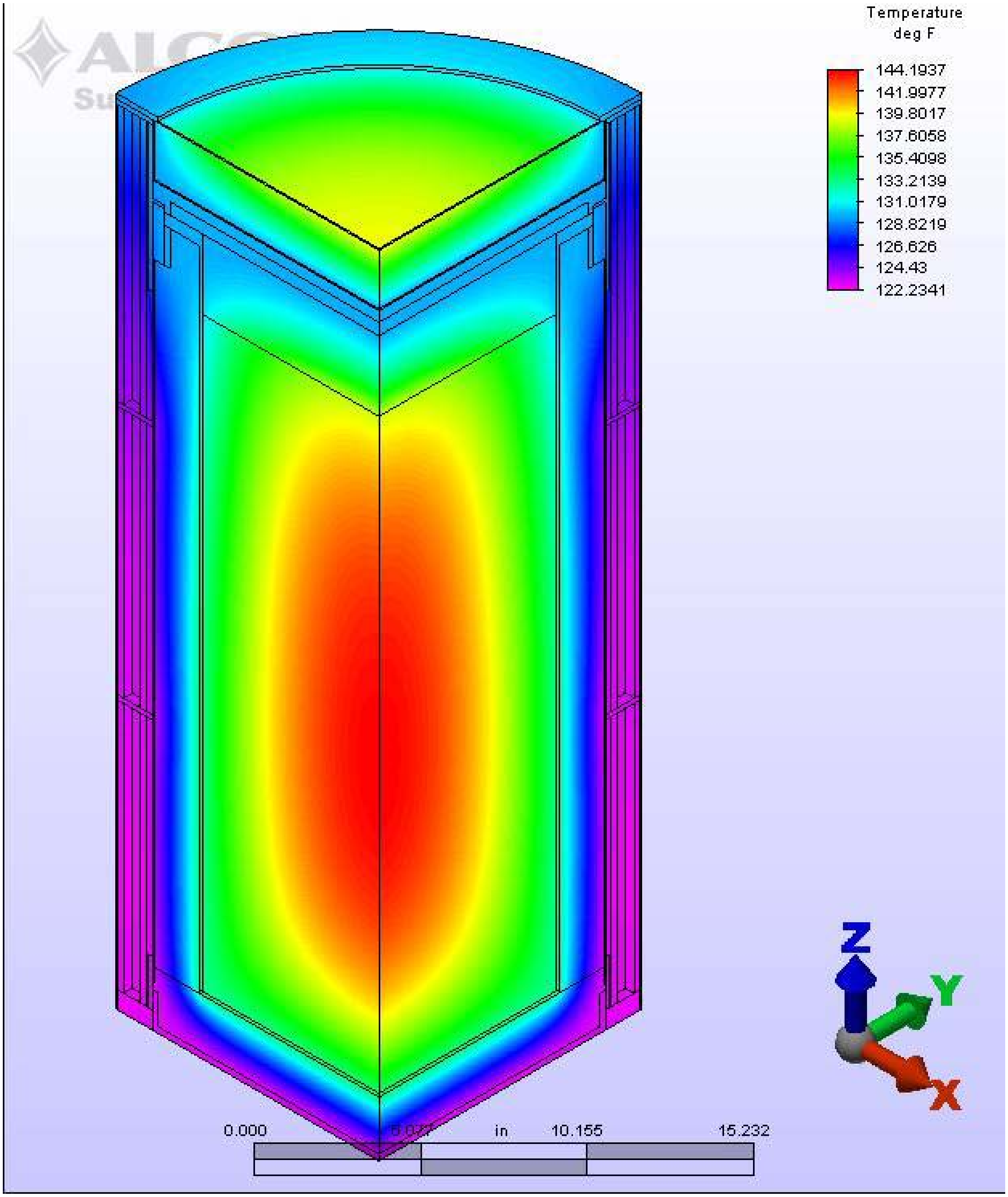

Figure 3-1 Normal Hot Package Peak Temperature Distribution, 55-gallon Versa-Pac

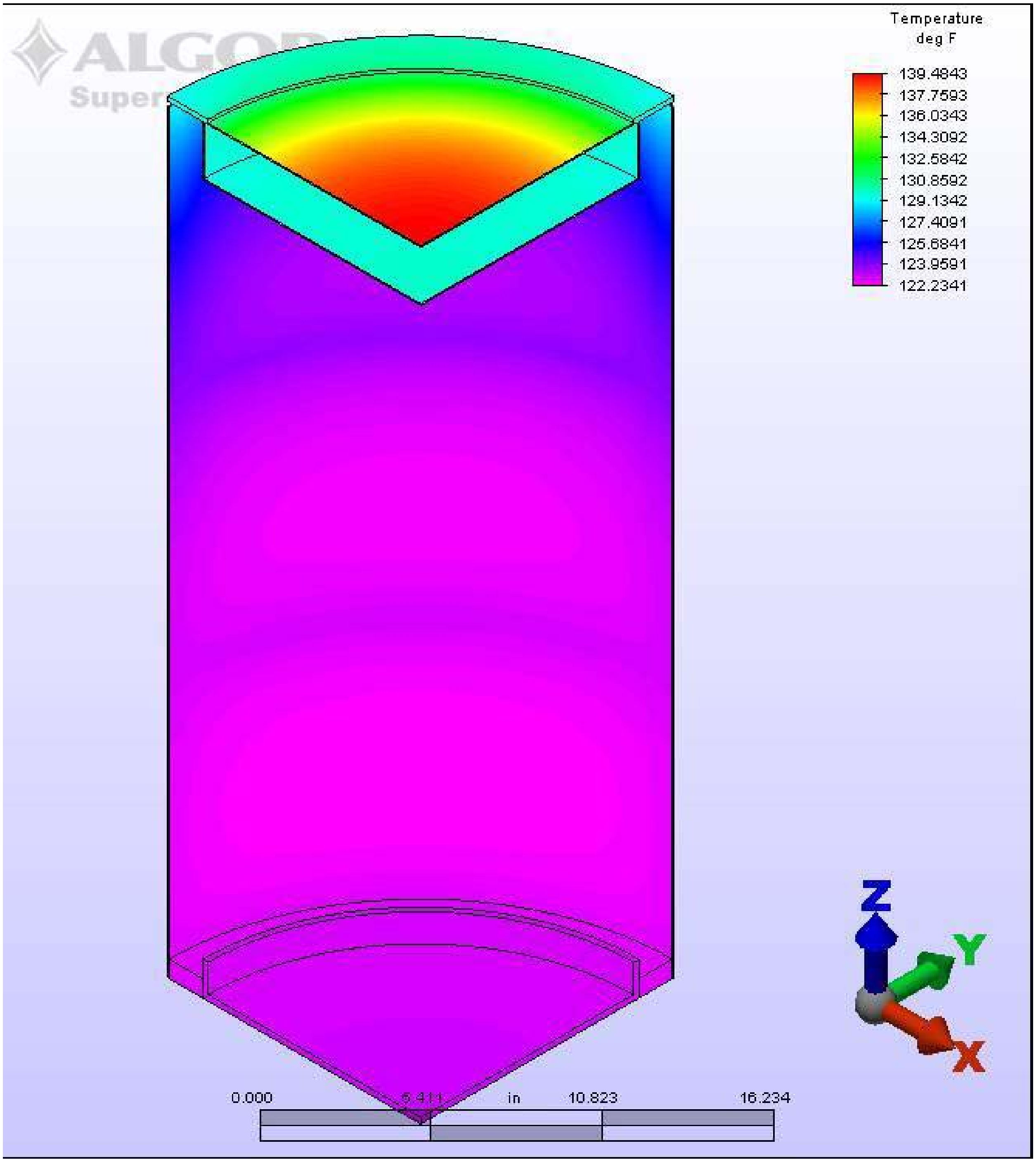

Figure 3-2 Normal Hot Outer Surface Peak Temperature Distribution, 55-gallon Versa-Pac

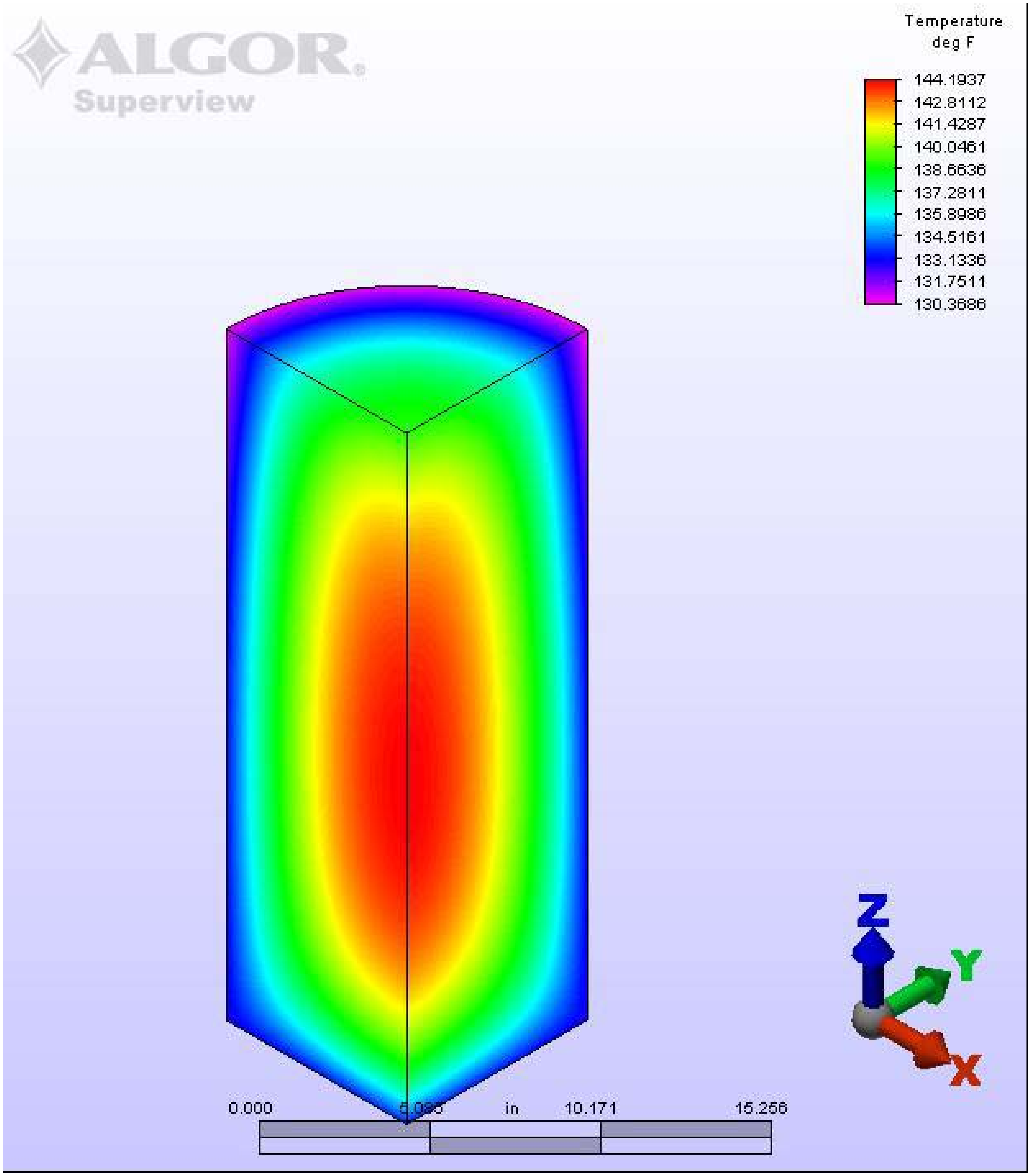

Figure 3-3 Normal Hot Contents Peak Temperature Distribution, 55-gallon Versa-Pac

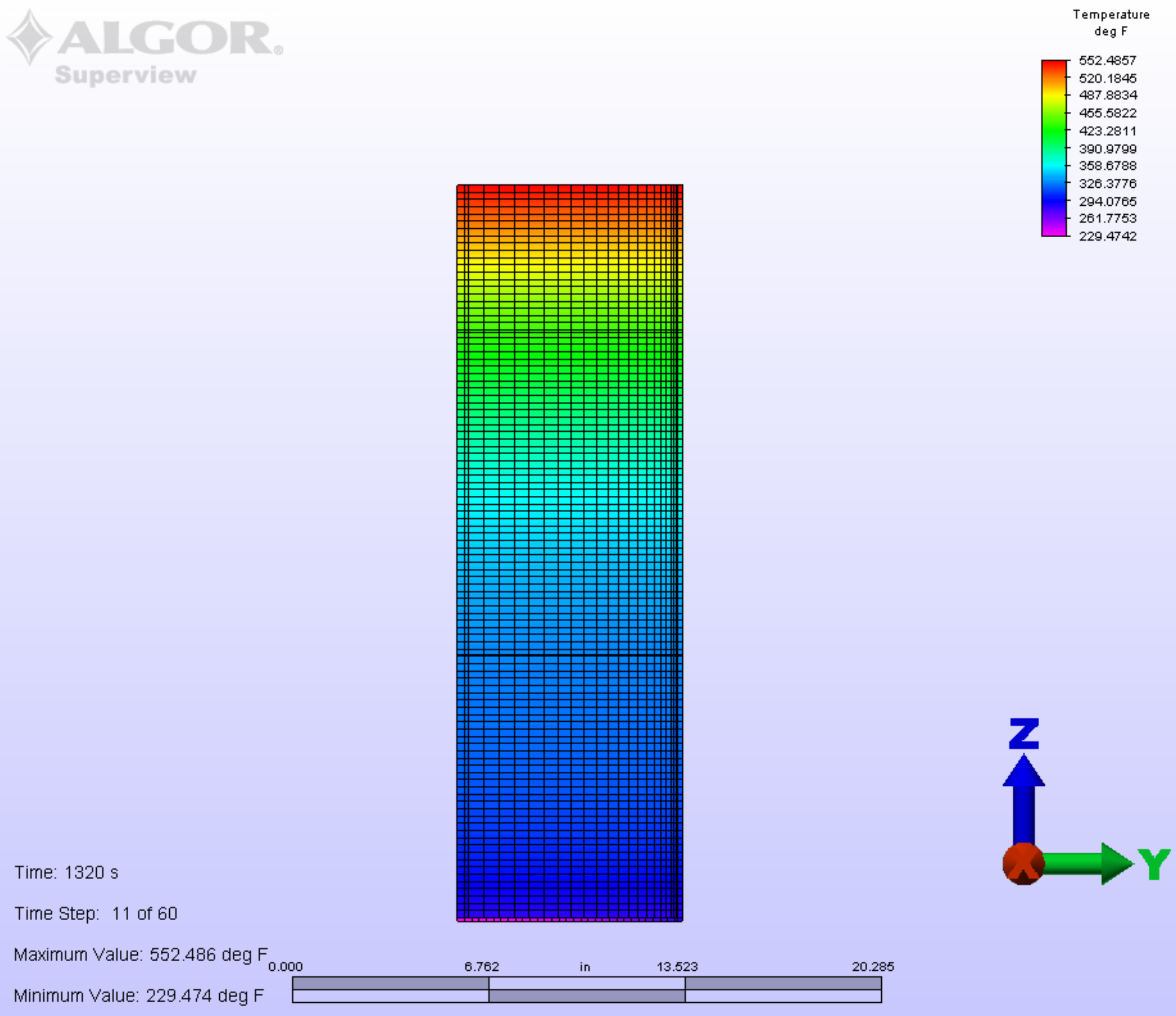

Figure 3-4 Maximum Fire Event Temperature at Cool-down Sequence, 22 minutes after Cessation of Fire, Contents

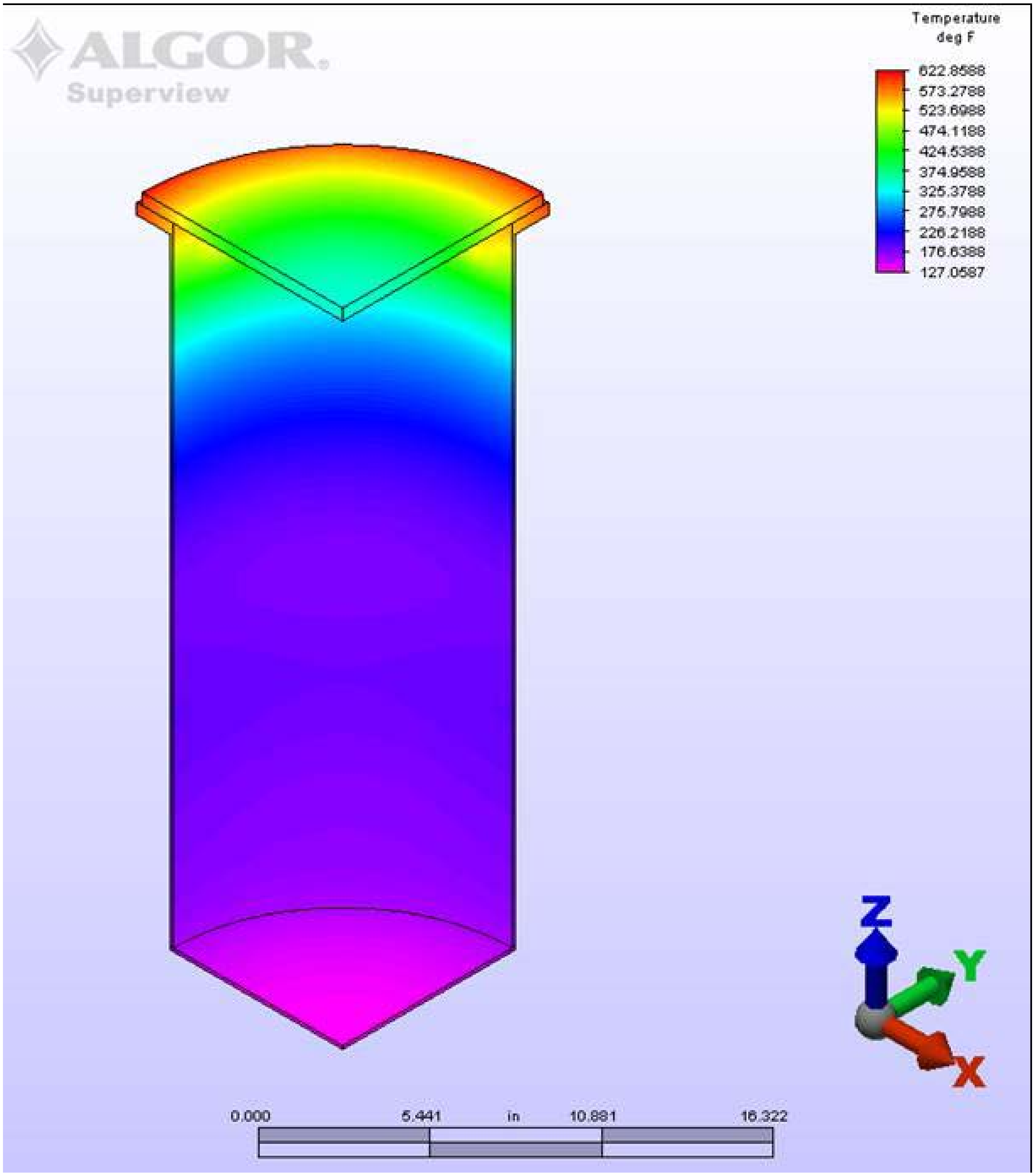

Figure 3-5 Fire Event temperature at 30 minutes, Payload Cavity and Flanges (including polyurethane plug area)

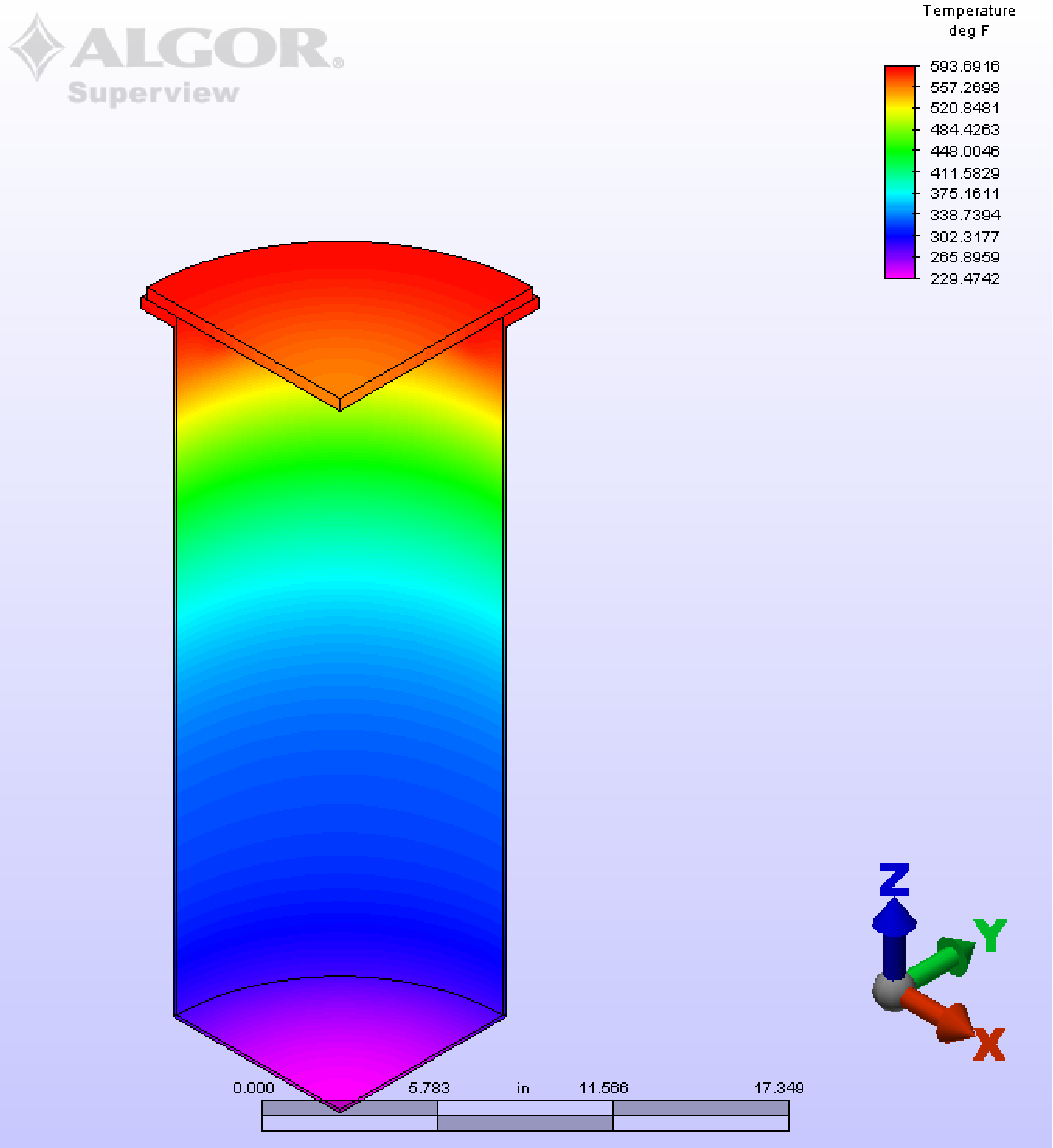

Figure 3-6 Fire Event & Cool-down temperature at 55 total minutes, Payload Cavity and Flanges (including polyurethane plug area)

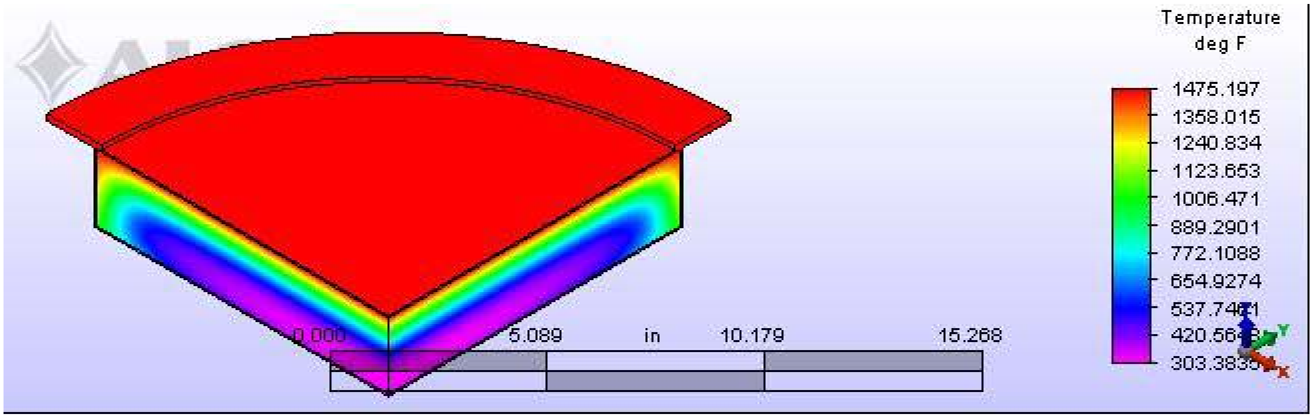

Figure 3-7 Fire Event temperature at 30 minutes, Package Lid

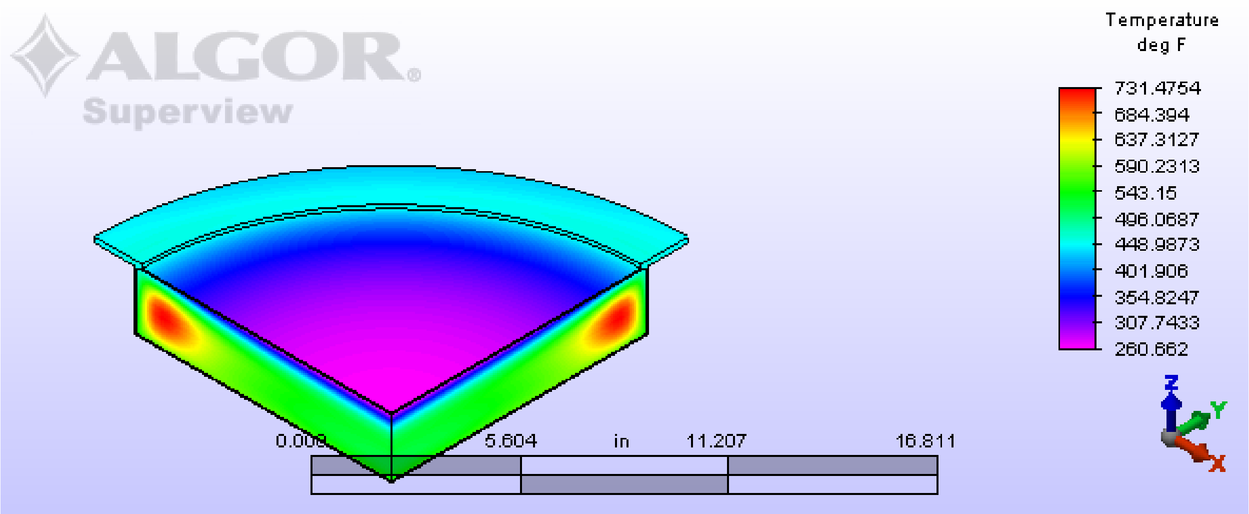

Figure 3-8 Fire Event and Cool-down temperature at 55 total minutes, Package Lid

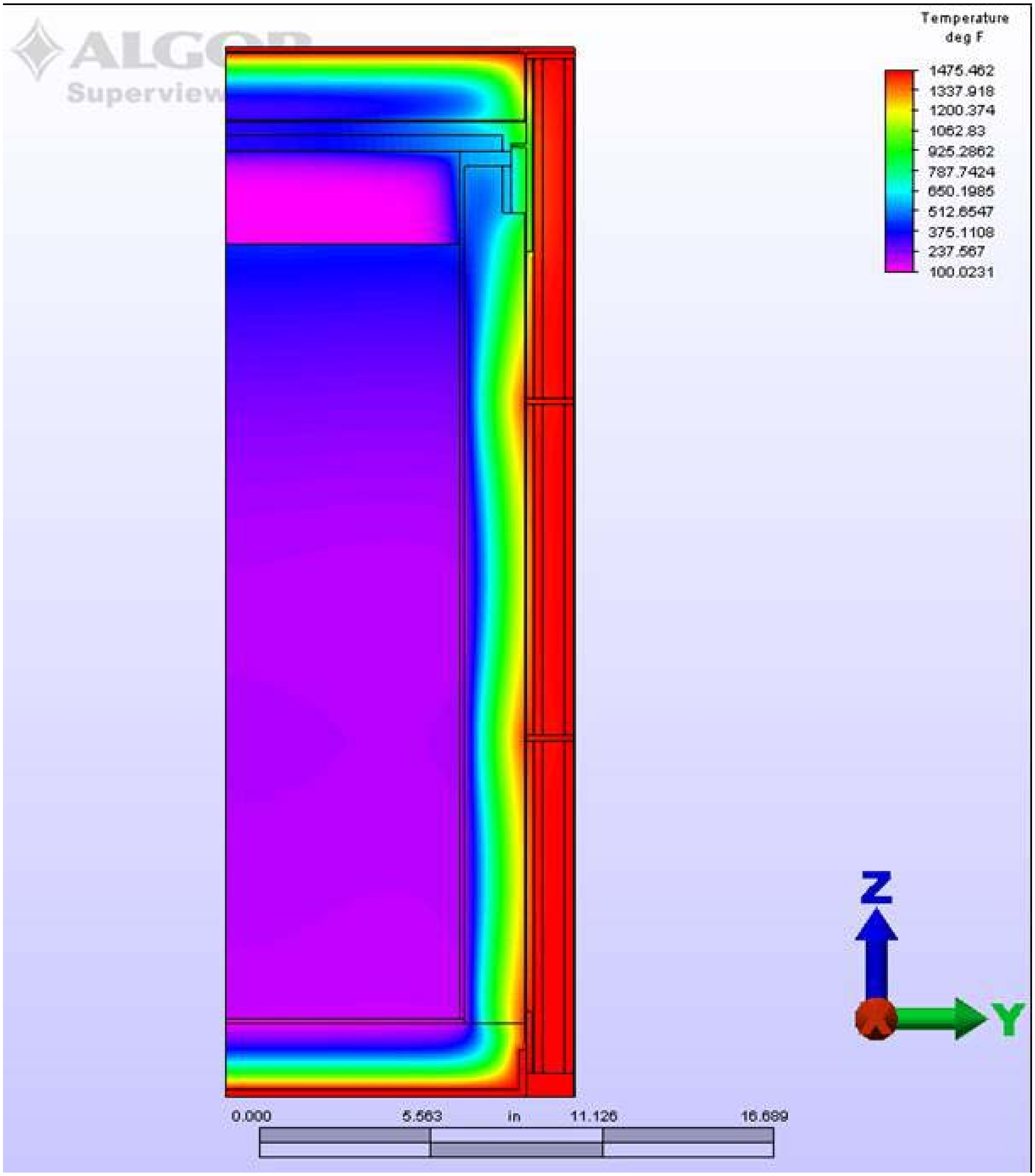

Figure 3-9 Fire Event temperature at 30 minutes, Package side view

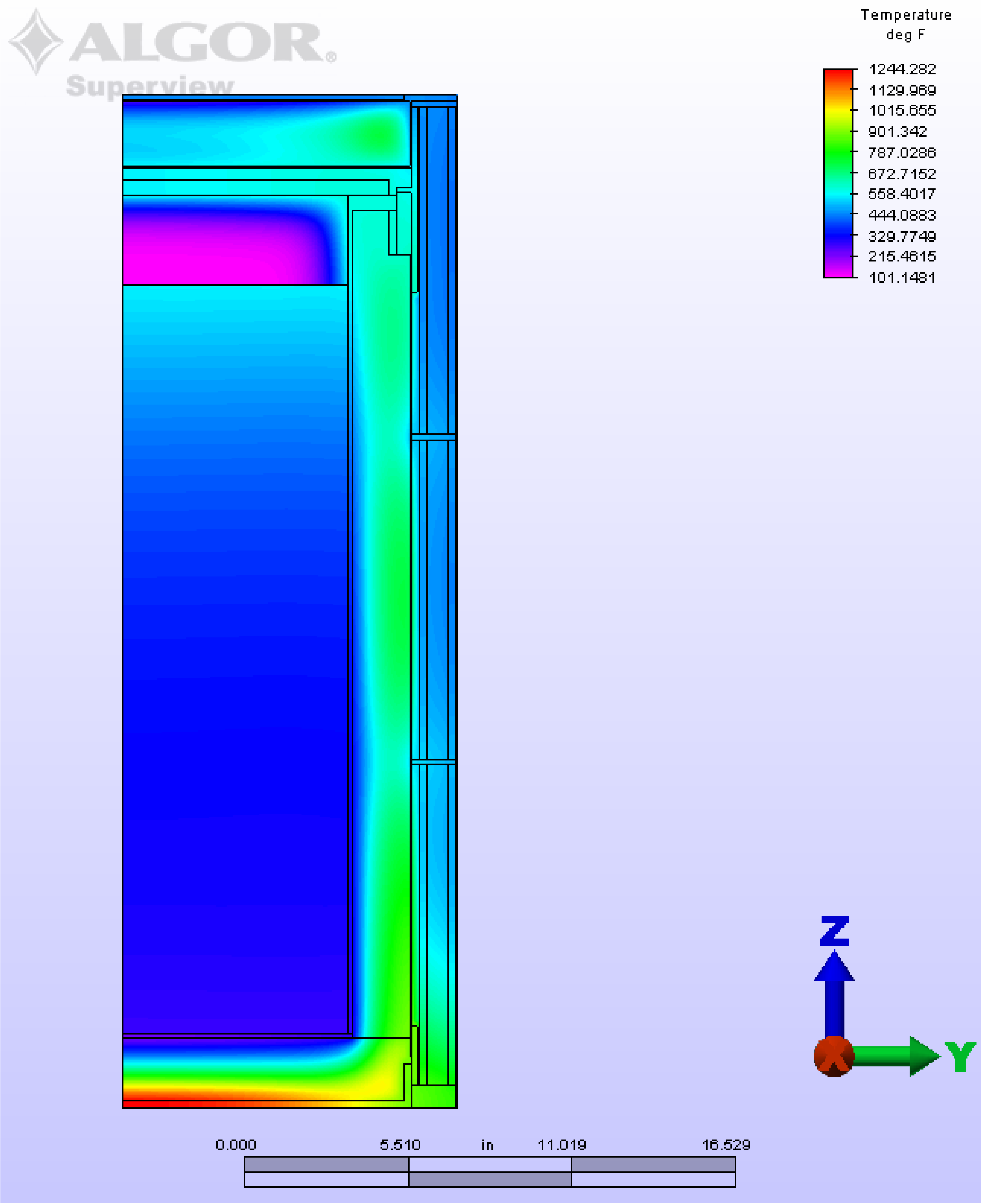

Figure 3-10 Fire Event and Cool-down temperature at 55 total minutes, Package side view

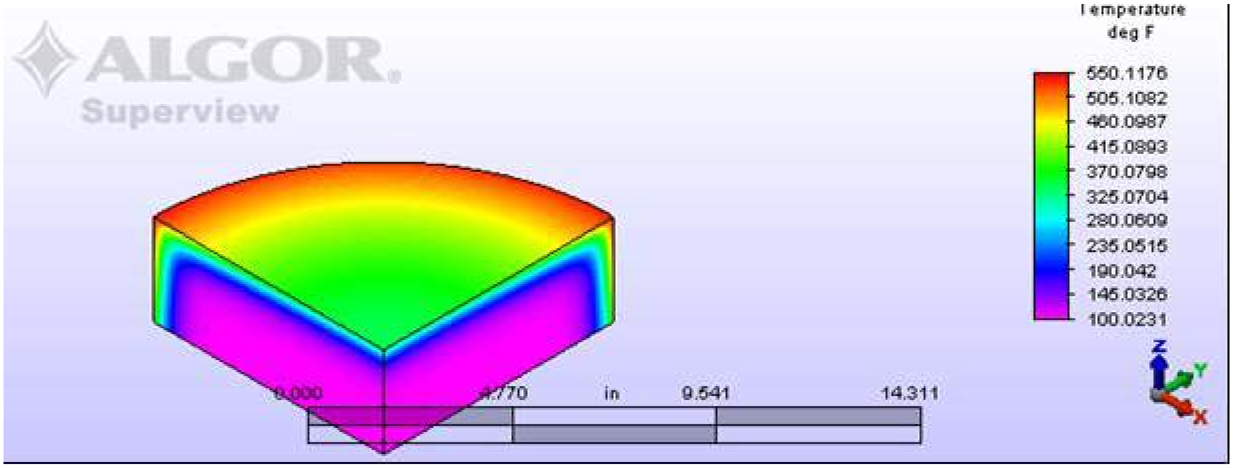

Figure 3-11 Fire Event temperature at 30 minutes, polyurethane plug

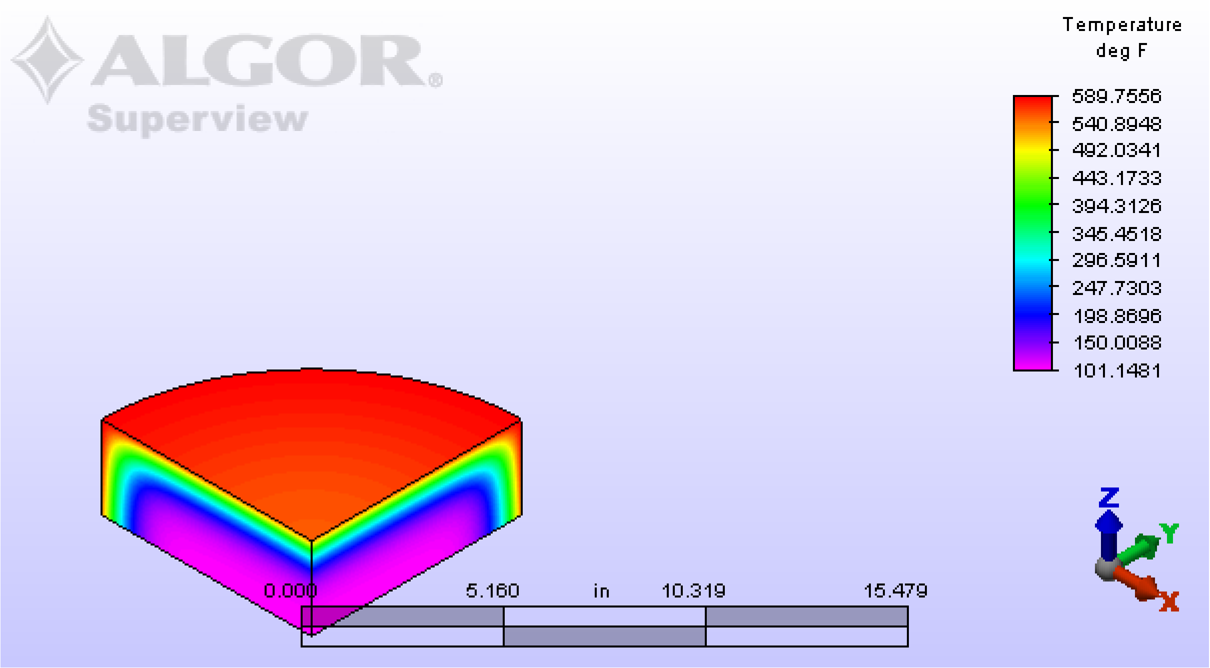

Figure 3-12 Fire Event and Cool-down temperature at 55 total minutes, polyurethane plug

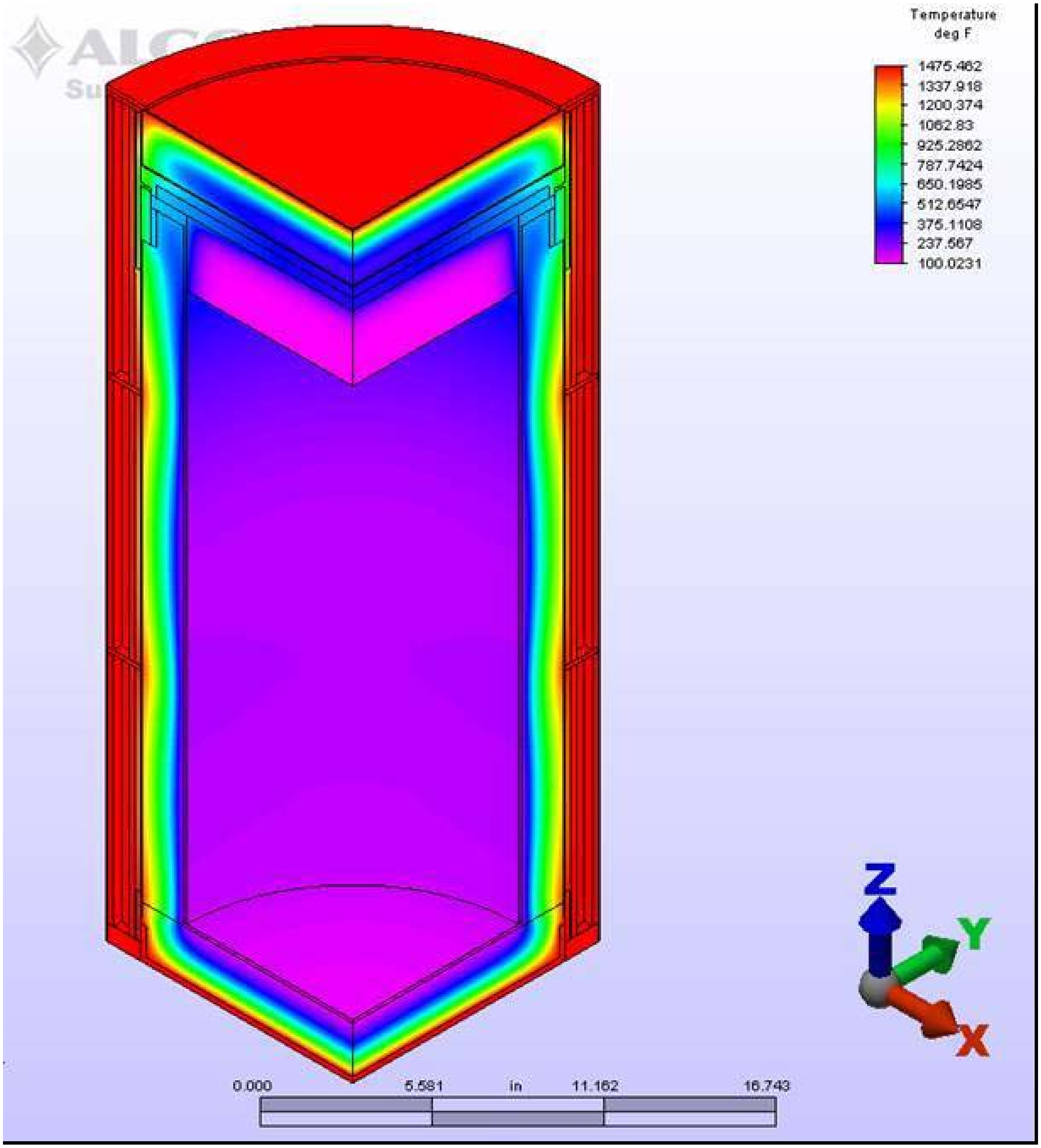

Figure 3-13 Fire Event temperature at 30 minutes, Isometric view of temperature distribution

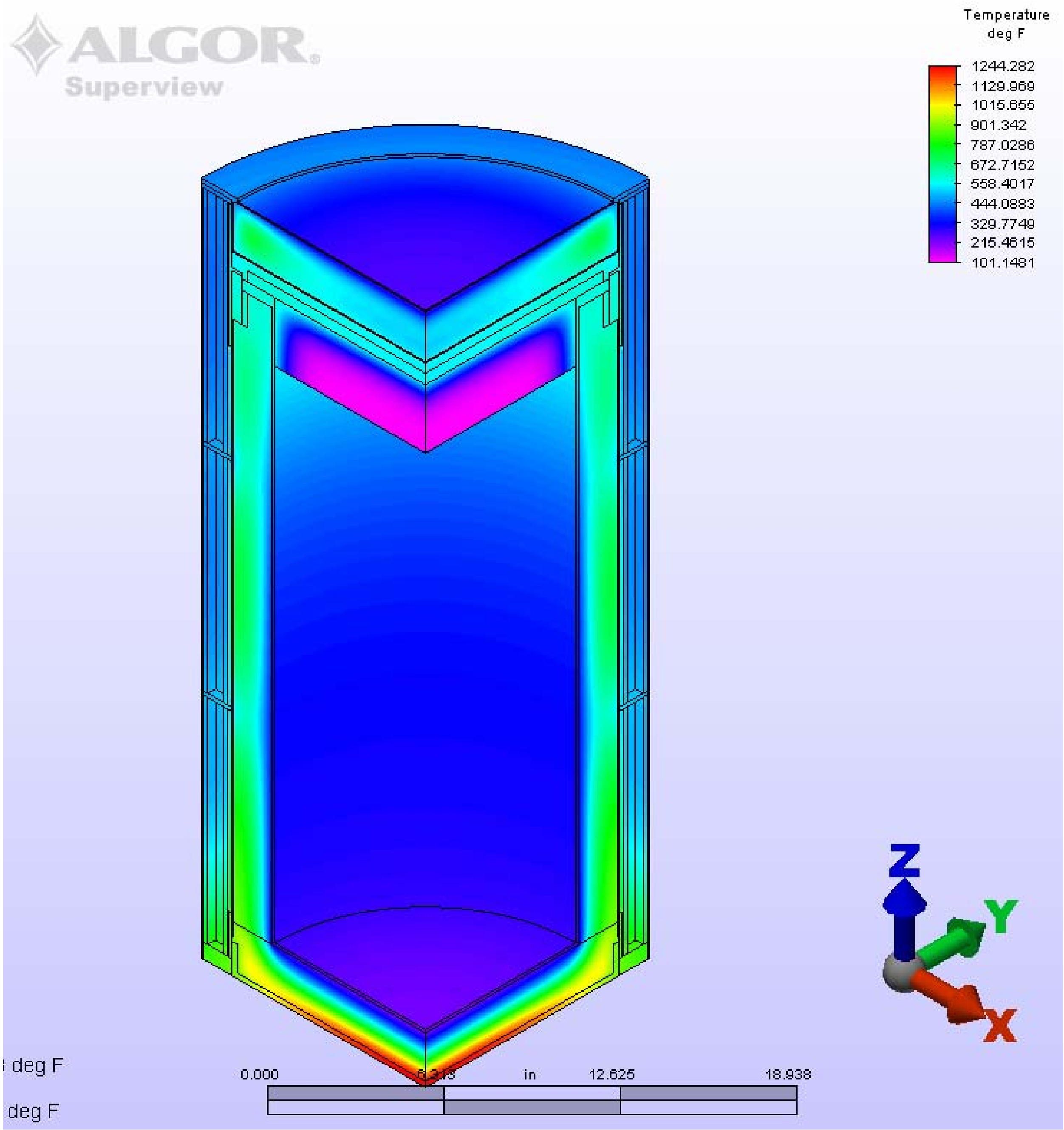

Figure 3-14 Fire Event and Cool-down temperature at 55 total minutes, Isometric view of temperature distribution

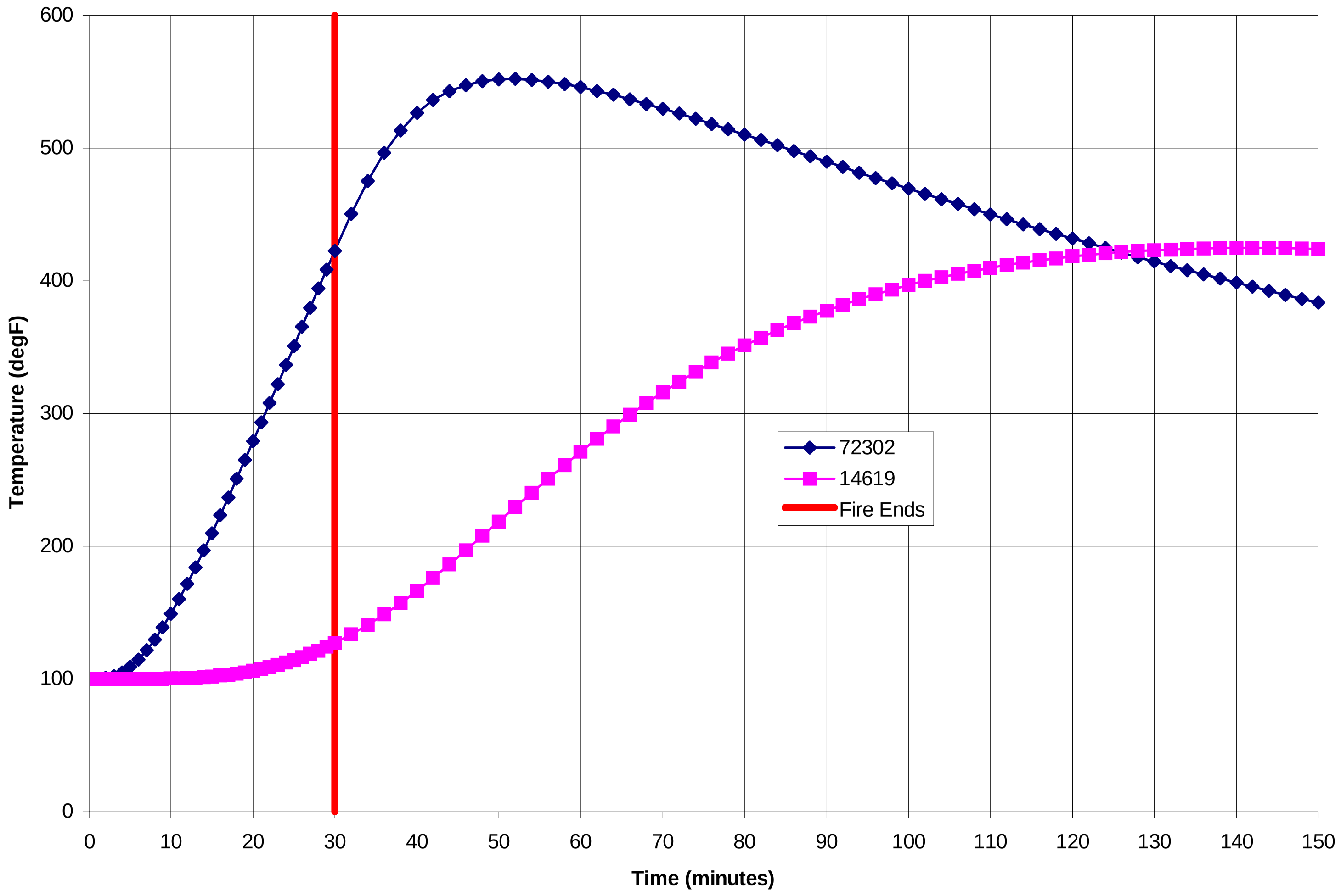

Figure 3-15 Fire Event and Cool-down temperature as a function of Seconds (beginning of cool-down= 0sec) for Payload Cavity Nodes 72302 (at the bottom of the polyurethane insert) and 14619 (at the center of the payload cavity floor part PB)

Appendix 3.5.1 Description of the Thermal Model

In order to evaluate the performance of the Versa-Pac for all conditions of transport, a quarter-symmetric transient finite element analysis (FEA) model was developed using ALGOR Release 18.1. This appendix provides a description of the thermal models.

Both 55-gallon and 110-gallon packages were modeled; the 55-gallon package was found to be bounding in performance and therefore the results for the 110-gallon package are not reported. Also, the package was modeled with and without contents, and the model without contents, even without the decay heat input, was found to be bounding. These results are expected, as can be demonstrated by a simple inspection of the equation of state used in the transient analyses:

$$Q = m\, C_p\, \Delta T$$

Where

Q is the heat input (fixed by the fire boundary condition),

m is the mass of the package,

C_p is the equivalent specific heat of the package, and

ΔT is the change in temperature of the package.

Since Q is constrained, any increase in m due to the addition or exclusion of contents leads to a lower ΔT. Also, any increase in C_p due to the addition or exclusion of contents leads to a lower ΔT. Thus, exclusion of the contents is expected to produce the highest temperatures on the interior wall of the package. Although Q is slightly higher for the 110-gallon Versa-Pac due to the slightly higher external surface area to which the fire is applied, this is greatly offset by the increased payload capacity and volume of steel and insulation added to the package.

All components were modeled using brick elements. The typical and maximum element side lengths used in the model are 0.25" and 0.79", respectively. With the exception of the air gap between the outer lid and the payload cavity lid, the package is a conduction-only problem. In order to simplify the calculation matrix, the air gap was also reduced to a conduction equivalent condition using the method described in Appendix 3.5.2.

Table 3.5.1.1 provides a comparison of the modeled dimensions versus the nominal package dimensions for the 55-gallon Versa-Pac. Table 3.5.1.2 provides a comparison of the modeled dimensions versus the nominal package dimensions for the 110-gallon Versa-Pac. Table 3.5.1.3 provides the thermal material properties used in the analyses in basic units; Table 3.5.1.4 provides the same information in traditional English units. Table 3.2 lists the conditions analyzed, including the initial conditions and heat loads.

For the fire analysis, the external surface nodes were constrained to a temperature of 1475°F. For both the 55-gallon and 110-gallon versions, the contents was modeled with a decay heat load of 0.022 $\text{in-lb}_f/\text{s} / \text{in}^3$ and 0.0085 $\text{in-lb}_f/\text{s} / \text{in}^3$ for the 55-gallon and 110-gallon packages, respectively for a conservative total package heat load of 11.4 W (with the exception of the void case, where the contents is not included in the model). The model was run for 30 time steps, with each time step 60 seconds long. The convergence tolerance was set to 0.000001 for the non-linear analysis.

For the cooldown sequence, natural convection was applied to the external nodes, assuming an ambient temperature of 100°F. The convection coefficients are applied based on the nodal temperature of the external nodes and are updated at each timestep. The convection coefficients are calculated based on the Rayleigh number and free convection coefficients as presented by Reference 1:

$$Ra_L = [g\ \beta\ (T_s - T_\infty)\ L^3]/\nu\alpha$$

Where:

Ra_L is the Rayleigh number based on the characteristic plate length,

g is gravitational acceleration, 9.81 m/s,

β is the volumetric thermal expansion coefficient for air, evaluated at the average film temperature, $(T_s - T_\infty)/2$, and approximated as $1/T_{\text{film average, absolute}}$,

T_s is the surface temperature of the heated plate at the node of interest, °C,

T_∞ is the ambient air temperature, 38°C (100°F),

L is the characteristic length of the heated plate, 0.8128 m (32"),

ν is the kinematic viscosity of air evaluated at the average film temperature, $(T_s - T_\infty)/2$, in m^2/s, and

α is the thermal diffusivity of air evaluated at the average film temperature, $(T_s - T_\infty)/2$, in m^2/s.

Note that for evaluation of the Rayleigh Number the temperatures need not be in absolute units, since the delta is used in the formulation.

The sides of the package are treated as a vertical heated plate:

$$Nu_{L,\ avg} = [0.825 + (0.387\ Ra_L^{1/6})/(1 + (0.492/Pr)^{9/16})^{8/27}]^2$$

Where:

$Nu_{L,\ avg}$ is the average Nusselt number,

Ra_L is the Rayleigh number based on the characteristic plate length, and

Pr is the Prandtl number for air evaluated at the average film temperature, $(T_s - T_\infty)/2$.

Per Reference 1, this correlation is deemed appropriate for vertical cylinders if:

$$D/L \geq 35/Gr^{1/4},$$

Where:

D is the diameter of the cylinder, 0.57 m (22.5") for the 55-gallon VersaPac,

L is the height of the cylinder, 0.81 m (32"),

Gr is the Grashof number and is defined as:

$$Gr = [g\ \beta\ (T_s - T_\infty)\ L^3]\ /\ \nu^2$$

For the range of potential package surface temperatures, the correlation is well within the appropriate range for use of the vertical heated plate correlation.

The circular top of the package is treated as a horizontal plate:

$$Nu_{L,\,avg} = 0.54\ Ra_L^{\ 1/4} \quad (10^4 \leq Ra_L \leq 10^7).$$

Per Reference 1, the characteristic length to be used in the Rayleigh number calculation is defined as:

$$L = A_s / P = 0.14\text{ m}$$

Where:

A_s is the surface area of the plate, $\pi D^2/4$, and

P is the perimeter of the plate, πD.

For the range of potential package surface temperatures and the characteristic length, the correlation is well within the appropriate range for use of the horizontal heated plate correlation.

The natural convection coefficient input to the code is calculated from the Nusselt Number as:

$$h_{avg} = Nu_{L,\,avg}\ k / L,$$

Where:

h_{avg} is the natural convection coefficient for the horizontal or vertical heated plates,

$Nu_{L,\,avg}$ is the average Nusselt Number as defined previously, and

k is the thermal conductivity of air evaluated at the average film temperature, $(T_s - T_\infty)/2$.

For purposes of calculating the convection coefficients, 24 discrete package wall temperatures were selected for evaluation, ranging from 39°C to 810°C. Using an ambient air temperature of 100°F (37.8°C), the convection coefficient was calculated in units of W/m^2K and were then converted to the units used in the Algor code ($in\text{-}lb_f/s\text{-}R\text{-}in^2$). When the nodal temperature falls between the evaluated points, the Algor code linearly interpolates the convection coefficient.

Table 3.5.1.5 summarizes the material properties of air from Reference 1. Table 3.5.1.6 presents the convection coefficient calculations and the coefficients that were input to the code. For both the 55-gallon and 110-gallon versions, the contents was modeled with a decay heat load of 0.022 in-lbf/s / in^3 and 0.0085 in-lbf/s / in^3 for the 55-gallon and 110-gallon packages, respectively for a conservative total package heat load of 11.4 W (with the exception of the void case, where the contents is not modeled). The cooldown sequence utilized the fire sequence nodal temperatures at the end of the 30 minute fire sequence as the initial temperature of the nodes. Insolation was applied to the exterior surface nodes at the rate specified by regulation (see Table 3.2) for 12-hours on and 12-hours off. The model was run for 120 time steps, with each time step 60 seconds long (in order to conserve space, the results were recorded at every third time step only). The convergence tolerance was set to 0.000001 for the non-linear analysis. Since the peak temperatures were reached within the first hour of the cooldown, the results bound the remainder of the cooldown to equilibrium NCT conditions.

The 55-gallon model is illustrated in Figures 3.5.1-1 through 3.5.1-14. The 110-gallon model is illustrated in Figure 3.5.1-15. These same models were used for all NCT and HAC fire and cooldown sequences.

Reference 1: Incropera, Frank P. and David P. DeWitt, *Fundamentals of Heat and Mass Transfer Third Edition, John Wiley & Sons*, New York, 1981, pp. 530-554, A15.

Table 3.5.1- 1 Comparison of Modeled Components versus Nominal Package Components for the 55-gallon Versa-Pac

Model Part #	Drawing component ID	Material of construction	Modeled material (see Table 3.5.1-2)	Component nominal thickness	Modeled component thickness
1	PE & FD	A36	Isotropic steel	1 / 4”	0.250”
2	PF	A36	Isotropic steel	3 / 4”	0.750”
3	FA	A36	Isotropic steel	3/16”	0.188”
4	SA & FA	A1011	Isotropic steel	16 ga.	0.060”
5	FB	A36	Isotropic steel	3/16”	0.188”
9	FC	A1011	Isotropic steel	16 ga.	0.060”
10	PG	A36	Isotropic steel	3/16”	0.188”
11	PB	A1011	Isotropic steel	10 ga.	0.140”
12	PI	A36	Isotropic steel	3/16”	0.188”
13	PA & PH	A1011 & A36	Isotropic steel	10 ga. & 1/4”	0.140” & 0.500”[1]
14	PC, DL, SB, SC	A1011	Isotropic steel	10 ga., 16 ga., 16 ga. & 16 ga.	0.140”, 0.060”, 0.060” & 0.060”
15	FK	A36	Isotropic steel	¼” x 1½” tall	0.250” x 1.50” tall
16, 17, 18	IA	Alumina silica insulation	Temperature dependent isotropic alumina silica	1.5”	1.25”
19	IB	6pcf polyurethane	6pcf polyurethane	2 1/8”	2.125”
24	IA	Alumina silica insulation	Temperature dependent isotropic alumina silica	2”	1.94”
25	IC	6pcf polyurethane	6pcf polyurethane	2 3/16”	2.188”
26, 27, 28, 29, 30, 31	TB	A500 GR.B	Isotropic steel	1¼” sq x $^{3}/_{16}$” x ~32” tall, volume=25.5 in^3 each	~1.18” sq x 0.2125”, ~32” tall, volume = 26.3 in^3 each
62	PolyU insert	10 pcf polyurethane	9.8 pcf polyurethane	3”	3.00”
71	PI	A36	Isotropic steel	3/16”	0.188”
79	IE & IF	Fiberglass	Fiberglass	0.5”	0.500”
96	PD	A36	Isotropic steel	½”	0.500”
104	N/A	N/A	Air	0.5” thick at lid	0.44” thick at lid
115	BB	A36	Isotropic steel	1¼” x 1¼” x 1½”	1.25” x 1.25” x 1.5”
120	N/A	N/A	CONTENTS	15” diameter x 24.06” tall	15.22” diameter x 25.24” tall

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[1] Although this component thickness is modeled at twice the actual component thickness, this is considered to be conservative, since it provides an enhanced pathway for heat conduction to the interior of the package.

Table 3.5.1- 2 Comparison of Modeled Components versus Nominal Package Components for the 110-gallon Versa-Pac

Model Part #	Drawing component ID	Material of construction	Modeled material (see Table 3.5.1-2)	Component nominal thickness	Modeled component thickness
1	PE & FD	A36	Isotropic steel	1 / 4”	0.250”
2	PF	A36	Isotropic steel	3 / 4”	0.750”
3	FA	A36	Isotropic steel	3/16”	0.188”
4	SA & FA	A1011	Isotropic steel	16 ga.	0.060”
5	FB	A36	Isotropic steel	3/16”	0.188”
9	FC	A1011	Isotropic steel	16 ga.	0.060”
10	PG	A36	Isotropic steel	3/16”	0.188”
11	PB	A1011	Isotropic steel	10 ga.	0.140”
12	PI	A36	Isotropic steel	3/16”	0.188”
13	PA & PH	A1011 & A36	Isotropic steel	10 ga. & 1/4”	0.140” & 0.500”[2]
14	PC, DL, SB, SC	A1011	Isotropic steel	10 ga., 16 ga., 16 ga. & 16 ga.	0.140”, 0.060”, 0.060” & 0.060”
15	FK	A36	Isotropic steel	¼” x 1½” tall	0.250” x 1.50” tall
16, 17, 18	IA	Alumina silica insulation	Temperature dependent isotropic alumina silica	1.5”	1.25”
19	IB	6pcf polyurethane	6pcf polyurethane	3 ½”	2.125”
24	IA	Alumina silica insulation	Temperature dependent isotropic alumina silica	2 ½”	1.94”
25	IC	6pcf polyurethane	6pcf polyurethane	3 ¼”	2.188”
26, 27, 28, 29, 30, 31	TB	A500 GR.B	Isotropic steel	1¼” sq x $^{3}/_{16}$” x ~40 $^{3}/_{4}$” tall, volume=32.5 in^{3} each	~1.18” sq x 0.2125” x ~40 $^{3}/_{4}$” tall, volume = 33.5 in^{3} each
62	PolyU insert	10 pcf polyurethane	9.8 pcf polyurethane	3”	3.00”
71	PI	A36	Isotropic steel	3/16”	0.188”
79	IE & IF	Fiberglass	Fiberglass	0.5”	0.500”
96	PD	A36	Isotropic steel	½”	0.500”
104	N/A	N/A	Air	0.5” thick at lid	0.44” thick at lid
115, 116 & 117	BB	A36	Isotropic steel	1¼” x 1¼” x 1½”	1.25” x 1.25” x 1.5”
120	N/A	N/A	CONTENTS	21” diameter x 32.25” tall	NA

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[2] Although this component thickness is modeled at twice the actual component thickness, this is considered to be conservative, since it provides an enhanced pathway for heat conduction to the interior of the package.

Table 3.5.1- 3 Thermal Material Properties for the Versa-Pac (Basic Units)

Material	Density (lb_f -s^2/in)/(in^3)	Thermal Conductivity (in-lb_f)/(s-in-8F)	Specific Heat (in-lb_f)/(lb_f s^2/in)- 8F	Heat Generation Rate (in-lb_f)/(s-in^3)	Source
Isotropic steel	7.35E-4	5.84	4.1849E5	N/A	General industry data (matweb, ALGOR material library)
8 pcf Temperature dependent isotropic alumina silica	1.199E-5	8F TC 27 0.007926 500 0.007926 1000 0.016 1500 0.026 1800 0.037 2000 0.048	9.374E5	N/A	Century Industries SOP6.12; general industry data (matweb, Cer-wool, Fiberfrax)
Fiberglass – Extren525 Isophthalic polyester resin	1.606E-4	0.072	1.009E6	N/A	Century Industries SOP6.13, also “Typical Properties – FRP Structural Shapes”, Enduro Systems, Inc., www.endurocomposites.com.
Isotropic 6.0 pcf Polyurethane	8.993E-6	3.386E-3	1.273E6	N/A	Century Industries SOP6.11, also General industry data (matweb). Not used in model since alumina silica is bounding
Isotropic 9.8 pcf Polyurethane	1.469E-5	5.026E-3	1.576E6	N/A	Century Industries SOP6.11, also General industry data (matweb). Not used in model since alumina silica is bounding
Air, conduction + radiation	1.087E-7	L=0.44” 8F$_{average}$ TC -40 0.017 22.4 0.017 202.4 0.040 382.4 0.083 562.4 0.147 742.4 0.237 922.4 0.357 1102 0.513 1282 0.709 1462 0.949 1642 1.239	8.671E5	N/A	see Appendix 3.5.2
Contents 1, wood	8.094E-5	0.022	3.358E5	0.022 (55-gal) 0.0085 (110 gal)	General industry data (matweb)
Contents 2, void	N/A	N/A	N/A	N/A	N/A
Contents 3, solid steel	7.35E-4	5.84	4.1849E5	0.022 (55-gal) 0.0085 (110 gal)	General industry data (matweb, ALGOR material library)

Table 3.5.1- 4 Thermal Material Properties for the Versa-Pac (English Units)

Material	**Density (lb / ft^3)**	**Thermal Conductivity (BTU / hr-ft-8F)**	**Specific Heat (BTU / lb-8F)**	**Heat Generation Rate (BTU / hr-in^3)**	**Source**
Isotropic steel	2.836E-01	2.251	0.116	N/A	General industry data (matweb, ALGOR material library)
8 pcf Temperature dependent isotropic alumina silica	4.630E-03	8F TC 27 3.083E-03 500 3.083E-03 1000 6.167E-03 1500 1.000E-02 1800 1.425E-02 2000 1.850E-02	0.260	N/A	Century Industries SOP6.12; general industry data (matweb, Cer-wool, Fiberfrax)
Fiberglass – Extren525 Isophthalic polyester resin	6.192E-02	2.775E-02	0.280	N/A	Century Industries SOP6.13, also “Typical Properties – FRP Structural Shapes”, Enduro Systems, Inc., www.endurocomposites.com.
Isotropic 6.0 pcf Polyurethane	3.472E-03	1.333E-03	0.353	N/A	Century Industries SOP6.11, also General industry data (matweb). Not used in model since alumina silica is bounding
Isotropic 9.8 pcf Polyurethane	5.671E-03	1.917E-03	0.437	N/A	Century Industries SOP6.11, also General industry data (matweb). Not used in model since alumina silica is bounding
Air, conduction + radiation	4.225E-05	L=0.44” 8F$_{average}$ TC -40 6.583E-03 22.4 6.583E-03 202.4 1.542E-02 382.4 3.200E-02 562.4 5.667E-02 742.4 9.133E-02 922.4 1.377E-01 1102 1.978E-01 1282 2.733E-01 1462 3.658E-01 1642 4.777E-01	0.241	N/A	see Appendix 3.5.2
Contents 1, wood	3.125E-02	8.500E-03	0.093	0.008481 (55-gal) 0.003277 (110 gal)	General industry data (matweb)
Contents 2, void	N/A	N/A	N/A	N/A	N/A
Contents 3, solid steel	2.836E-01	2.251	0.116	0.008481 (55-gal) 0.003277 (110 gal)	General industry data (matweb, ALGOR material library)

Table 3.5.1- 5 Material Properties for Air used to evaluate Natural Convection Coefficiencts

All values taken from Reference 1.

Air Temperature (K)	ν *10^6	k * 10^3	α * 10^6	Pr
	m^2/s	W/m-K	m^2/s	
300	15.89	26.3	22.5	0.707
350	20.92	30.0	29.9	0.700
400	26.41	33.8	38.3	0.690
450	32.39	37.3	47.2	0.686
500	38.79	40.7	56.7	0.684
550	45.57	43.9	66.7	0.683
600	52.69	46.9	76.9	0.685
650	60.21	49.7	87.3	0.690
700	68.10	52.4	98.0	0.695

Table 3.5.1- 6 Natural Convection Coefficients for the Versa-Pac Cool-down Sequence

Film Temperature (K) (note 2)	Film Temperature (C) (note 2)	Film Temperature (F) (note 2)	ν (10^6 m^2/s) (note 1 & 2)	K (10^3 W/m-K) (note 1 & 2)	α (10^6 m^2/s) (note 1 &2)	Pr (note 1 &2)	Nodal Wall temperature (F)	Nodal Wall temperature (C)	Ra vertical	Ra Horizontal	Nu Vertical (note 3)	Nu Horizontal (note 4)	h vertical, (W/m^2-K)	h horizontal, (W/m^2-K)	h vertical (in-lb_f/s-R-in^2)	h horizontal (in-lb_f/s-R-in^2)
300	27.0	80.6	15.89	26.3	22.5	0.707	61.2	16.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
311	37.9	100.2	16.99	27.1	24.1	0.705	100.4	38.0	9.23E+06	4.71E+04	30.48	7.96	1.02	1.54	3.2245E-03	4.8868E-03
312	38.9	102.0	17.09	27.2	24.3	0.705	104.0	40.0	9.05E+07	4.63E+05	59.23	14.08	1.98	2.73	6.2827E-03	8.6728E-03
317	43.9	111.0	17.59	27.5	25.0	0.705	122.0	50.0	4.62E+08	2.36E+06	96.82	21.17	3.28	4.17	1.0409E-02	1.3212E-02
322	48.9	120.0	18.09	27.9	25.7	0.704	140.0	60.0	7.81E+08	3.99E+06	113.70	24.13	3.91	4.81	1.2388E-02	1.5266E-02
327	53.9	129.0	18.59	28.3	26.5	0.703	158.0	70.0	1.05E+09	5.39E+06	124.70	26.01	4.34	5.26	1.3768E-02	1.6675E-02
332	58.9	138.0	19.10	28.7	27.2	0.703	176.0	80.0	1.29E+09	6.58E+06	132.67	27.35	4.68	5.60	1.4839E-02	1.7763E-02
337	63.9	147.0	19.60	29.0	28.0	0.702	194.0	90.0	1.49E+09	7.61E+06	138.74	28.36	4.96	5.88	1.5718E-02	1.8655E-02
342	68.9	156.0	20.10	29.4	28.7	0.701	212.0	100.0	1.66E+09	8.49E+06	143.49	29.15	5.19	6.12	1.6463E-02	1.9415E-02
350	77.0	170.6	20.92	30.0	29.9	0.700	241.2	116.2	1.89E+09	9.65E+06	149.27	30.09	5.51	6.45	1.7476E-02	2.0455E-02
392	118.9	246.0	25.52	33.2	36.9	0.692	392.0	200.0	2.31E+09	1.18E+07	158.76	31.66 (note 5)	6.48	7.51	2.0559E-02	2.3806E-02
400	127.0	260.6	26.41	33.8	38.3	0.690	421.2	216.2	2.32E+09	1.19E+07	158.92	31.70 (note 5)	6.61	7.65	2.0962E-02	2.4274E-02
442	168.9	336.0	31.42	36.7	45.8	0.687	572.0	300.0	2.17E+09	1.11E+07	155.57	31.18 (note 5)	7.03	8.18	2.2300E-02	2.5947E-02
450	177.0	350.6	32.39	37.3	47.2	0.686	601.2	316.2	2.13E+09	1.09E+07	154.60	31.02 (note 5)	7.09	8.27	2.2504E-02	2.6219E-02
492	218.9	426.0	37.75	40.1	55.2	0.684	752.0	400.0	1.86E+09	9.52E+06	148.19	29.99	7.32	8.60	2.3219E-02	2.7285E-02
500	227.0	440.6	38.79	40.7	56.7	0.684	781.2	416.2	1.81E+09	9.26E+06	146.93	29.79	7.36	8.66	2.3338E-02	2.7472E-02
542	268.9	516.0	44.47	43.4	65.1	0.683	932.0	500.0	1.55E+09	7.93E+06	140.01	28.66	7.47	8.88	2.3703E-02	2.8169E-02
550	277.0	530.6	45.57	43.9	66.7	0.683	961.2	516.2	1.51E+09	7.70E+06	138.73	28.45	7.49	8.92	2.3768E-02	2.8297E-02
592	318.9	606.0	51.53	46.4	75.2	0.685	1112.0	600.0	1.29E+09	6.59E+06	132.25	27.36	7.55	9.07	2.3955E-02	2.8776E-02
600	327.0	620.6	52.69	46.9	76.9	0.685	1141.2	616.2	1.25E+09	6.40E+06	131.08	27.17	7.56	9.10	2.3991E-02	2.8867E-02
642	368.9	696.0	58.99	49.2	85.6	0.689	1292.0	700.0	1.08E+09	5.50E+06	125.15	26.15	7.58	9.20	2.4052E-02	2.9177E-02
650	377.0	710.6	60.21	49.7	87.3	0.690	1321.2	716.2	1.05E+09	5.35E+06	124.08	25.96	7.59	9.22	2.4066E-02	2.9238E-02

Film Temperature (K) (note 2)	Film Temperature (C) (note 2)	Film Temperature (F) (note 2)	v $(10^6$ $m^2/s)$ (note 1 & 2)	K $(10^3$ W/m-K) (note 1 & 2)	α $(10^6$ $m^2/s)$ (note 1 &2)	Pr (note 1 &2)	Nodal Wall temperature (F)	Nodal Wall temperature (C)	Ra vertical	Ra Horizontal	Nu Vertical (note 3)	Nu Horizontal (note 4)	h vertical, (W/m^2-K)	h horizontal, (W/m^2-K)	h vertical $(in\text{-}lb_f/s\text{-}R\text{-}in^2)$	h horizontal $(in\text{-}lb_f/s\text{-}R\text{-}in^2)$
692	418.9	786.0	66.82	52.0	96.3	0.694	1472.0	800.0	9.02E+08	4.61E+06	118.65	25.02	7.59	9.29	2.4060E-02	2.9459E-02
697	423.9	795.0	67.61	52.2	97.3	0.695	1490.0	810.0	8.87E+08	4.53E+06	118.04	24.92	7.59	9.30	2.4061E-02	2.9487E-02
700	427.0	800.6	68.10	52.4	98.0	0.695	1501.2	816.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Notes on Table 3.5.1-5:

1. Air material properties are taken from Reference 1 as presented by Table 3.5.1-4. For temperatures between the values provided by the Reference, the material properties are linearly interpolated.
2. The material property values presented are for the air film temperature, which is assumed to be the average of the wall temperature and ambient (1008F≈37.88C≈310.98K).
3. Per Reference 1, the correlation is valid over all ranges of Rayleigh numbers.
4. Per Reference 1, the correlation is valid over a range of Rayleigh numbers from 10^4 to 10^7.
5. Although these Rayleigh numbers are slightly out of range of the correlation, they are conservatively lower than that calculated using the correlation provided by Reference 1 applicable at higher Rayleigh numbers and so is considered acceptable for use.

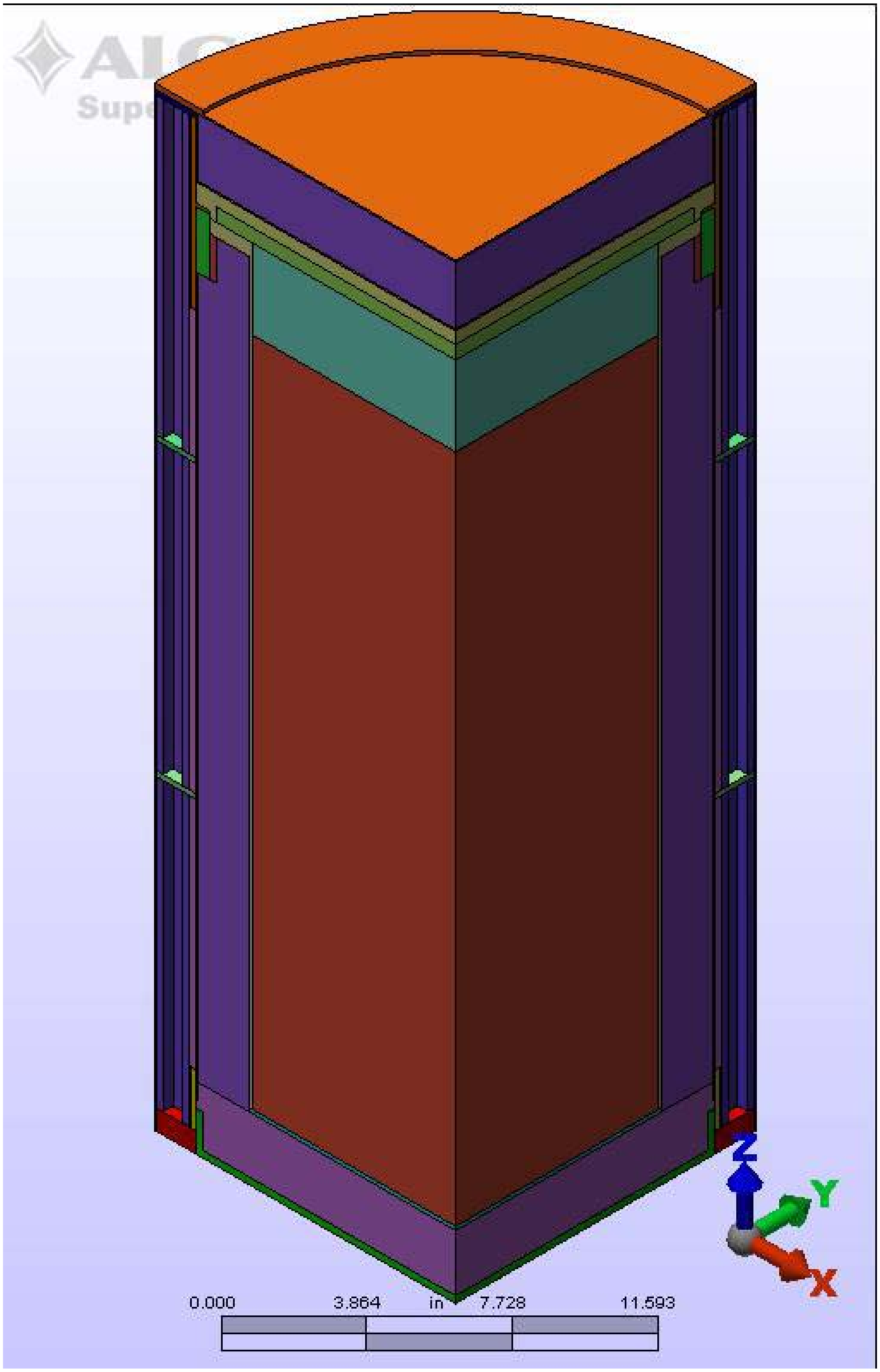


Figure 3.5.1- 1 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, all parts shown

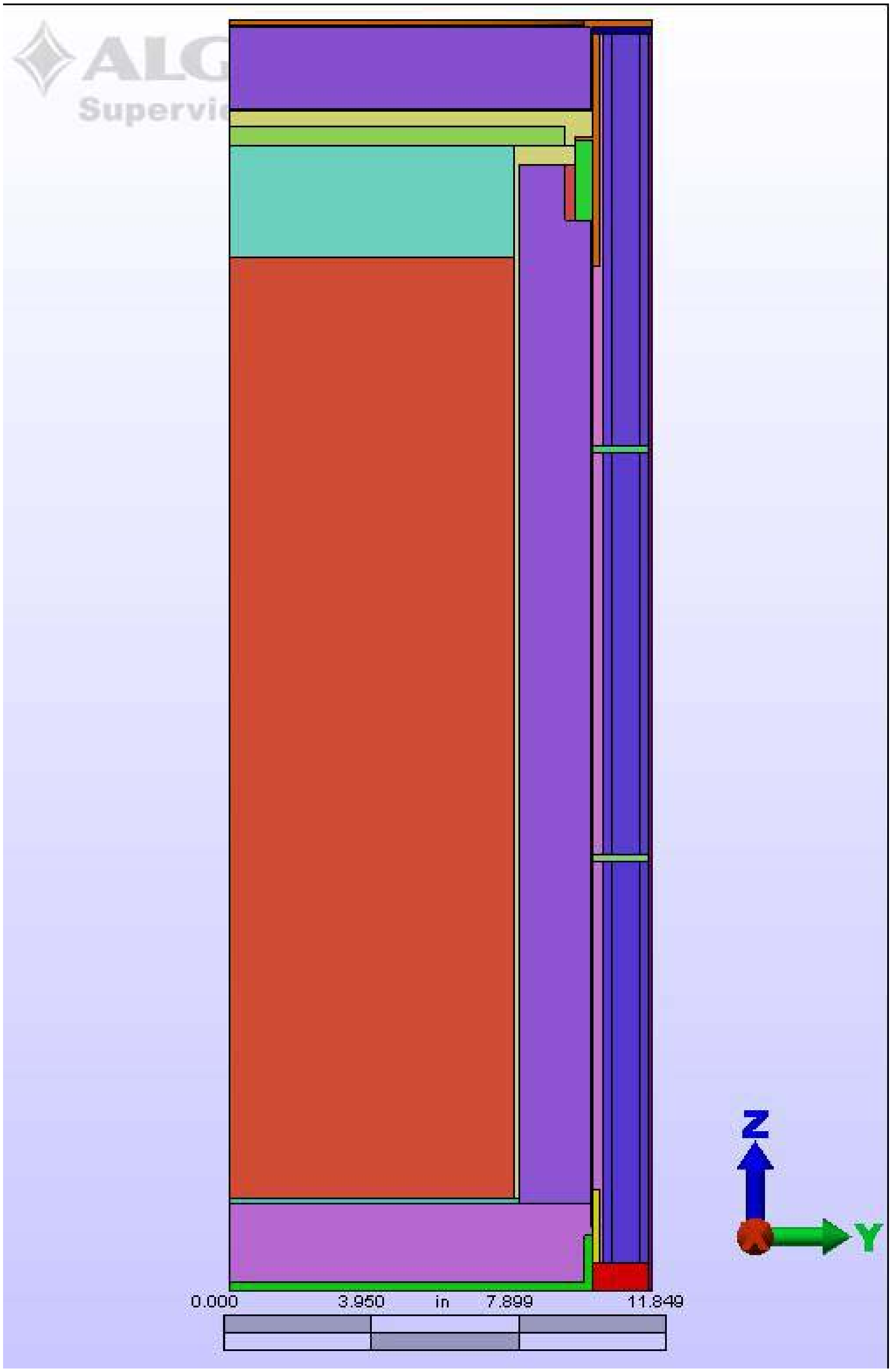


Figure 3.5.1- 2 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, all parts shown, side view

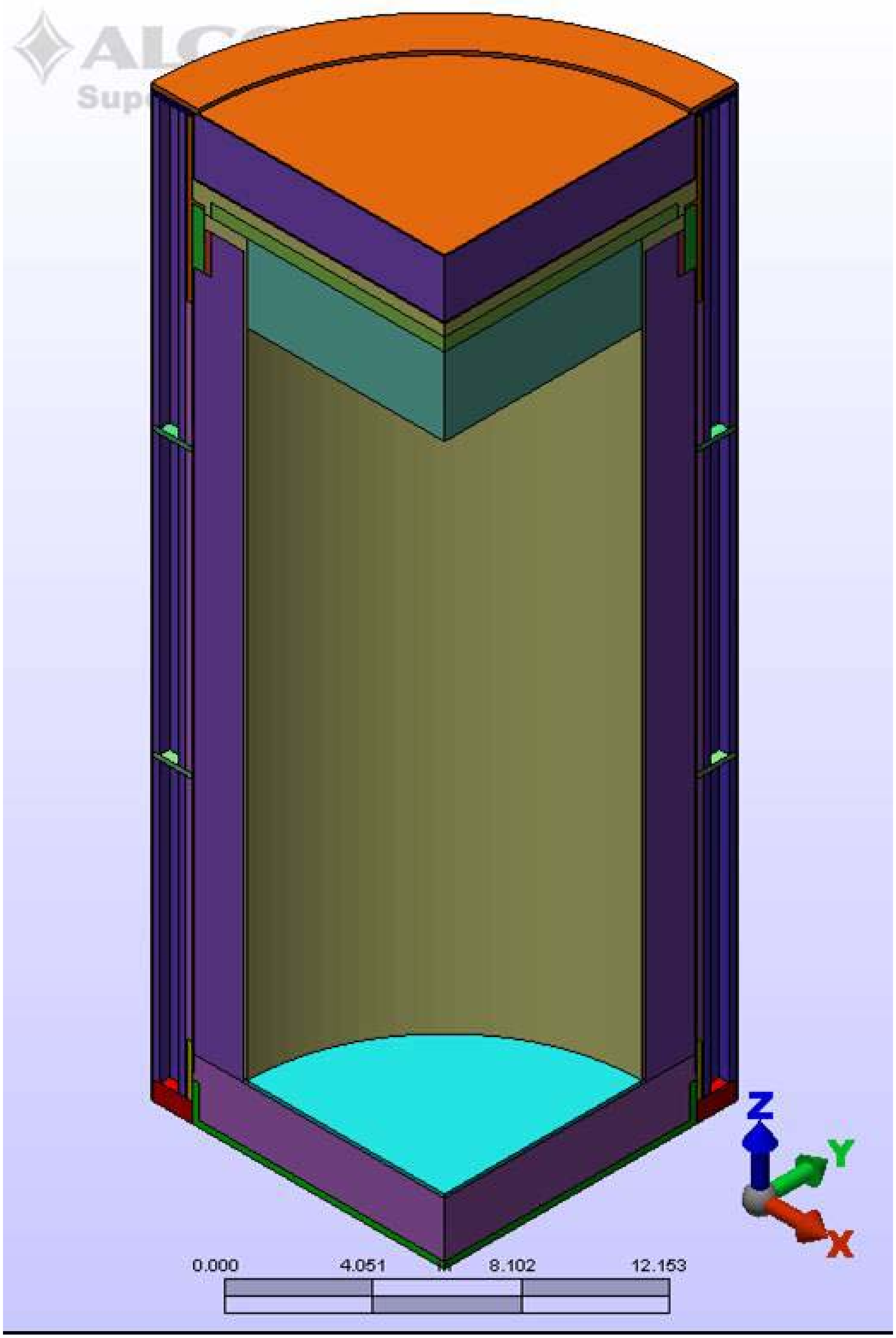


Figure 3.5.1- 3 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, contents not shown

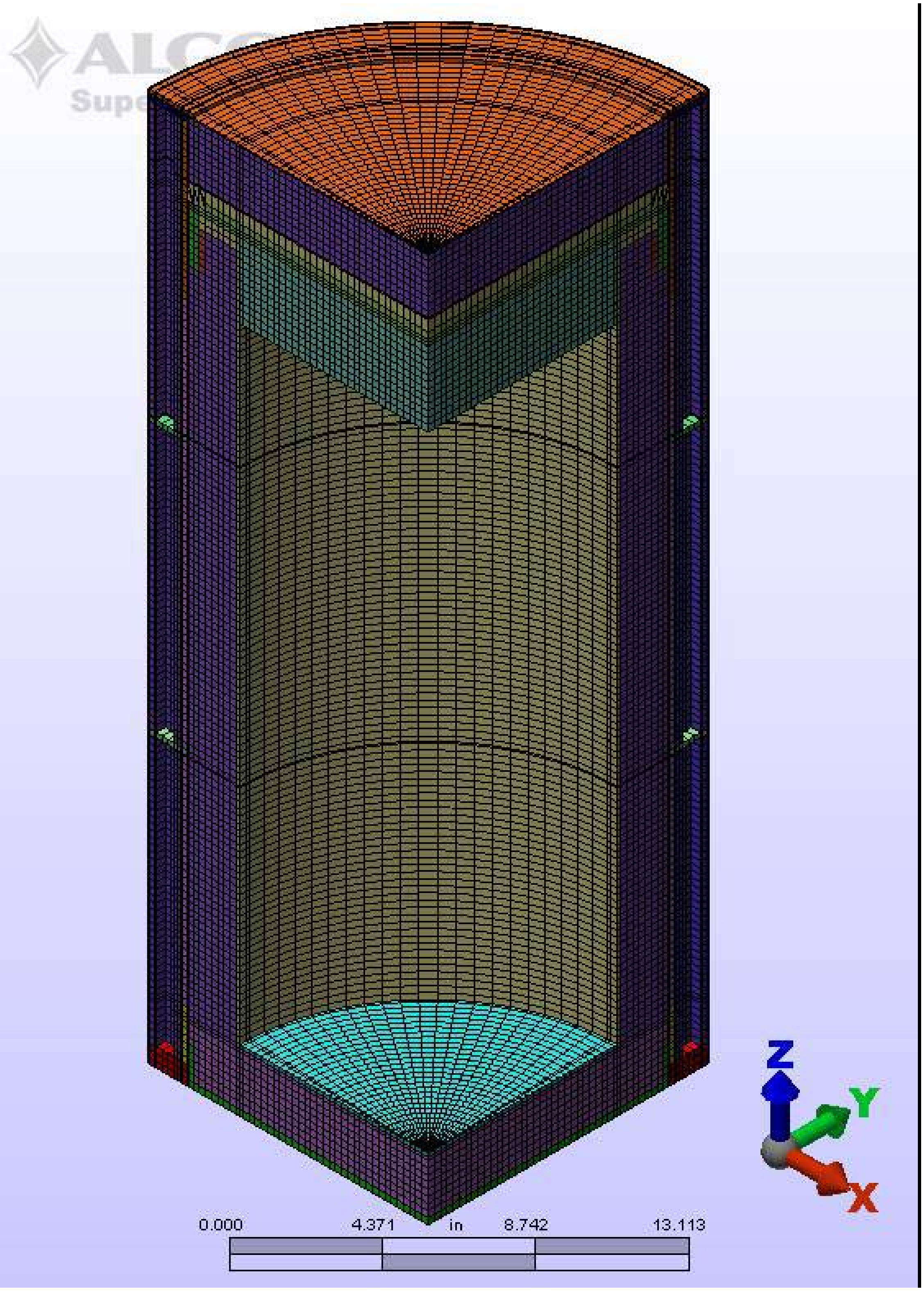


Figure 3.5.1- 4 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, contents not shown, mesh view

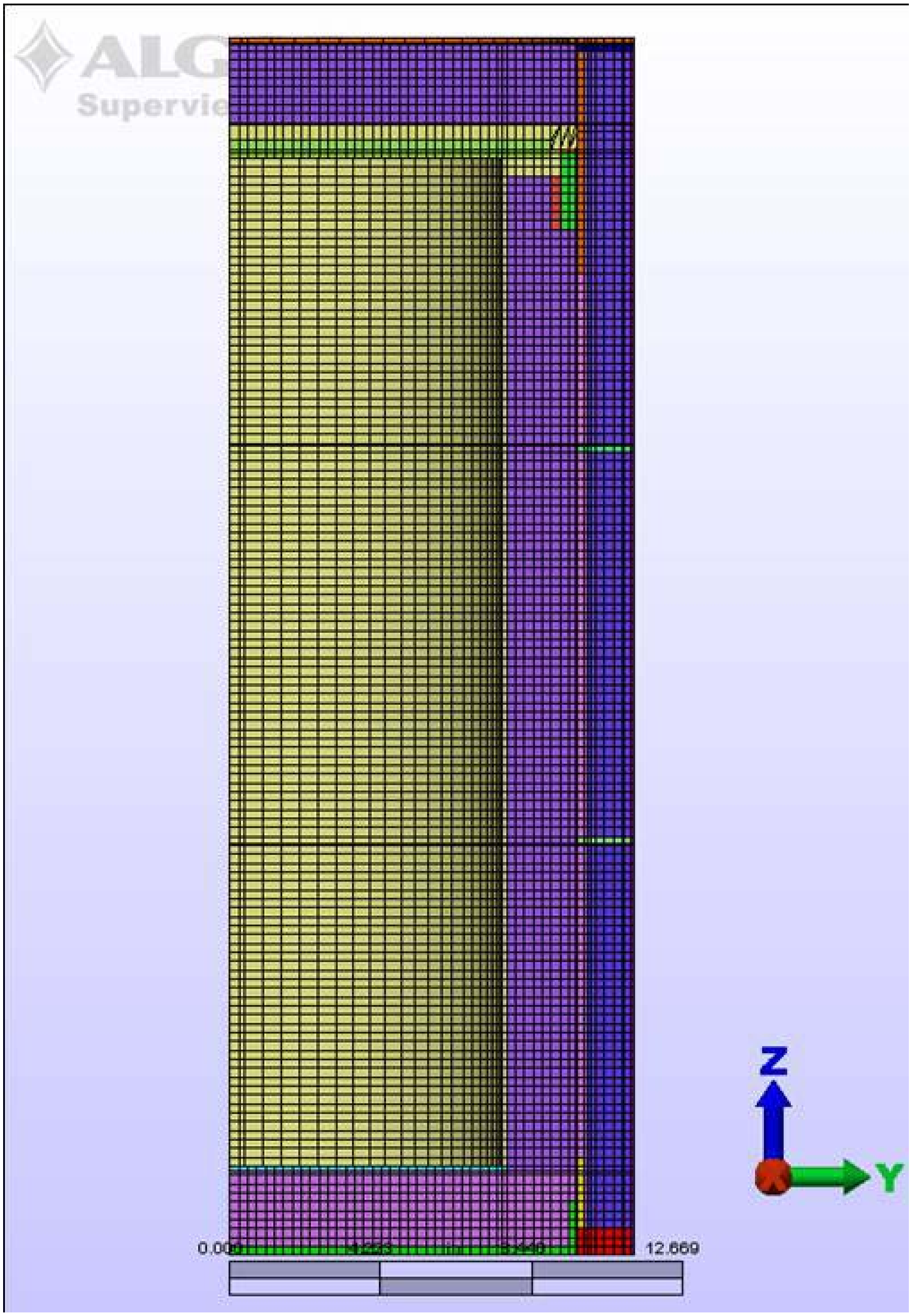


Figure 3.5.1- 5 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, contents not shown, side view with mesh

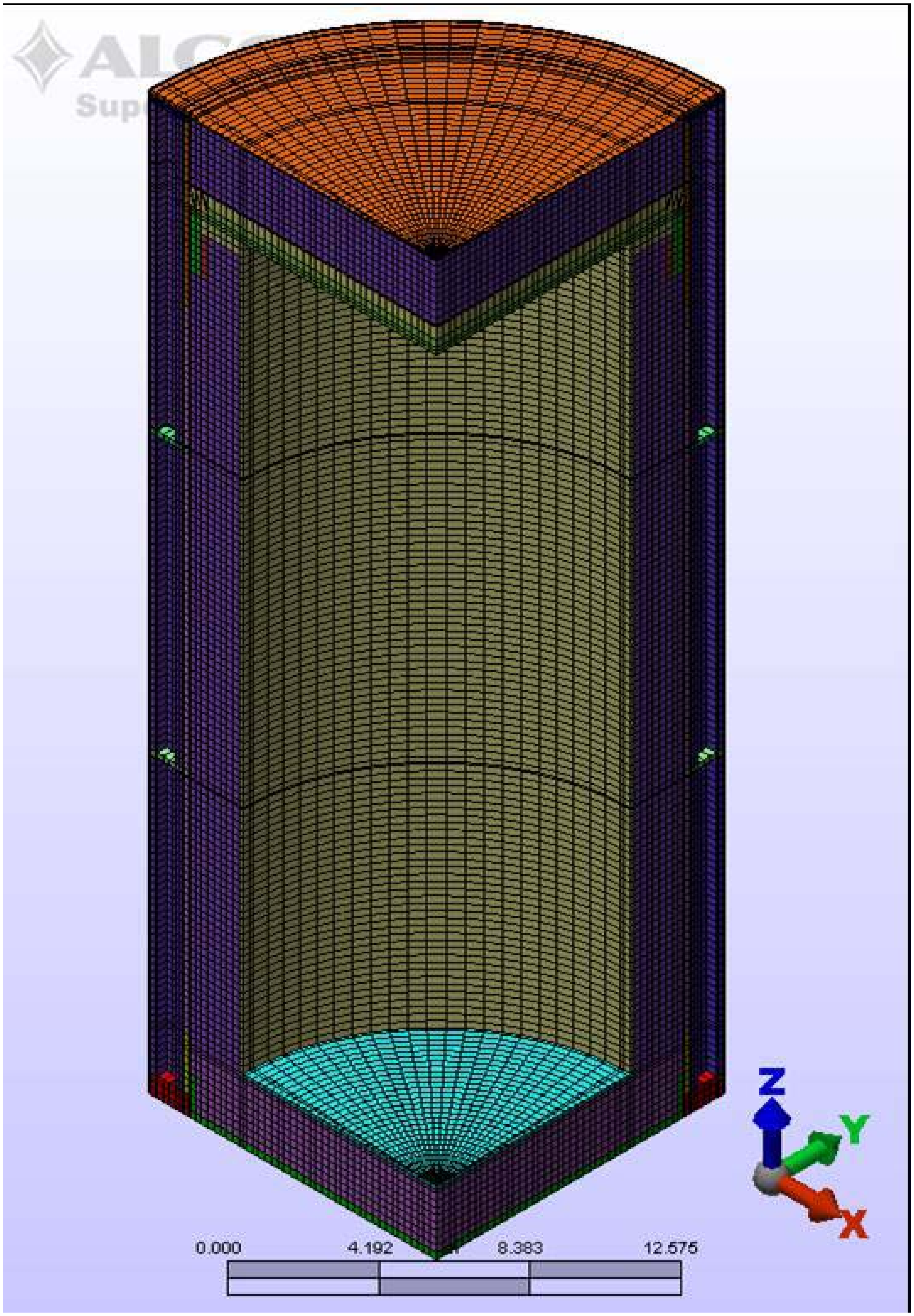


Figure 3.5.1- 6 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, Drum Lid removed (air gap between lids is shown in yellow)

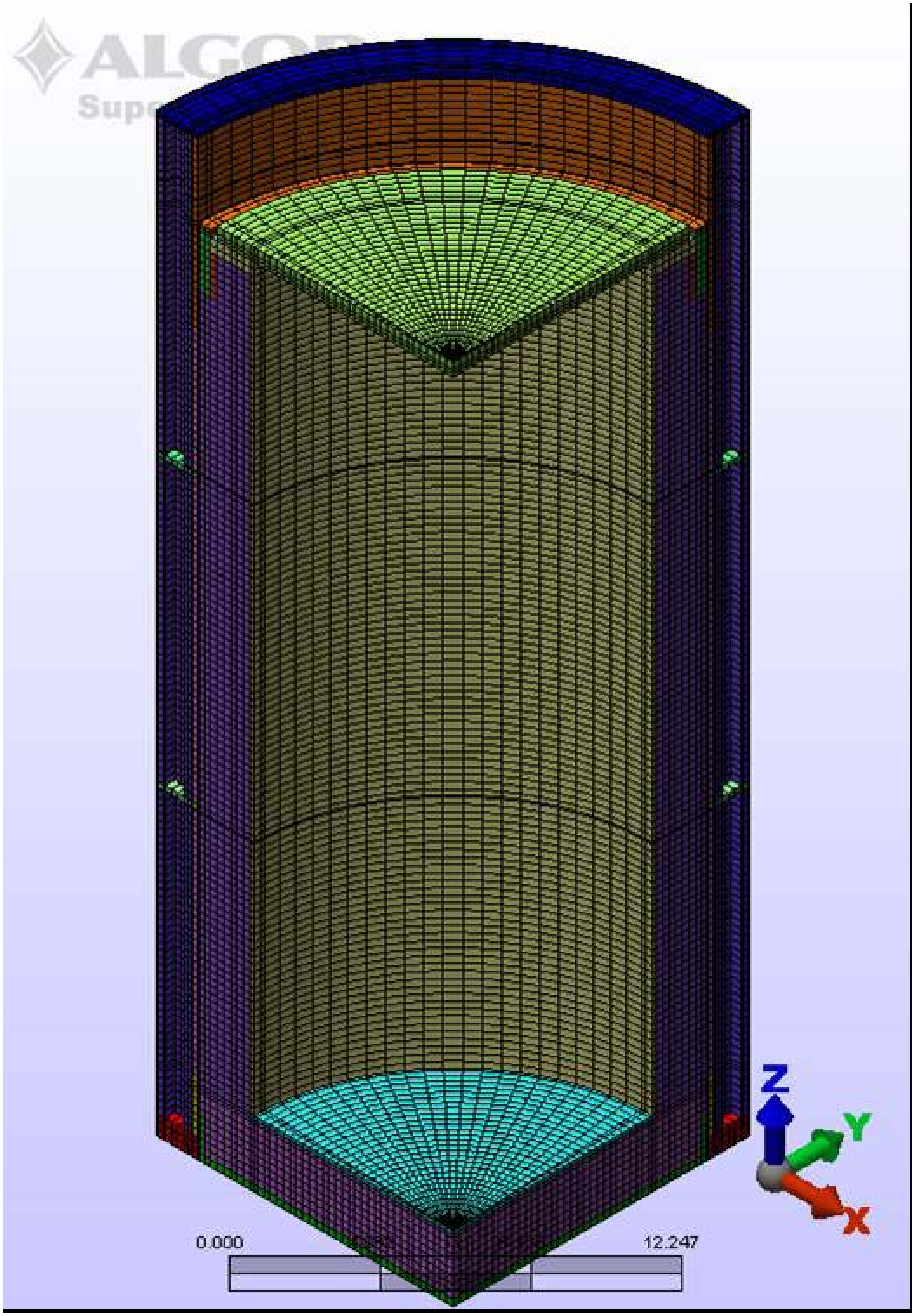


Figure 3.5.1- 7 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac

(drum lid & insulation plug not shown)

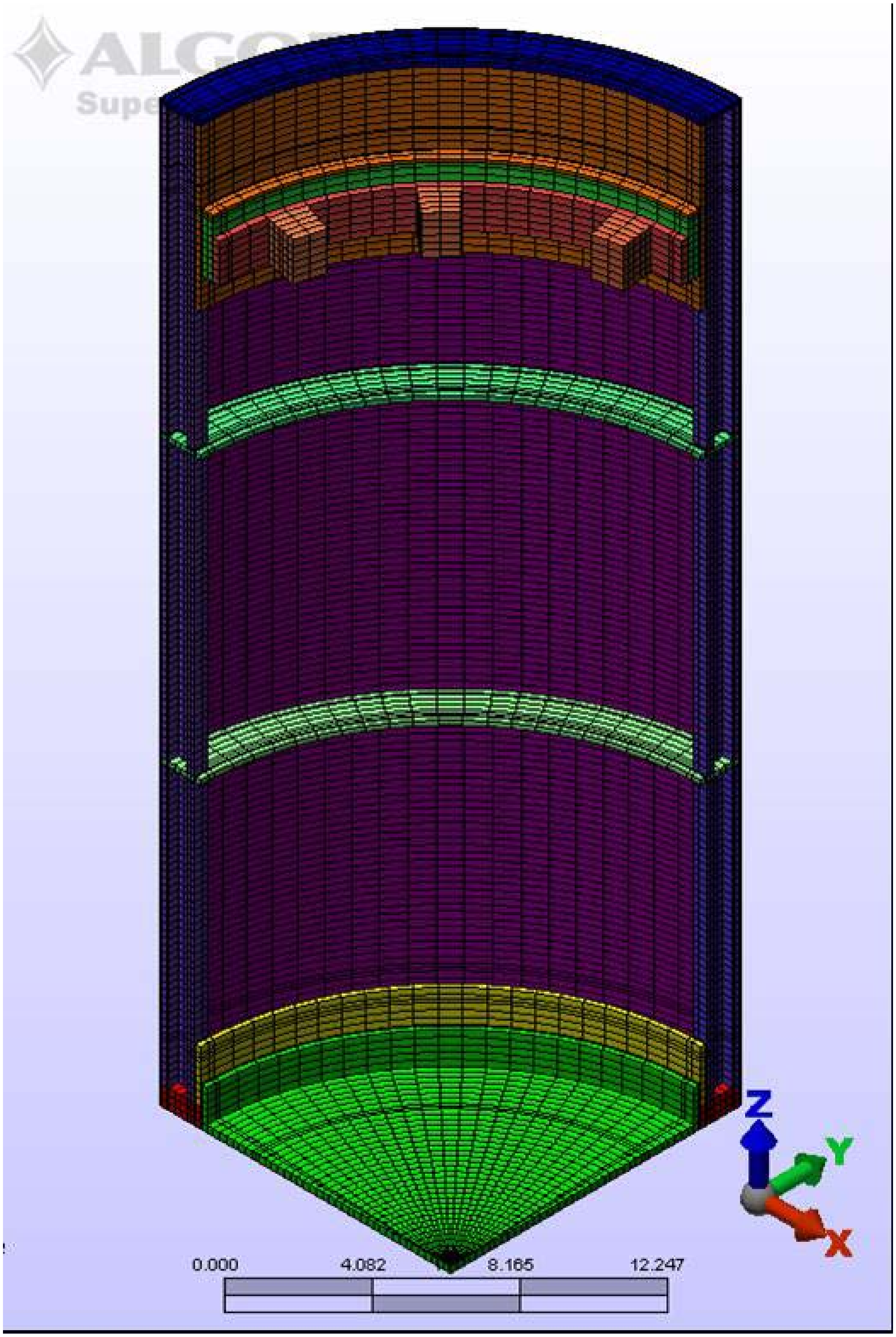


Figure 3.5.1- 8 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, External Metal structure, Fiberglass, & Payload Cavity bolting blocks (payload cavity, drum lid, insulation plug & component SA not shown)

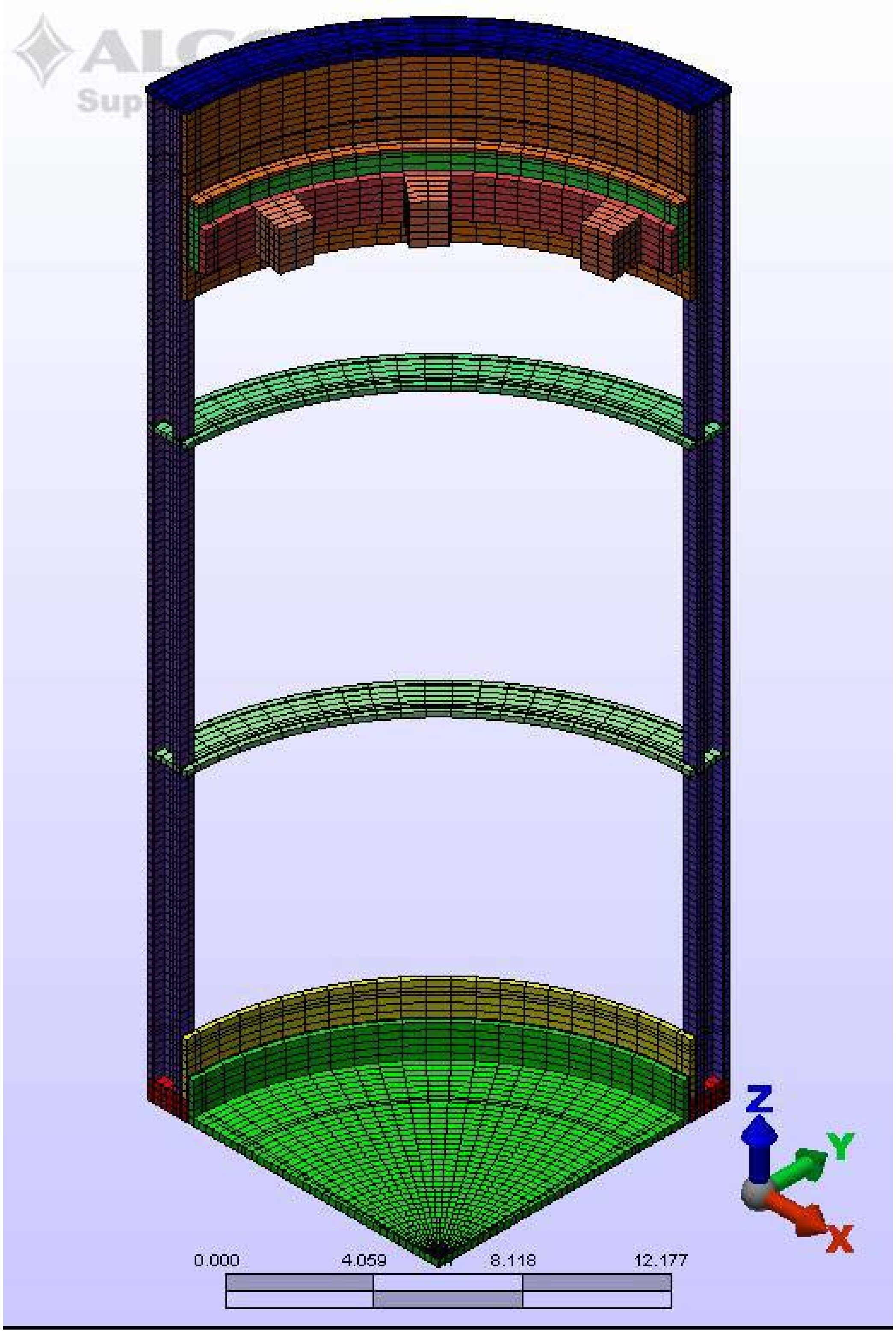


Figure 3.5.1- 9 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, Metal Reinforcing Members

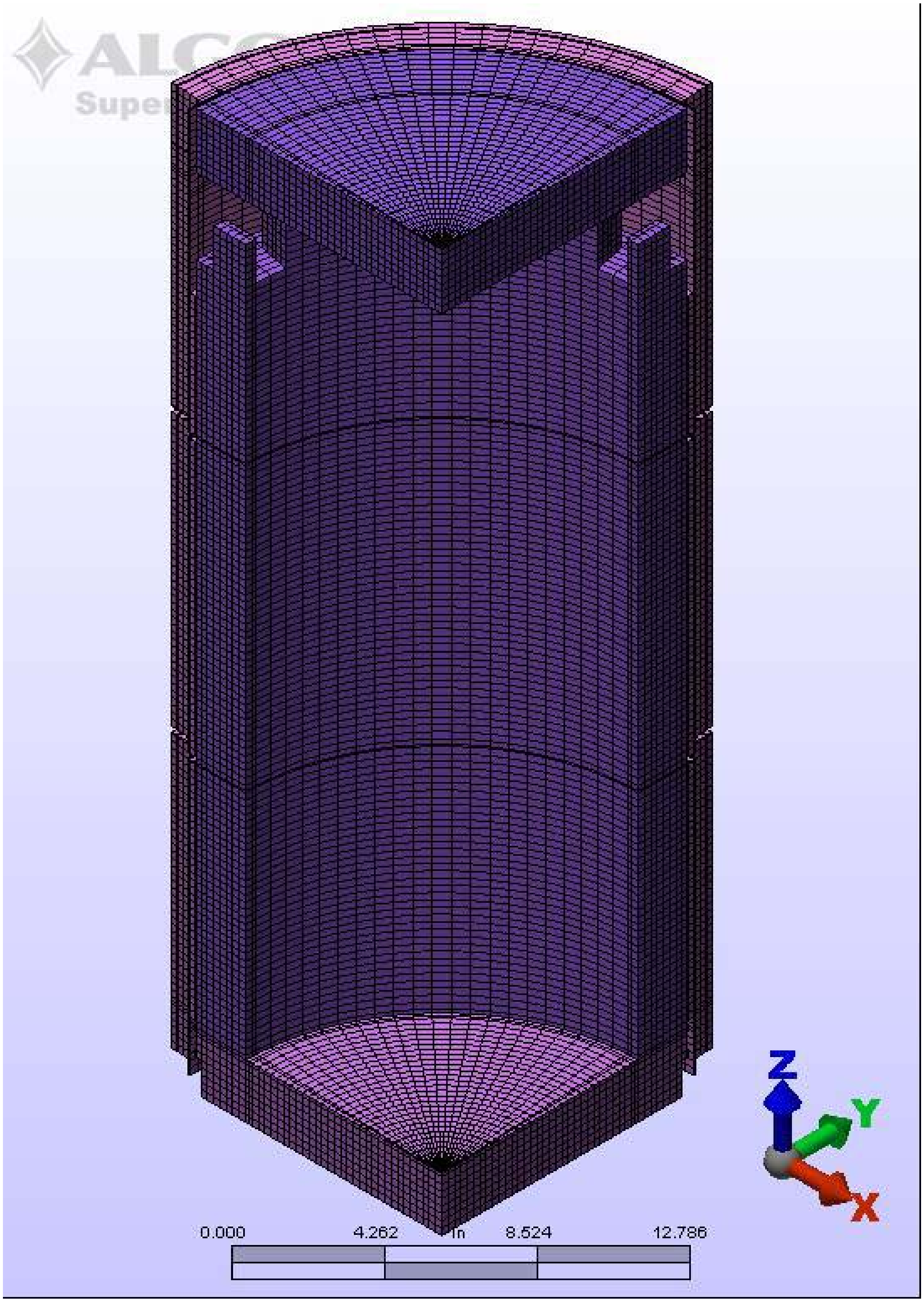


Figure 3.5.1- 10 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, Insulation

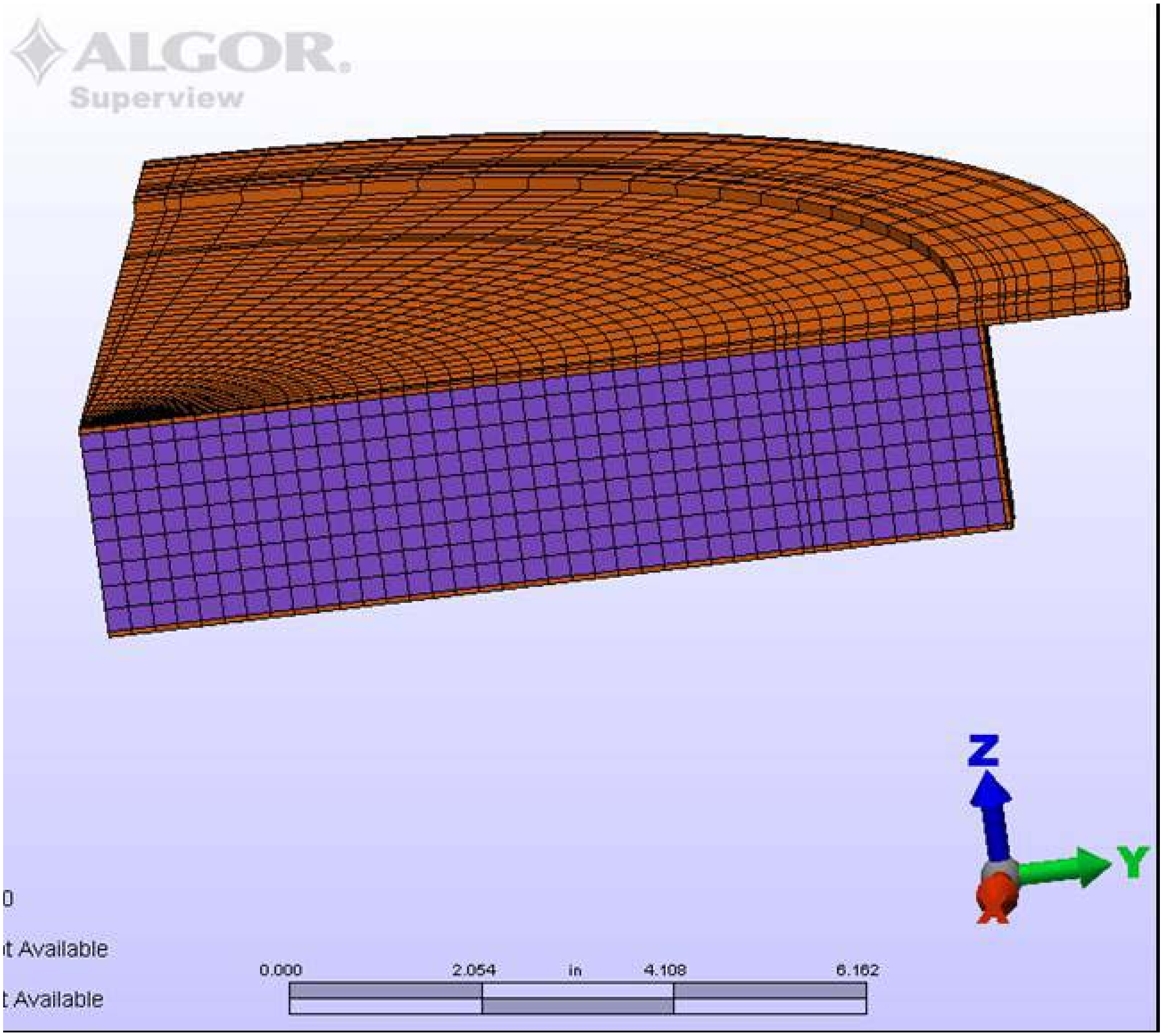


Figure 3.5.1- 11 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, Outer Lid

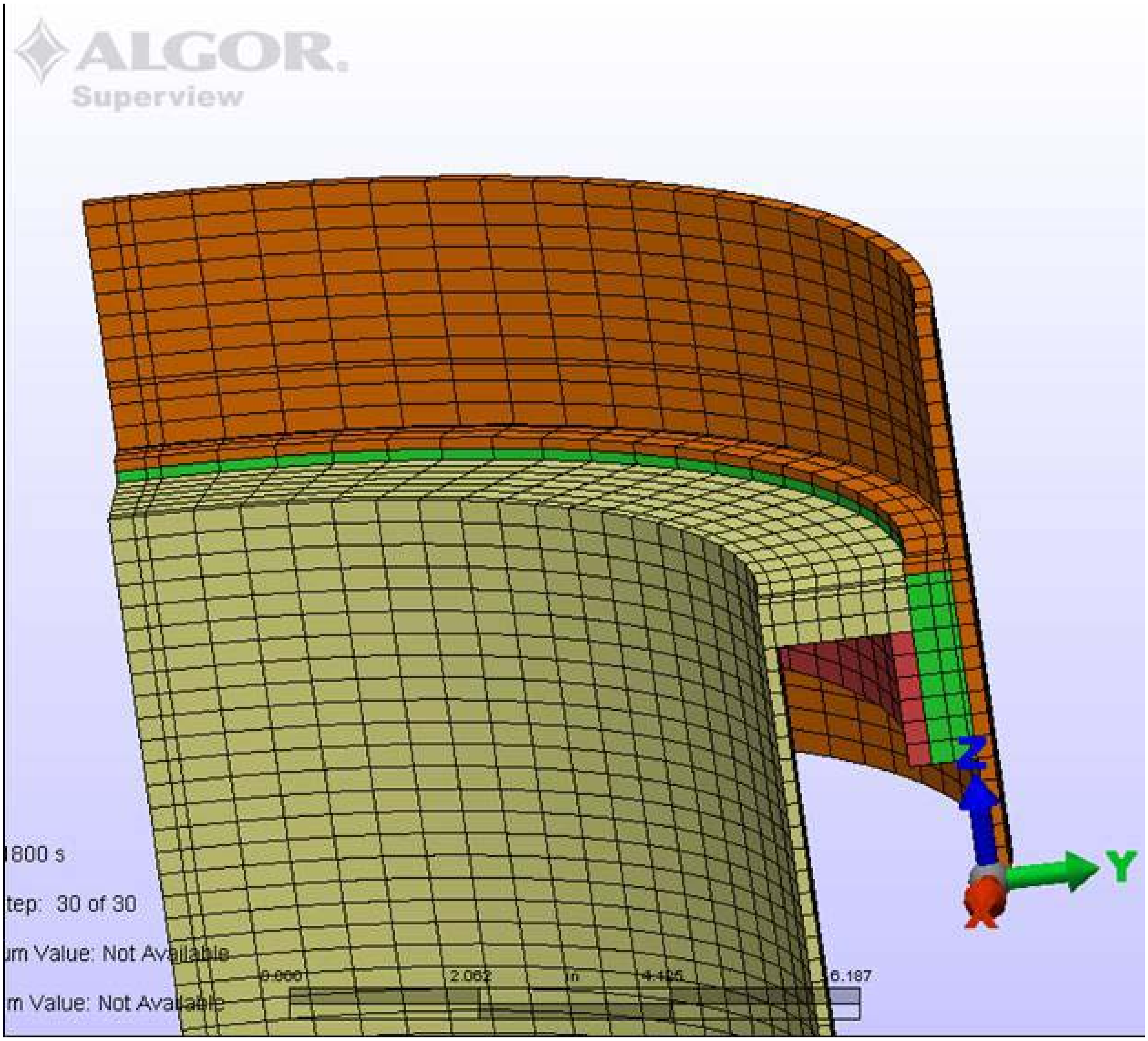


Figure 3.5.1- 12 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, Detail View, Payload Cavity, Fiberglass, and Rivet block (bolting block BB not shown)

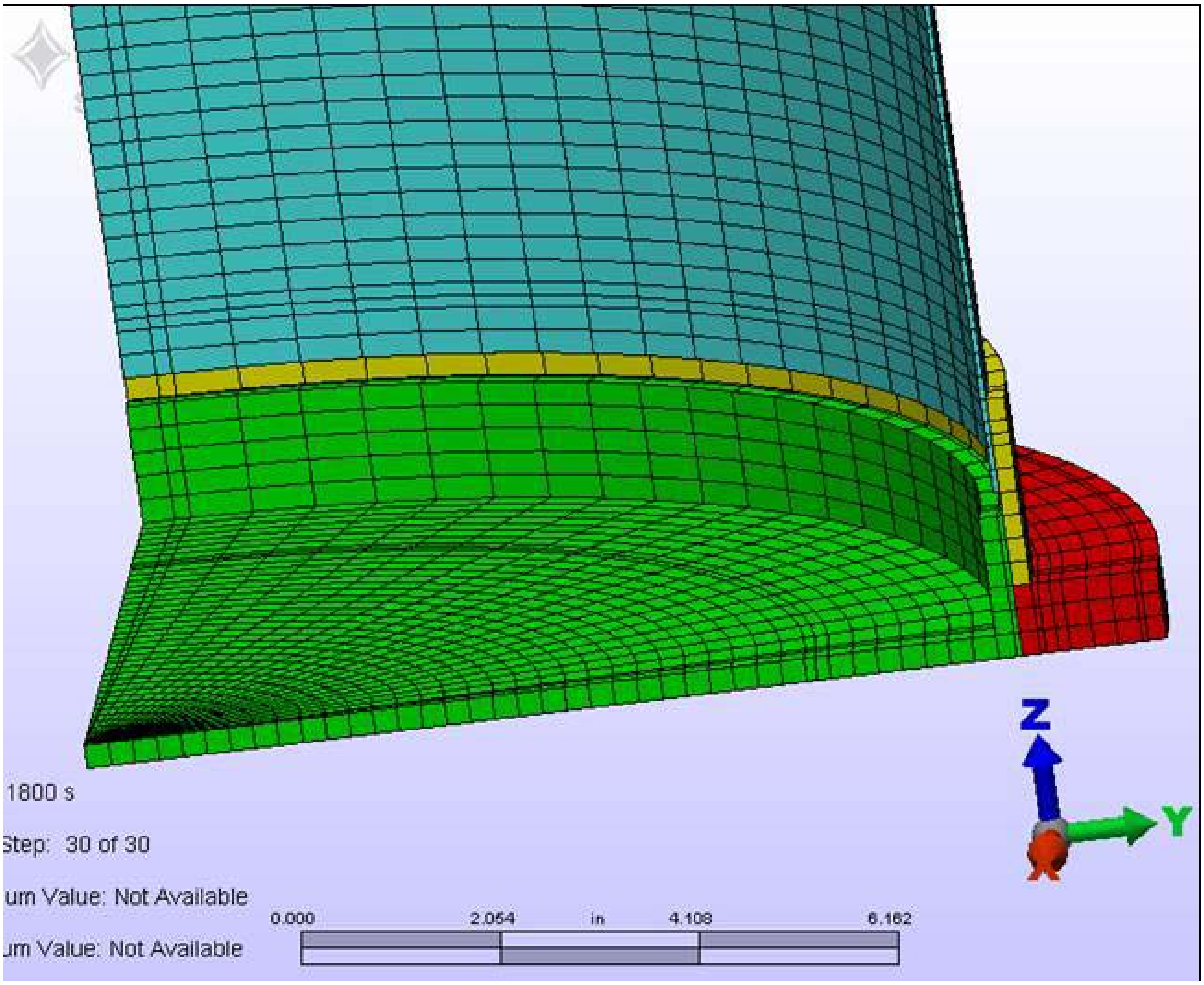


Figure 3.5.1- 13 Quarter-symmetric Thermal Model of the 55-gallon Versa-Pac, Detail View, Lower reinforcing structure

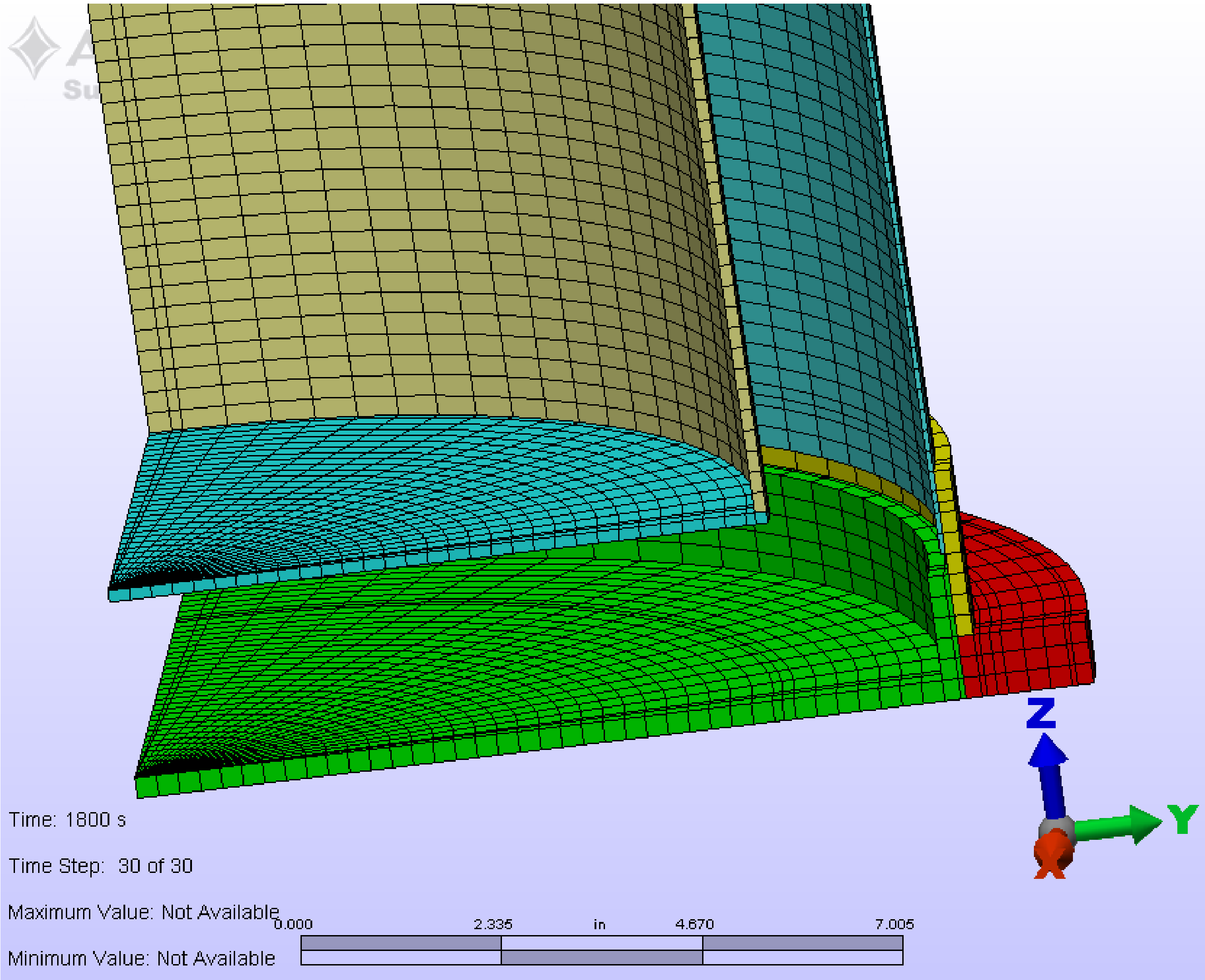


Figure 3.5.1- 14 Quarter-symmetric Thermal Model of 55-gallon Versa-Pac, Detail View, Lower Reinforcing structure with Payload Cavity shown

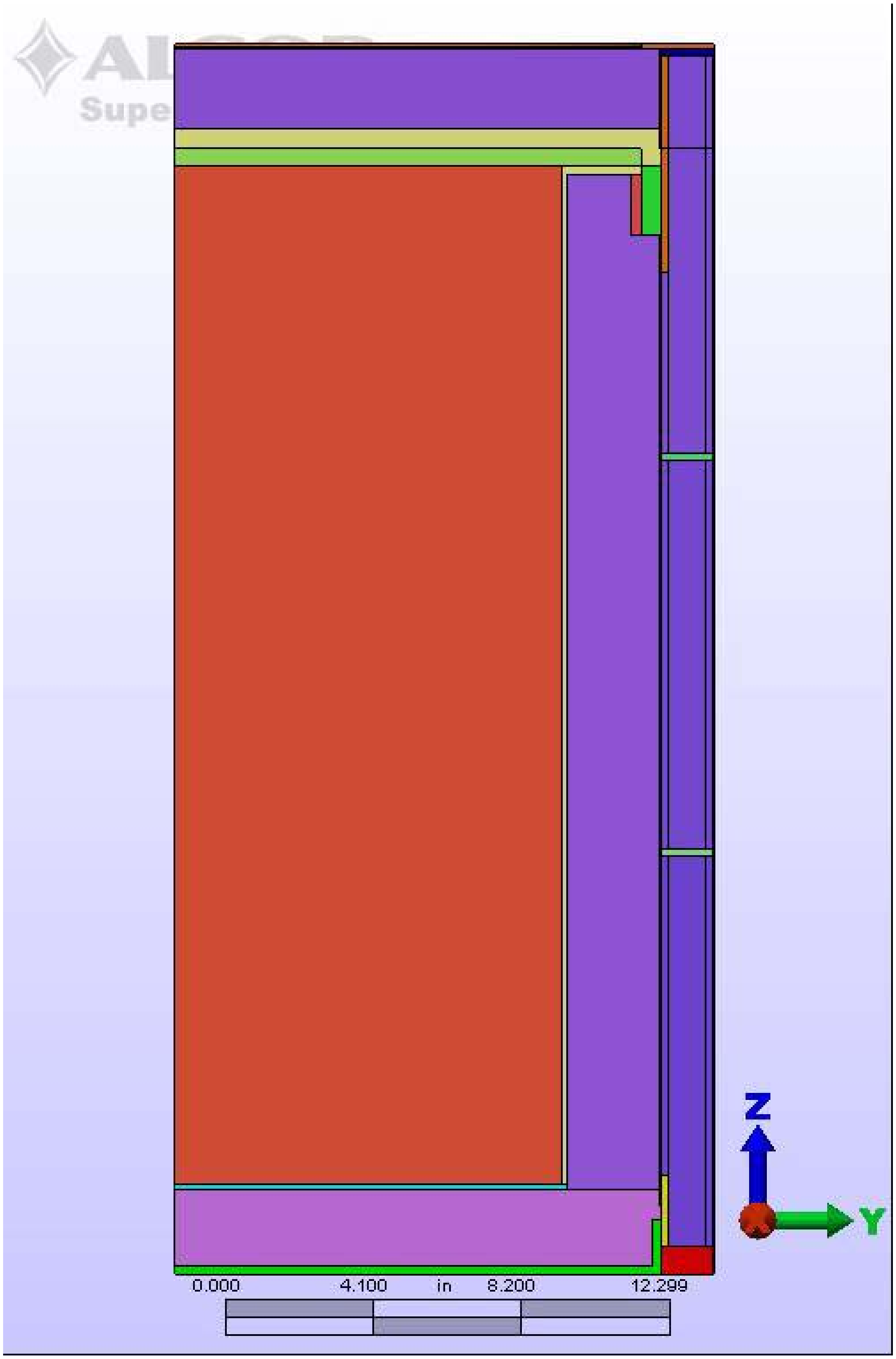


Figure 3.5.1- 15 Quarter-symmetric Thermal Model of 110-gallon Versa-Pac, all parts shown except polyurethane plug, side view

Appendix 3.5.2, Excerpted from ALGOR Non-Linear Thermal Transient Heat Transfer Analysis Manual, *Emulation of body-to-body radiation as temperature dependent conduction*

In some cases, body-to-body radiation can be emulated using temperature dependent conduction as shown in the figure below:

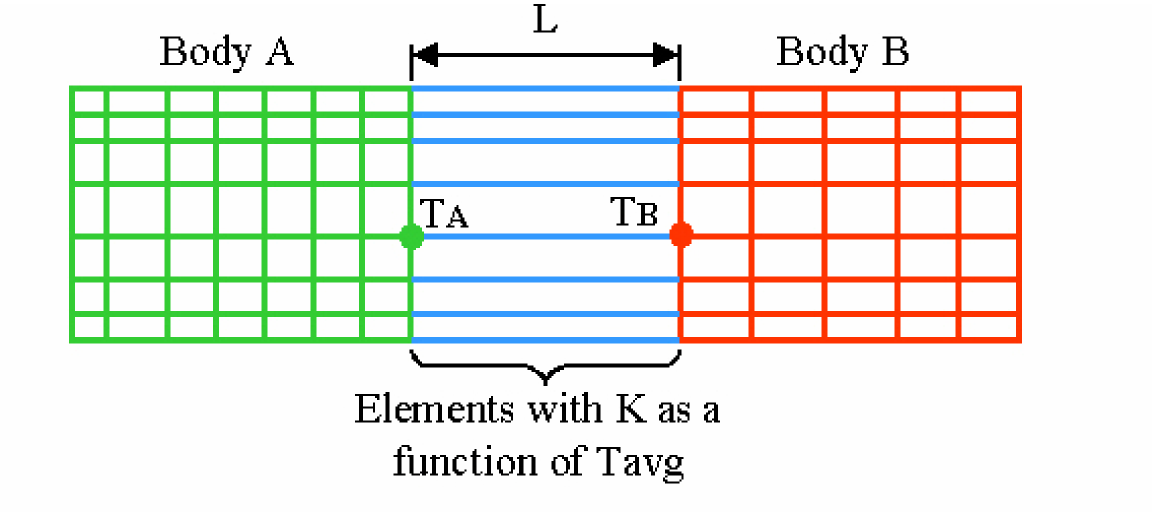


Figure 2: Body to Body Radiation

The requirements for this approximation to be accurate are as follows:

1. The view factor between the bodies must be close to 1.
2. The heat flux out of the system is negligible; that is, there is no radiation to the environment.
3. The surface area of each body is equal.
4. The expected temperatures of the surfaces are approximately known either from hand calculations, experimentation or previous analysis (multiple iterations).

The heat exchanged between two bodies which see each other and nothing else can be written based on the "surface resistance" and "space resistance" of the bodies as

$$\dot{q} = \frac{A\sigma\left(T_A^4 - T_B^4\right)}{\frac{1-\varepsilon_A}{\varepsilon_A} + \frac{1}{VF_{AB}} + \frac{1-\varepsilon_B}{\varepsilon_B}}$$

Where T_A and T_B are the temperatures of surfaces A and B (in absolute temperatures), ε_A and ε_B are the emissivities of surfaces A and B, and VF_{AB} is the view factor between the two surfaces.

The heat flow due to conduction between the two bodies is

$$q = kA\frac{\Delta T}{L}$$

Since the heat flow due to radiation must equal the heat flow by conduction, equating the above two equations and expanding $T_A^4 - T_B^4$ as follows

$$T_A^4 - T_B^4 = \left(T_A^2 + T_B^2\right)\left(T_A^2 - T_B^2\right) = \left(T_A^2 + T_B^2\right)\left(T_A + T_B\right)\left(T_A - T_B\right)$$

leads to the solution

$$K = \frac{L\sigma\left(T_A^2 + T_B^2\right)\left(T_A + T_B\right)}{\frac{1-\varepsilon_A}{\varepsilon_A} + \frac{1}{V F_{AB}} + \frac{1-\varepsilon_B}{\varepsilon_B}}$$

using absolute temperatures.

Letting $T_{average} = (T_A+T_B)/2$, then $T^2_{average}$ is approximately $(T^2_A+T^2_B)/4$.

Using this substitution, and assuming the emissivities are 1 and the view factor is 1, this is further simplified to:

$$K \cong L\sigma(8)(T_{average})^3$$

Since the radiant heat transfer and conduction through the air occur in parallel the conduction coefficient is added to the psuedo radiant coefficient for input into the problem.

One layer of elements is constructed in a new part between the two bodies. The material model is set to orthotropic so that the material properties are temperature dependent. The conductivity is calculated at estimated surface temperatures T_A and T_B (in absolute temperature) using the above equation. The calculated conductivity is entered in the material properties at a temperature of $T_{average}=0.5(T_A+T_B)$. Additional data points are entered by evaluating $T_{average}$ and K at other values of T_A and T_B. A range of temperatures $T_{average}$ is included in the material properties so that the calculated temperature is not outside of the range of material properties.

Appendix 3.5.3, Excerpted from Safety Analysis Report for the Century Champion Type B Package Thermal Test

Introduction

The Century Industries Versa-Pac Shipping Container is an evolutionary package design based on the design and testing of the Century Industries Champion Type B package. Due to the similarity in both package designs, tests involving the Century Industries Champion, although not directly applicable, can be used to support the safety basis of the Versa-Pac design as supplemented by further analysis and tests. Tests involving the Champion package that are applicable to the design of the Versa-Pac include drop tests, thermal and immersion tests. The thermal test further indicates the lack of the thermal stresses in the design. The design similarities are further presented with attachment of the test results for the Champion package.

Design Comparison

Both packages share the same basic structural components in that they have an inner and outer liner of sheet metal that is surrounded by vertical and horizontal stiffeners. Both package designs use the same ceramic fiber blanket insulation between the inner and outer liners and also surrounding the radial portion of the containment boundary. Both designs have approximately the same polyurethane foam in their respective bottom and top portions of the container. Both designs are based on an inner structure that slides into an outer drum. Therefore, both package designs should have a similar thermal response including thermal stresses. However, the temperature profiles may be different as further discussed.

The package designs differ in the type of insulation that surrounds the inner containment area. The Champion surrounds the containment area with polyurethane foam that is poured in place while the Versa-Pac utilizes ceramic fiber blanket insulation within the same area.

The Champion utilizes a leak testable inner vessel as the primary containment with a secondary blind cap flange on top of the main sealing flange while the Versa-Pac uses only a ½” blind flange with a high temperature fibrous sleeve at the containment boundary.

Thermal Test

Figure 3.5.3-1 shows the Century Champion Package rigging for the thermal test. Figure 3.5.3-2 displays a typical view of the package during the 30 minute 1475^{o}F thermal test phase. Figure 3.5.3-3 displays the package upon completion of the thermal testing prior to conduct of the immersion test.

Summary of Results

The metallic components of the package, as shown in Figure 3.5.3-3, do not show any signs of failure or fatigue at the conclusion of the thermal test. This demonstrates that thermal stresses induced during thermal testing are low and within the structural capacity of the components. The polyurethane insulation is considered to be a sacrificial component, and in performing its function its structure is broken down by the heat of the fire. However, the polyurethane components (including the internal polyurethane plug utilized in the Versa-Pac) do provide load-carrying capability for the packaging, and the steel components provide the strength and structure required to maintain the packaging intact following the event. The 30 minute thermal test including the post-test natural cool-down did not cause any seam or closure separation in the package. The package structure including outer closure drum does not shown any signs of failure or fatigue. These observations from the testing of the Century Champion are directly applicable to the Versa-Pac design since their outer structures are identical. Therefore, the Versa-Pac design is not anticipated to be subject to deleterious thermal stresses during the required 30 minute thermal test at 1475°F.

Pages 14 and 15 of the Champion Safety Analysis Report are provided as pages 5 and 6 to Appendix 3.5.3. The test results indicate that during a 44-minute fire exposure, the lower portion of the inner vessel attained a maximum temperature of 450°F. Testing of the Versa-Pac would be expected to produce similar results since the structures and thermal insulation are similar to the Champion. The analytical analysis presented in Section 3.0, Thermal Evaluation, indicate a maximum temperature to the contents of 552°F for the Versa-Pac using a 3-inch polyurethane foam plug in the top of the containment vessel. With the plug removed, the analytical results approach 600°F. The analytical results seem reasonable and are generally performed to bound actual thermal tests with sufficient margin to ensure the design meets the requirements. Therefore, the lower temperature experienced in the fire testing of the Champion seems reasonable. In an actual fire test of the Versa-Pac, the maximum temperature at the containment boundary would be expected to be less than 600°F. A lower temperature is anticipated since the Versa-Pac design uses a fiberglass thermal break in the area of the containment boundary closure.

Figure 3.5.3-1 Champion Package on Test Stand – View from Thermocouple Shielding Tube

Figure 3.5.3-2 Champion Package during Thermal Testing Phase

Figure 3.5.3-3 Champion Package Post-Thermal Test

9.2.3.4 Drop Test 4

Figure D-30 shows Drop Test 4 (puncture test, side orientation). Pre-test conditions were:

a) Drop Angle 0° (measured horizontally)
b) Drop Height 40 in. to impact face

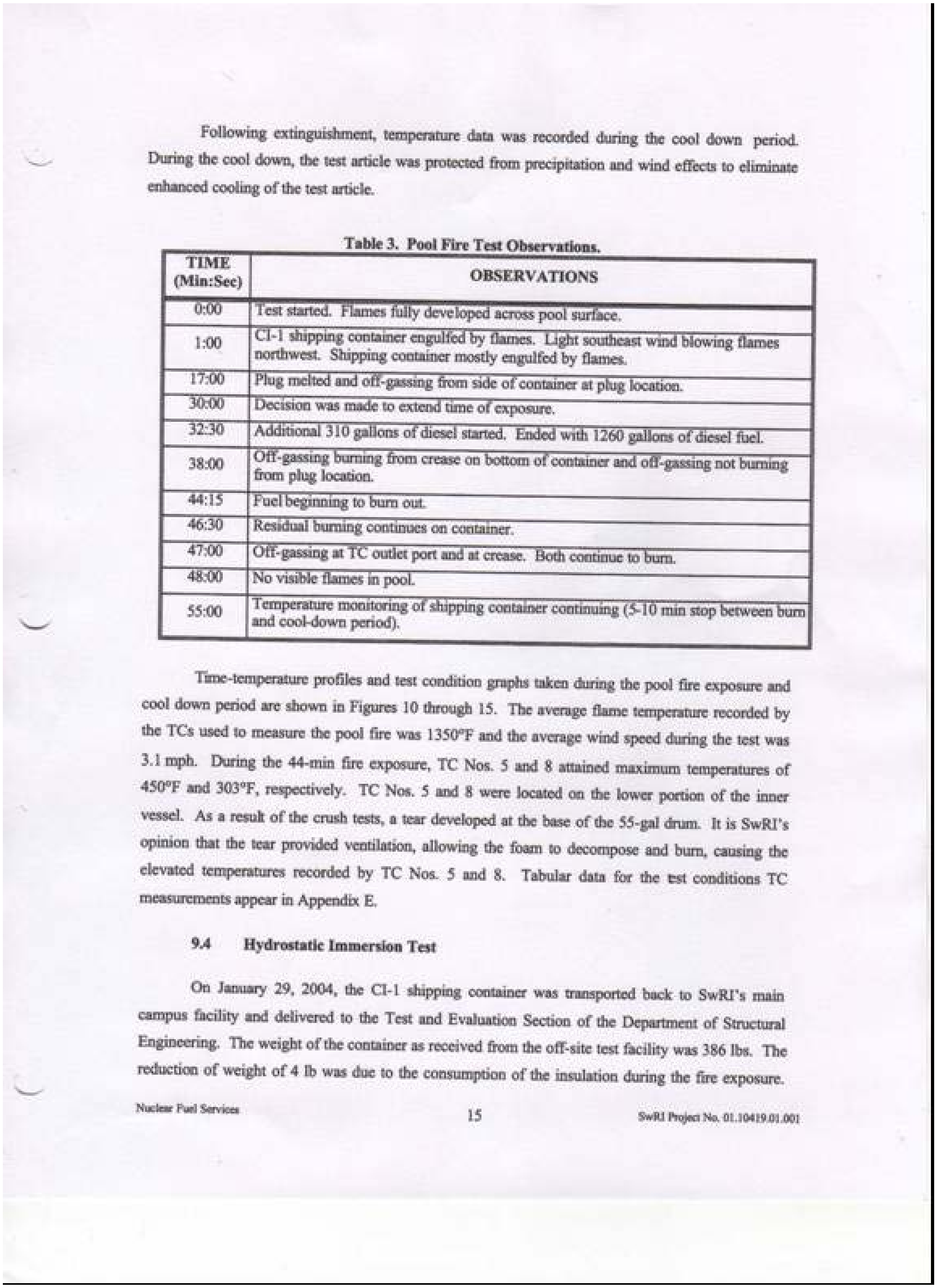
The shipping container was released cleanly and impacted the puncture bar in the proper location and orientation. The container remained on its side after impacting the cylindrical puncture bar (see Figure D-32). Deformation data of the exterior was measured and recorded by Fire Technology personnel. Video was taken of the drop event and color photographs showing the extent of damage were taken and are included with this report.

All testing was completed successfully, and all phases of this testing were witnessed by SwRI QA/QC and NSF and Century Industries personnel.

After all drops were completed the CI-1 shipping container was placed in a conditioning chamber overnight and the test article was exposed to warm heat. The test article was exposed to ambient air at a temperature of 140°F ± 10°F for more than 15 hours prior to the fire test.

9.3 Pool Fire Performance Evaluation Test

The CI-1 shipping container was transported to the remote test site in Sabinal, Texas, and the pool fire test described in Title 10 CFR 71.73 (c)(4) was performed on January 28, 2004. Messrs. Mike Arnold and Rick McVey representing Century Industries, Mr. Preston Foster representing BMX Technologies, and Mr. Joseph Pugh representing Nuclear Fuel Services were present to witness the tests. Following initial startup procedures and transfer of 950 gal of diesel fuel to the burn pan, the data acquisition equipment was verified and the fuel was ignited to begin the 30-min pool fire test. Based on visual observation and flame temperatures, it was decided by Century Industries and SwRI to extend the fire exposure due to the lack of complete fire engulfment to the shipping container. An additional 310 gallons of diesel fuel was added for the additional 14 min of burn to compensate for the incomplete engulfment and low flame temperatures. A total of 1260 gallons of diesel fuel was used for the 44 min burn period. A larger pool fire may mitigate these adverse affects. Table 3 lists the significant observations during the pool fire exposure and post-test cool down period.



Following extinguishment, temperature data was recorded during the cool down period. During the cool down, the test article was protected from precipitation and wind effects to eliminate enhanced cooling of the test article.

Table 3. Pool Fire Test Observations.

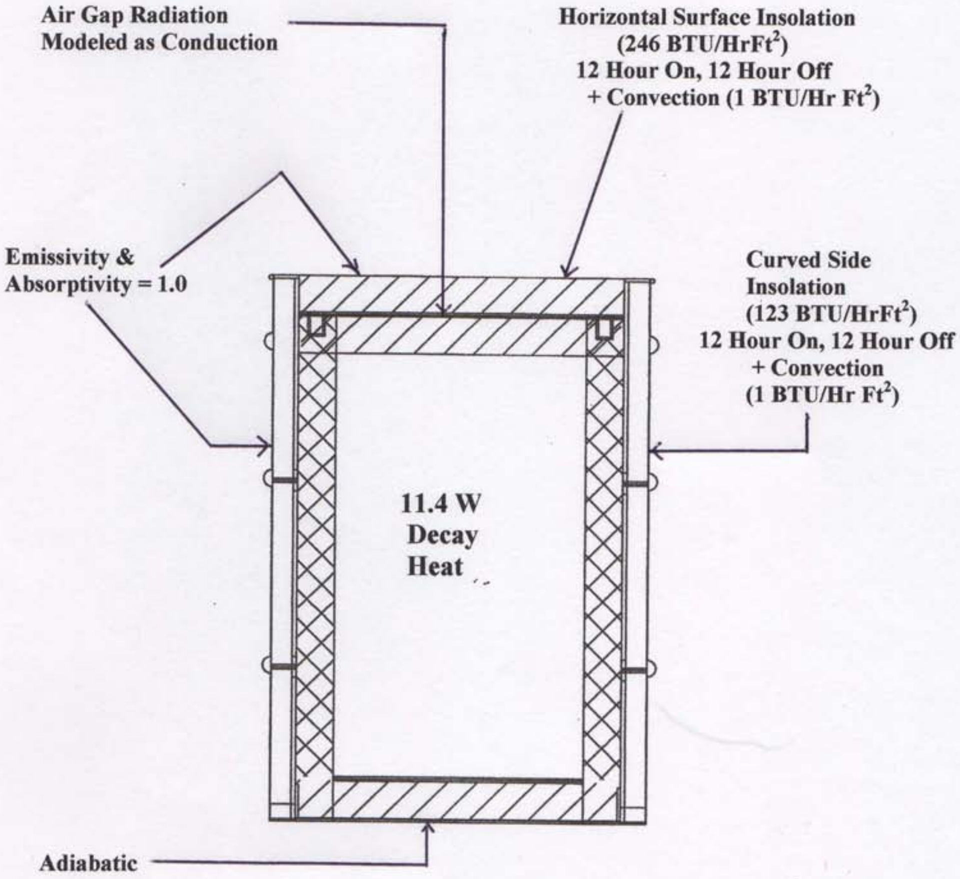
TIME (Min:Sec)	OBSERVATIONS
0:00	Test started. Flames fully developed across pool surface.
1:00	CI-1 shipping container engulfed by flames. Light southeast wind blowing flames northwest. Shipping container mostly engulfed by flames.
17:00	Plug melted and off-gassing from side of container at plug location.
30:00	Decision was made to extend time of exposure.
32:30	Additional 310 gallons of diesel started. Ended with 1260 gallons of diesel fuel.
38:00	Off-gassing burning from crease on bottom of container and off-gassing not burning from plug location.
44:15	Fuel beginning to burn out.
46:30	Residual burning continues on container.
47:00	Off-gassing at TC outlet port and at crease. Both continue to burn.
48:00	No visible flames in pool.
55:00	Temperature monitoring of shipping container continuing (5-10 min stop between burn and cool-down period).

Time-temperature profiles and test condition graphs taken during the pool fire exposure and cool down period are shown in Figures 10 through 15. The average flame temperature recorded by the TCs used to measure the pool fire was 1350°F and the average wind speed during the test was 3.1 mph. During the 44-min fire exposure, TC Nos. 5 and 8 attained maximum temperatures of 450°F and 303°F, respectively. TC Nos. 5 and 8 were located on the lower portion of the inner vessel. As a result of the crush tests, a tear developed at the base of the 55-gal drum. It is SwRI's opinion that the tear provided ventilation, allowing the foam to decompose and burn, causing the elevated temperatures recorded by TC Nos. 5 and 8. Tabular data for the test conditions TC measurements appear in Appendix E.

9.4 Hydrostatic Immersion Test

On January 29, 2004, the CI-1 shipping container was transported back to SwRI's main campus facility and delivered to the Test and Evaluation Section of the Department of Structural Engineering. The weight of the container as received from the off-site test facility was 386 lbs. The reduction of weight of 4 lb was due to the consumption of the insulation during the fire exposure.

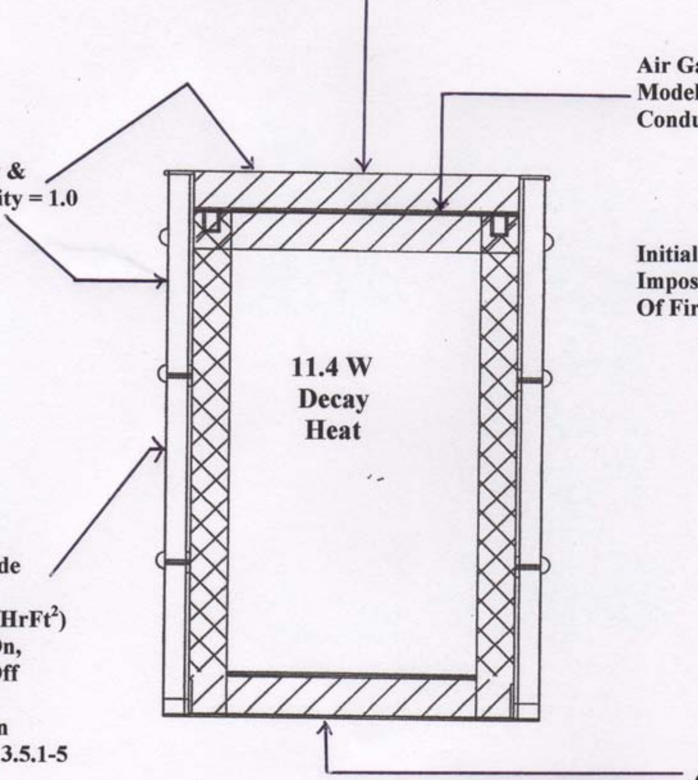
Appendix 3.5.4



NCT

**Package is Modeled Using Conduction Only. ¼ Symmetry, All Brick Elements.
Default Node Temperature = 100°F**

Horizontal Surface Insolation
(246 BTU/HrFt^2), 12 Hour On, 12 Hour Off
+ Horizontal Convection per Table 3.5.1-5



Air Gap Radiation
Modeled as
Conduction

Emissivity &
Absorptivity = 1.0

Initial Temperature
Imposed From End
Of Fire Sequence

Curved Side
Insolation
(123 BTU/HrFt^2)
12 Hour On,
12 Hour Off
+ Vertical
Convection
Per Table 3.5.1-5

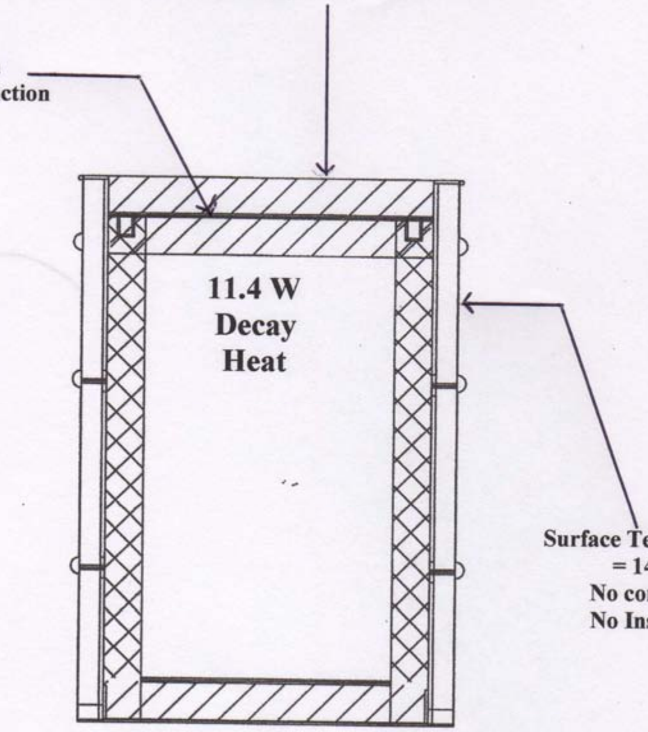
Adiabatic
0 Insolation

Cool-Down Sequence

2 Hour Duration,
Conduction Only,
¼ Symmetry, All Brick Elements

Surface Temperature = 1475°F
No convection, No Insolation

Air Gap Radiation
Modeled as Conduction



Surface Temperature
= 1475°F
No convection,
No Insolation

Surface Temperature = 1475°F
No convection, No Insolation

<u>Fire Sequence</u>

30 Minutes Duration,
Emissivity & Absorptivity = 1.0
Conduction Only, ¼ Symmetry, All Brick Elements

Appendix 3.5.5 Thermal Stress Evaluation of the Polyurethane Plug Insert

At the request of USNRC, a thermal stress evaluation was completed for the polyurethane plug (part 62 described in Table 3.5.1-1) that is utilized within the payload cavity. An equivalent part was not utilized in the Champion package fire test (presented as additional performance information, see Appendix 3.5.3); this finite element analysis provides the equivalent data.

ALGOR Release 18.1 was used for the evaluation. The parts, nodes, and elements of the model described in Appendix 3.5.1 and shown in Figures 3.5.1-1 through 3.5.1-15 were used to generate a thermal stress model, and the results from the fire and cooldown model described in Section 3 were imposed on the thermal stress model.

The evaluation utilized static stress conditions with linear material models, and the thermal and mechanical material properties utilized in the model are provided in Tables 3.5.5-1, 3.5.5-2 and 3.5.5-3. The polyurethane compressive modulus varies, depending on the direction of foam rise during its fabrication. Additionally, the compressive modulus is temperature-sensitive. For purposes of bounding the expected performance, the compressive modulus of the polyurethane plug was selected conservatively to produce the highest thermal stress. To confirm the correct selection, a sensitivity case was run.

The evaluation assumes that continuity is maintained at the planes of symmetry of the quarter-model, as shown in Figure 3.5.5-1. Also, a single node at the center of the packaging base (also shown in Figure 3.5.5-1) was constrained against translation in the x-, y- and z-directions.

The temperature condition producing the highest thermal stress in the polyurethane plug is the condition where the steel packaging components are at a low temperature in comparison with the polyurethane plug, since the thermal expansion coefficient of the polyurethane plug is larger than that of the encasing steel components. This maximum thermal differential occurs at 150 minutes (0 minutes is at the start of the fire event) for the VersaPac evaluation. Thus, the thermal stress evaluation was completed utilizing the packaging and contents temperature distribution corresponding to 150 minutes. This distribution is illustrated in Figure 3.5.5-2.

The maximum evaluated stress in the polyurethane plug is 78 psi and is much less than the compressive strength of the material; however, it should be noted that the polyurethane plug is not a structural component of the package, and is considered to be a sacrificial component in the event of a fire.

Table 3.5.5- 1 Material Properties for Versa-Pac Components, excluding Polyurethane Foam

Material	Density (lb / ft^3)	Modulus of Elasticity (psi)	Poison's Ratio	Thermal Expansion Coefficient (in/in/◦F)	Source
Isotropic steel	2.836E-01	2.9E+7	0.29	6.5E-6	ALGOR material library (Mechanics of Materials, 2nd Ed., F.P Beer and E.R. Johnston, Jr.)
8 pcf Temperature dependent isotropic alumina silica	All alumina silica insulation conservatively modeled as 6pcf polyurethane for the thermal stress evaluation (temperatures generated in the fire and cooldown model)				
Fiberglass – Extren525 Isophthalic polyester resin	6.192E-02	8.0E+6	0.3	1.0E-5	Century Industries SOP6.13, also "Typical Properties – FRP Structural Shapes", Enduro Systems, Inc., www.endurocomposites.com
Air	4.225E-05	5000*	0.3*	1E-16*	*Mechanical properties selected such that the air doesn't impose or carry load.
Contents 1, wood	Contents modeled as solid steel to maximize thermal expansion (temperatures generated in the fire and cooldown model)				
Contents 2, void	Contents modeled as solid steel to maximize thermal expansion (temperatures generated in the fire and cooldown model)				
Contents 3, solid steel	2.836E-01	2.9E+7	0.29	6.5E-6	ALGOR material library (Mechanics of Materials, 2nd Ed., F.P Beer and E.R. Johnston, Jr.)

Table 3.5.5- 2 6 pcf Polyurethane Foam Material Properties

Source: General Plastics Manufacturing Company, www.generalplastics.com accessed 1/31/2010.
Nominal Physical Property Data for **LAST-A-FOAM® FR-3700 Rigid Foam** at **6** pounds per cubic foot density

Property	English	Metric
Density (pcf) (kg/m^3)	6	96
Compressive Strength (psi) (kPa) Parallel to Rise		
@ -65° F	243	1675
@ 75° F	154	1063
@ 200° F	102	704
@ 250° F	74	509
Perpendicular to Rise		
@ -65° F	198	1367
@ 75° F	139	955
@ 200° F	82	564
@ 250° F	64	440
Compressive Modulus (psi) (kPa) Parallel to Rise		
@ -65° F	5418*	37357
@ 75° F	4253	29322
@ 200° F	3261	22486
@ 250° F	2383	16428
Perpendicular to Rise		
@ -65° F	4308	29701
@ 75° F	3437	23701
@ 200° F	2465	16998
@ 250° F	2064	14231
Tensile Strength (psi) (kPa)		
Parallel to Rise	182	1252
Perpendicular to Rise	174	1200

Source: General Plastics Manufacturing Company, www.generalplastics.com accessed 1/31/2010.
Nominal Physical Property Data for **LAST-A-FOAM® FR-3700 Rigid Foam** at **6** pounds per cubic foot density

Property	English	Metric
Tensile Modulus (psi) (kPa)		
Parallel to Rise	5947	41008
Perpendicular to Rise	5662	39037
Shear Strength (psi) (kPa)		
Rise Parallel to Specimen Width	116	799
Rise Parallel to Specimen Thick	116	798
CTE: (in/in/°F) (K^-1)	~3.4x10^-5	~6.1x10^-5
Poisson's Ratio	~0.3	~0.3

* Bounding value used in FEA model.
Values used in the model are shown in red

Table 3.5.5- 3 10 pcf Polyurethane Foam Material Properties

Source: General Plastics Manufacturing Company, www.generalplastics.com accessed 1/31/2010.
Nominal Physical Property Data for **LAST-A-FOAM® FR-3700 Rigid Foam** at **10** pounds per cubic foot density

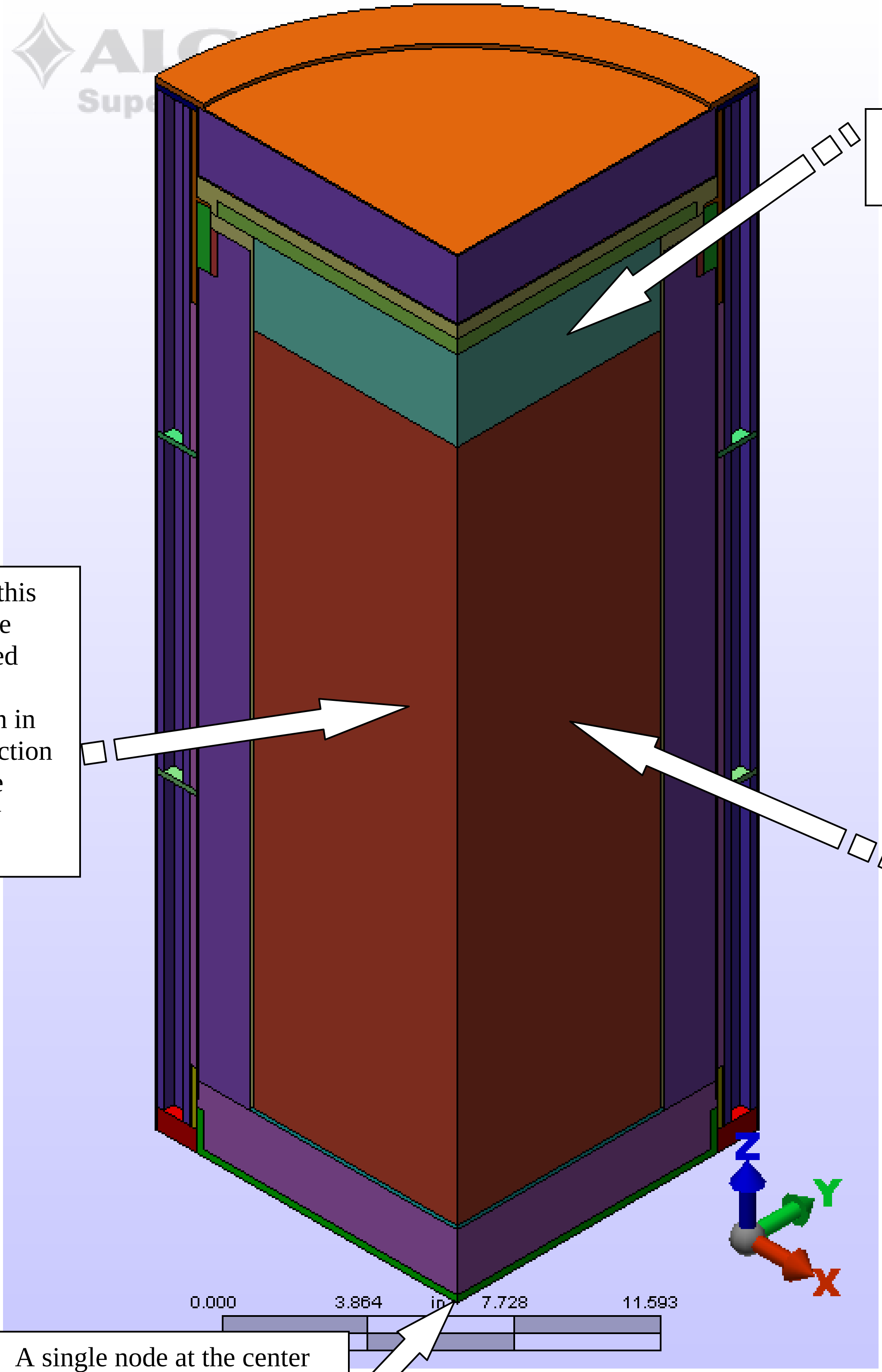
Property	English	Metric
Density (pcf) (kg/m^3)	10	160
Compressive Strength (psi) (kPa) Parallel to Rise		
@ -65° F	552	3809
@ 75° F	350	2415
@ 200° F	215	1485
@ 250° F	143	988
Perpendicular to Rise		
@ -65° F	527	3630
@ 75° F	325	2238
@ 200° F	209	1440
@ 250° F	146	1008
Compressive Modulus (psi) (kPa) Parallel to Rise		
@ -65° F	11306*	77955
@ 75° F	10156	70028
@ 200° F	7250	49986
@ 250° F	5797	39969
Perpendicular to Rise		
@ -65° F	10958	75557
@ 75° F	8759	60390
@ 200° F	6365	43888
@ 250° F	5797	39969
Tensile Strength (psi) (kPa)		
Parallel to Rise	319	2202
Perpendicular to Rise	313	2155

Source: General Plastics Manufacturing Company, www.generalplastics.com accessed 1/31/2010.
Nominal Physical Property Data for **LAST-A-FOAM® FR-3700 Rigid Foam** at **10** pounds per cubic foot density

Property	English	Metric
Tensile Modulus (psi) (kPa)		
Parallel to Rise	11855	81742
Perpendicular to Rise	12489	86111
Shear Strength (psi) (kPa)		
Rise Parallel to Specimen Width	249	1719
Rise Parallel to Specimen Thick	242	1670
CTE: (in/in/°F) (K^-1)	~3.4x10^-5	~6.1x10^-5
Poisson's Ratio	~0.3	~0.3

*** Bounding value used in FEA model.**

Values used in the model are shown in red



10 pcf Polyurethane Plug

Nodes in this plane were constrained against translation in the y-direction to provide symmetry

Nodes in this plane were constrained against translation in the x-direction to provide symmetry

A single node at the center of the base was constrained against translation in the x-, y- and z directions

Figure 3.5.5- 1 FEA Model and boundary conditions

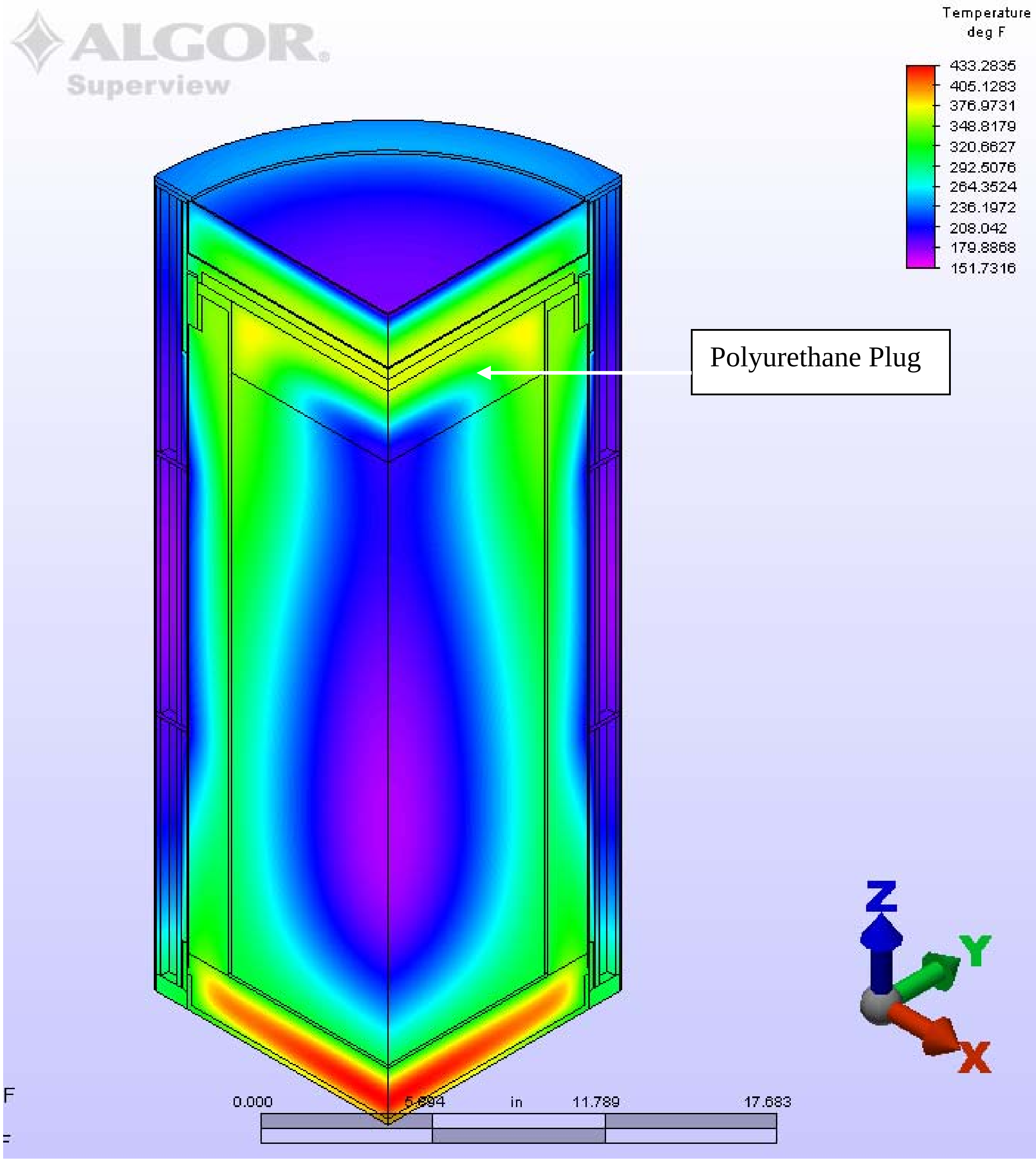
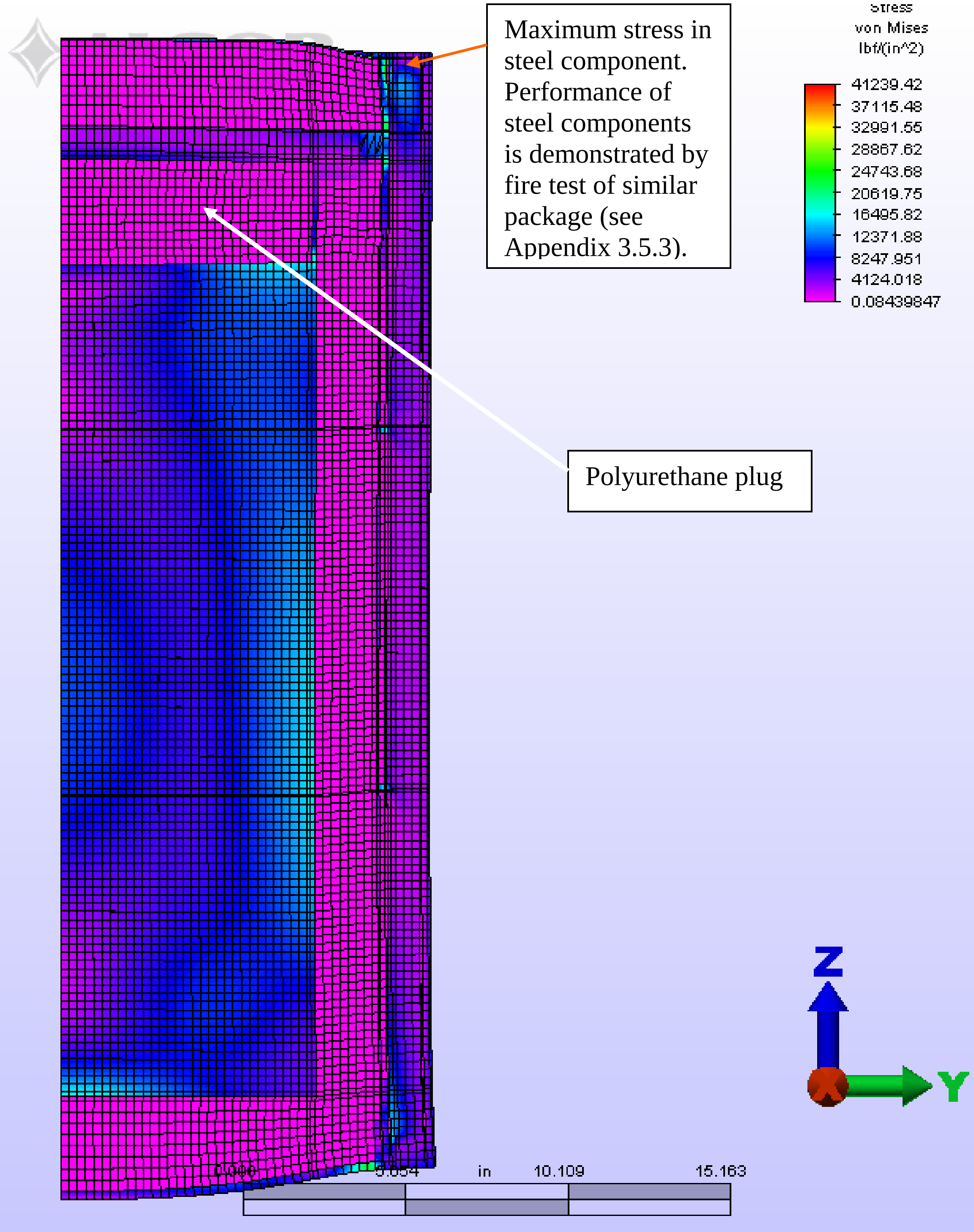


Figure 3.5.5- 2 Imposed Temperature Distribution



Maximum stress in steel component. Performance of steel components is demonstrated by fire test of similar package (see Appendix 3.5.3).

Polyurethane plug

Figure 3.5.5- 3 Side View of Thermal Expansion at 150 minutes, Von Mises Stress Distribution Shown

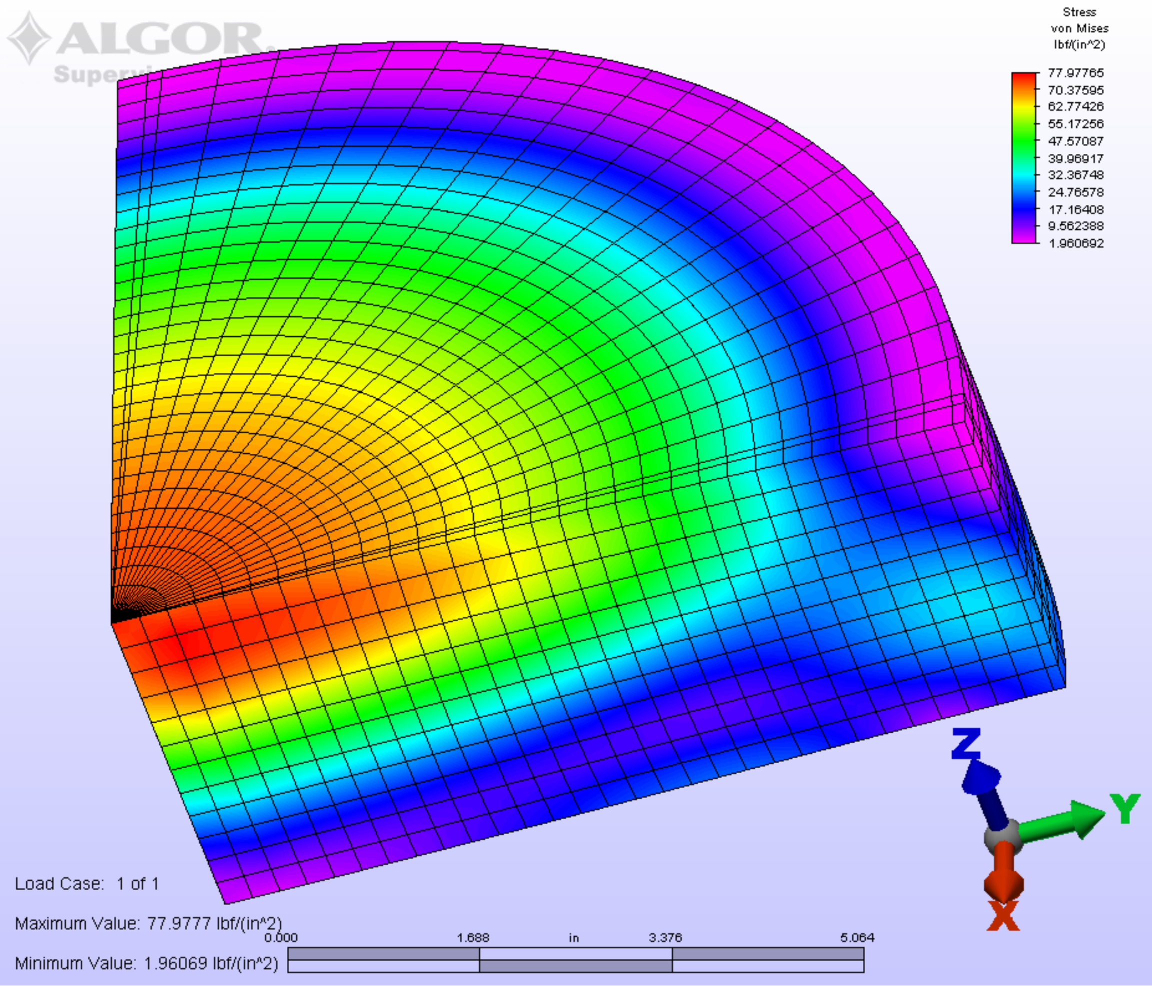


Figure 3.5.5- 4 Thermal Stress on the Polyurethane Plug (Von Mises) at 150 minutes

Blank

SECTION FOUR

CONTAINMENT

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4 CONTAINMENT

4.1 Description of the Containment System

The containment boundary of the package is defined as the payload vessel with its associated welds, payload vessel high temperature heat resistant fiberglass sleeve gasket, payload vessel blind flange, and reinforcing ring.

The payload vessel is comprised of a 10-gauge carbon steel sheet for the body and bottom. The upper end of the vessel is fitted with a ¼” inner carbon steel flange ring with a $^{1}/_{2}$” thick carbon steel blind flange. The vessel has three circumferential welds (two at the flange, one at the base) and one longitudinal weld. An $^{1}/_{8}$” high temperature resistant fiberglass sleeve gasket is used between the steel flange ring and blind flange. The payload vessel blind flange is secured to the flange with twelve ½” bolts. There are no penetrations, valves or venting devices used within the containment boundary.

A specified torque is applied to the closure bolts and tightened as part of the closure steps defined within Section 7.1.3 to assure positive closure of the containment boundary, and given the mode of the closure, it cannot be opened unintentionally. The use of lock washers assures that the closure bolts are not loosed due to vibration during shipment. A location for installation of a tamper-indicating device is provided at the drum closure.

4.2 Containment under Normal Conditions of Transport

The Versa-Pac Shipping Container is classified as a Type A Fissile package. Performance tests consistent with the requirements of 10CFR71.71 and 10CFR71.73 have demonstrated that the Versa-Pac effectively prevents loss or dispersal of the radioactive contents under the postulated conditions of transport. Additionally, the tests have demonstrated that there is no substantial reduction in the effectiveness of the packaging during normal conditions of transport; thus, there is no significant increase in external surface radiation levels resulting from the postulated conditions of transport. Section 2.0 provides a description of the tests performed and analyses completed. Section 6.0 demonstrates that the package remains subcritical under normal and hypothetical accident conditions.

Since the package is not a sealed system, the internal pressure is maintained near atmospheric pressure for all conditions of transport. The maximum normal hot contents temperature is less than 212°F; thus, any water moisture remains in the liquid state and within the payload cavity.

4.3 Containment Requirements for Hypothetical Accident Conditions

As discussed in Section 4.2 and Section 2.0, performance tests consistent with the requirements of 10CFR71.71 and 10CFR71.73 have demonstrated that the Versa-Pac effectively prevents loss or dispersal of the radioactive contents under the postulated conditions of transport.

Section 6.0 demonstrates that the package remains subcritical under normal and hypothetical accident conditions.

Since the package is not a sealed system, the internal pressure of the package is maintained near atmospheric pressure for all conditions of transport. During the fire event, some water moisture within the payload will be converted to steam. Any pressure build up will be relieved through the package gaskets.

4.4 Leakage Rate Tests for Type B Packages

This section is not applicable.

4.5 List of Appendices

This section is not applicable.

SECTION FIVE

SHIELDING EVALUATION

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5 SHIELDING EVALUATION

Gamma and neutron shielding are not required for the materials transported in the Century Versa-Pac Shipping Container. However, it is the responsibility of the shipper to assure compliance with 10 CFR 71.47 regarding radiation standards for each individual shipment.

SECTION 6
CRITICALITY EVALUATION

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LIST OF TABLES AND FIGURES

6 Criticality Evaluation

The Century Versa-Pac Shipping Container is described in Section 1.2, *Package Description*. The package exists in two distinct but similar versions consisting of outer 55-gallon and 110-gallon drums.

The 55-gallon drum version of the Versa-Pac Shipping Container consists of a 16 gauge body, bottom and cover. The drum uses a 12 gauge bolted closure ring, standard carbon steel lugs, 5/8" diameter, ASTM A307 bolts and nuts, and a closed-cell EPDM gasket. The overall outer dimensions of the 55 gallon package are 23-1/16" OD x 34-3/4" in height to the top of the drum bolt ring. The drum cover is reinforced by an eighth-inch thick 22-3/8" OD x 18-3/8" ID plate, and four ½" bolts are provided to lend additional strength to the drum closure ring.

The 110-gallon version utilizes a 16 gauge body, bottom and cover. The drum uses a 12 gauge bolted closure ring, standard carbon steel lugs, 5/8" diameter ASTM A307 bolts and nuts, and a closed-cell EPDM gasket. The overall outer dimensions for the 110 gallon package are 30-7/16" OD x 42-3/4" in height to the top of the druim bolt ring. The drum cover is reinforced by an eighth-inch thick 29-3/4" OD x 27-1/4" ID plate and eight ½" bolts are provided to lend additional strength to the drum closure ring.

Both drums are further strengthened with vertical stiffeners fabricated from 1-1/4" carbon steel square tubing, two inner liners of rolled 16 gauge carbon steel insulated by ceramic fiber blanket encase the vertical tubing, and a ¼" carbon steel reinforcing plate on the bottom. Reinforcing angles and solid bars within the liners provides additional strength.

The package's interior is completely insulated with layered ceramic fiber blanket around the containment area with rigid polyurethane foam disks on the top and bottom. The ceramic fiber blanket and polyurethane foam provide shock and thermal protection to the containment area.

The containment and exterior structure including their respective closures provide two barriers to prevent the payload dispersion and water inleakage. An illustration of the packaging is provided in Figure 1-1.

The criticality analysis demonstrates that the payload material may be pre-packaged in hydrogenous or non-hydrogenous containers within the payload vessel. Hydrogenous pre-packaging materials consist of polyethylene, polypropylene, or PVC. PTFE or Teflon® pre-packaging material are also allowed. Metallic pre-packaging materials consisting of aluminum, stainless and carbon steel are further allowed provided their total weight is controlled to within the payload allotment of the package. In addition only materials listed in Table 1-4 are presently qualified for use within the Versa-Pac shipping container; all other materials must meet the 600°F minimum auto-ignition temperature describe in Section 1.2.2. The user is required to establish that the auto-ignition temperature is a minimum of 600°F using an established method, such as the method prescribed by ASTM D883 (Test Method for Reaction Threshold Temperature of Liquid and Solid Materials).

A summary of the results for the most reactive HAC cofiguration for the criticality evaluation is provided in Table 6-1. The most reactive HAC configuration was determined to consist of an arrangement of in-homogeneous spheres placed within the containment area of the package to achieve maximum interaction from contiguous packages in a triangular array.

6.1 Description of Criticality Design

6.1.1 Design Features

The Century Versa-Pac Shipping Container does not use any neutron moderators or absorbers, however minimum thicknesses of continuous sheet and plate carbon steel (e.g., containment liner, inner/outer liner, drum lid, body and bottom, including top and bottom reinforcing plates) are modeled in the analysis. Descrete carbon steel consisting of the vertical stiffeners, flanges, angles, and bars are not modeled. Also not modeled are the flange ring interfaces with the flange which are model assuming a continuous thickness of the flange material.

Criticality control of the Century Versa-Pac Shipping Container relies on control of the payload vessel diameter, the vessel-to-vessel spacing provided by the drum, and number of packagings that may be shipped together. Additionally, each payload is subject to a mass limit of 350 gram U-235. The U-235 mass limit is an absolute value which is typically defined as a nominal measured value with a measurement uncertainty at a 95% confidence level.

Further, the payload does not rely on moderation-control. Moderation in the payload vessel is evaluated using optimum polyethylene. The moderator is evaluated by varying the corresponding volume fractions. Polyethylene is further evaluated at an increased density. A polyethylene density of 0.98 g/cc conservatively bounds the use of pre-packaging materials containing carbon (including graphite and paraffin) and hydrogen. Basically, the higher density polyethylene bounds other moderating materials with a Hydrogen density less than or equal to 0.141 g/cc.[1]

Thus, the physical packaging design features that are important to criticality safety are the payload vessel diameter, the drum outer diameter, and the payload vessel body, body welds, blind flange and seals. Administrative control of the payload mass and shipment array must also be implemented.

6.1.2 Summary Table of Criticality Evaluation

Table 6-1 provides a summary of the results of the criticality evaluation of the Century Versa-Pac Shipping Container for the most reactive configuration. The 350 gram U-235 fissile mass modeled as a lumped 12.0-cm radius sphere leads to the most reactive configuration. A detailed description of the analytical models and methodology is provided in Section 6.3. All results are less than the conservative administrative Upper Subcritical Limit of 0.95 minus the code bias and bias uncertainty[2].

As indicated in Section 6.3, a single model is conservatively constructed to

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[1] Refer to Table 6-3 for a comparison of the moderating materials considered in this analysis.

[2] The k_{eff} used in all cases represents the KENO k_{eff} plus two sigma (sigma was typically on the order of 0.002). Discussion on the code bias and bias uncertainty is provided in Section 6.5.

represent the Normal Condition of Transport (NCT) and Hypothetical Accident Condition (HAC) package configurations for both the 55-gallon and 110-gallon package versions. As further indicated in Section 2.12.3, the tested 110-gallon package version sustained little damage from both the NCT and HAC testing suggesting small differences in the final evaluated package array sizes. Section 2.0 also indicates that prototype testing of both package designs shows that more damage resulted to the 110-gallon package version due to the heavier weight and greater distance between vertical stiffeners. Therefore, the criticality analysis model is conservatively constructed based on the 55-gallon package dimensions, due to the potential for higher package and fissile mass densities, with the conservative application of actual damage sustained during testing of the 110-gallon package version. This model conservatively bounds the HAC testing and is very conservative with respect to the NCT configuration for both package versions.

6.1.3 Criticality Safety Index (CSI)

The Criticality Safety Index (CSI) is 1.0. Arrays of at least 272 packages are evaluated for the Normal and Hypothetical Accident Conditions. Thus, N is 272/5 ≈ 55 or 272/2 = 136, and the minimum CSI is 55/60 ≈ 0.92, which is rounded upto 1.0. The corresponding maximum number of packages to be transported non-exclusive use based on a CSI of 1.0 is 50.

6.2 Fissile Material Contents

All materials shall be in solid form with no freestanding liquids; density is not limited. These materials quantities may not exceed 350 grams U-235 in any non-pyrophoric form, enriched up to 100 Wt%. Materials that may be shipped in the Versa-Pac include uranium oxides (U_yO_x), uranium metal (U-metal), uranyl nitrate crystals (UNX), and other uranium compounds (e.g., Uranyl Fluorides and Uranyl Carbonates) enriched up to 100 Wt% U-235. The uranium compounds may also contain carbon or graphite. UNX may be in the form of uranyl nitrate hexahydrate, trihydrate or dihydrate, and may contain any amount of moisture; however, the UNX must be in solid form with no freestanding liquid. The payload may be in homogeneous (powder or crystalline) or non-homogeneous (pelleted or lumped) form. Table 1-5 identifies the limits for U-324 and U-236 as applied to the Versa-Pac Shipping Container. The A_2 values are used as stated in 10 CFR 71 and are applied to the package since the payload is limited to normal form material.

The package is evaluated assuming optimum moderation using a bounding high-density polyethylene plastic (Density = 0.98 g/cc) and supports packaging applications containing both carbon (graphite) and hydrogen based materials. Non-fissile chemical impurities do not increase the reactivity of the system; therefore, they may be present in any quantity. The payload may be enriched in U-235 to 100 Wt%.

The payload material may be pre-packaged in hydrogenous or non-hydrogenous containers within the payload vessel. Hydrogenous pre-packaging materials may include polyethylene, polypropylene, and PVC. PTFE or Teflon pre-packaging material are also allowed. Metallic pre-packaging materials such as aluminum, stainless and carbon steel are further allowed provided their total weight is controlled to within the payload allotment of the package. In addition only materials listed in Table 1-4 are presently qualified for use within the Versa-Pac shipping container; all other materials must meet the 600°F minimum auto-ignition temperature describe in Section 1.2.2. The user is required to establish that the auto-ignition temperature is a minimum of 600°F using an established method, such as the method prescribed by ASTM D883 (Test Method for Reaction Threshold Temperature of Liquid and Solid Materials).

No materials, excluding the minimum steel wall thickness of the package, are used as neutron absorbers or moderators.

6.3 General Considerations

6.3.1 Model Configuration

Figure 6-1 provides a representation of the unit model used in the criticality analysis. The modeled dimensions represent a damaged 55-gallon package. The packaging consists of a cylindrical carbon steel shell surrounded by insulation, an inner/outer steel liner, and an outer carbon steel shell. The steel payload vessel, flange, and blind flange are modeled as carbon steel with reduced minimum dimensions. The drum, inner and outer liners, and upper and lower drum plates are also modeled as carbon steel with reduced minimum dimensions. An enrichment of 100 Wt% U-235 is used to evaluate all cases.

The constructed model evaluated in the criticality analysis, as also discussed in Section 6.1.2, conservatively represents the HAC package configuration (damaged package configuration) for the 55-gallon package design. The model is constructed considering worst case damage to both the 55-gallon and 110-gallon package designs. Due to the smaller package envelope of the 55-galon package design the package is inherently more reactive when compared to the 110-gallon package design. The modeled reduction in package dimensions leads to significant more interaction between packages and results in a lower CSI. The reduced dimensions of the modeled 55-gallon package (damaged package configuration) design results in a more reactive package array when compared to undamaged 55-gallon and 110-gallon designs. Therefore, the conservatively modeled HAC package configuration for the 55-gallon package design bounds the NCT (undamaged package configurations) for both the 55-gallon and 110-gallon packages and further bounds the HAC (damaged package configuration) for the 110-gallon package design. Further evaluation of the HAC (damaged package configuration) modeled array size to the more restrictive NCT criteria (5N) the resulting CSI (1.0) conservatively bounds the NCT criteria (5N) and HAC criteria (2N) for evaluation of package arrays using the single model.

With construction of a NCT model (undamaged package design) based on the 55-gallon design, the evaluated array size would be increased due to additional spacing afforded between fissile material in adjacent packages. This would further lead to a reduced CSI. Thus, a smaller package design, considering worst case damage of the two designs, to the most restrictive CSI criteria can conservatively represent the Versa-Pac 55-gallon and 110-gallon packages.

6.3.1.1 Model Conservatisms

Table 6-2 summarizes the dimensional changes to the test packages indicated as Test Articles with Serial Numbers 10550, 10551, and 10553. The pre and post test measured results for each package is provided in Section 2.12.3, *Century Industries Performance Test Report for the Versa-Pac*. The worst case dimensional reductions from these tests, as summarized in Table 6-2, are + 1/8" increase in the inner containment diameter, - 5/16" reduction in the outer drum diameter, and -1/4" reducion in the outer drum height (including lid). Note that the measured dimensions provided in Section 2.12.3 do not include the outer drum lid. Also, the outer drum diameter reduction only occurs on one side of the drum mostly due to compression of the area between drum stiffeners at the impact location of the test plate.

The overall outer dimensions of the 55 gallon package are 23" OD x 34-1/2" in height. Neglicting the drum stiffeners and bolt ring reduces the outer diameter to 22-1/2". For the bounding HAC/NCT model, the 55-gallon drum is further modeled with a reduced outer diameter of 1.313" which significantly bounds the maximum reduced dimension resulting from the tests of 0.313" (5/16"). The reduced outer diameter further bounds and still provides margin for the 1/8" increase in the inner containment diameter. The 55-gallon drum is further modeled with a reduced outer height of 0.875" which bounds the maximum reduced dimension resulting from the tests of 0.250" (1/4"). The containment area is further modeled at both nominal and with increased dimensions of 1/8" for the diameter and 1/16" for the height[3]. The nominal dimensions being 15" inner diameter with a height of 27 1/16". The overall outer dimensions of the 55 gallon package model are then 21.1875" OD x 33.625" in height. The drum and payload vessel walls, upper and lower plates are modeled at their minimum thickness as indicated in Table 6-3.

The four vertical members (square tubing), reinforcing angles, and bottom plate ring constructed from carbon steel have been conservatively neglected resulting in modeling less than 50% of the package carbon steel. All insulation products are conservatively modeled as optimum interspersed water moderation.

Packages and arrays of packages were also modeled with full density water boundary reflection.

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[3] Additional performance testing of the 55-gallon package version as documented in Section 2.12.4, indicates that the payload diameter is decreased by $^1/_{16}$". This decrease in diameter will have a net increase, although insignificant, on the k_{eff} for the homogeneous criticality model as discussed in Section 6.6.2.1. The reduced diameter has no impact on the in-homogeneous model k_{eff} since the reduction does not limit placement of the fissile lump. Also, additional array configurations are evaluated in Section 6.6.2.2.8 for the in-homogeneous models that demonstrate that the array k_{eff} is reduced as the fissile lump is moved inward.

6.3.2 Material Properties

Table 6-3 provides the materials and key dimensions used to evaluate the Century Versa-Pac Shipping Container. The density for each material used in the models is provided in Table 6-4. The default atomic number densities from the SCALE library were used for all materials and mixtures.

6.3.3 Computer Codes and Cross Section Libraries

The SCALE 4.4a code with the 44-Group Standard Cross Section Library was used to evaluate k_{eff} of the Century Versa-Pac Shipping Container under all conditions of transport. The code sequence BOMANI, NITAWL, and KENO VI (CSAS6) was used in all analyses.

The verification cases CSAS6 and KENOVI, as provided with the code for verification purposes, were executed prior to commencement of calculations and then upon completion of the final calculations. Other than time and date differences no additional differences were noted in a comparison of the different verification runs.

6.3.4 Demonstration of Maximum Reactivity

6.3.4.1 Fuel Density and Distribution

The fissile payload consisting of a maximum of 350 grams U-235 was modeled in all cases as U-Metal at an enrichment of 100 Wt%. This bounds other uranium compounds including oxides, fluorides, and nitrates. Moderation by both carbon and hydrogen, as discussed in Section 6.3.4.3, further bounds the presence of uranium containing carbon or graphite.

A fissile payload consisting of 350 grams U-235 was initially modeled as a function of the drum fill percentage ranging from 5% to 100% of the drum fill volume. The payload was also modeled as both spherical and cylindrical lumped configurations. The diameters of the spheres and cylinders were further varied to determine the effect on the fissile mass density. Also, the cylindrical heights were further varied to determine the effect on fissile mass density and interaction. The sensivity of k_{eff} with the fissile mass was further investigated at 375 and 400 grams U-235.

Polyethylene was modeled filling the voids of the fissile material with reductions in its volume fraction to consider partial moderation. The inner payload cavity, insulated package regions and exterior regions of the package were further evaluated with moderation ranging from partial to full water densities.

6.3.4.2 Heterogeneous Effects

All of the analyses of the Century Versa-Pac Shipping Container were completed using a homogeneous source material at an enrichment of 100 Wt%. The heterogenic effect noted with enriched Uranium is caused by the presence of U-238, which is not present in the model configurations. Therefore, the modeled homogeneous souce material is representative of and bounding of the proposed payload.

The material was modeled as descrete lumps as both spheres and cylinders to study in-homogeneous distribution effects of the fissile mass. The height-to-diameter ratio of the modeled cylinder was also varied. Spheres are typically more reactive than cylinders while cylinders are more interactive. The modeled conditions of the package will dictate the more reactive geometry. For instance, the modeled package carbon steel will have a more significant effect on the cylindrical geometry due to the higher degree of interaction between neibhoring cylinders. Both geometrical configurations are specifically evaluated in the criticality analysis.

6.3.4.3 Internal Moderation

6.3.4.3.1 Poly-Moderation

The fissile uranium mass was modeled with polyethylene (CH_2) moderation to bound a full range of packaging materials. The polyethylene was initially modeled at a density of 0.92 g/cc which results in a hydrogen density of 0.132 g/cc. This bounds water moderation (density of about 0.998 g/cc) with a corresponding hydrogen density of 0.112 g/cc. To bound other compounds containing more carbon and hydrogen, the polyethylene compound density is increased to 0.98 g/cc which increases the hydrogen density to 0.141 g/cc. At this increased density, the polyethylene moderation would bound paraffin ($C_{25}H_{52}$) at a density of 0.90 g/cc. Paraffin has a hydrogen density of 0.134 g/cc. Optimum poly-moderation with an increased poly-density is therefore demonstrated for the package.

With evaluation of partial poly-moderation of the fissile contents a full range of moderation is considered for the package. Since water-moderation is bounded by poly-moderation, any amount of water- or poly-moderation may be present in the package, and pre-packaging materials having a hydrogen density less than or equal to that of high density polyethylene (0.141 g/cc) do not need to be controlled for criticality purposes. Materials with a hydrogen density greater than 0.141 g/cc are not allowed.

6.3.4.3.2 Carbon-Moderation

The fissile uranium mass was modeled with polyethylene (CH_2) moderation to bound a full range of packaging materials. The polyethylene was modeled at a density of 0.98 g/cc which results in an evaluated carbon density of 0.840 g/cc.

In all instances, the carbon-moderated cases are bounded by the poly-moderated cases. For the unlimited moderation case, there is no limit imposed on pre-packaging material or carbon-containing pre-packaging materials, as the carbon-moderation case is bounded by the increased density poly-moderation case.

6.3.4.4 Interspersed Moderation

A full range of interspersed moderator (water) densities from 0.0001 to 1.00 g/cc were evaluated to determine the optimum interspersed moderator density for the packaging. Interspersed water moderation was evaluated for the thermal blanket and foam regions of the package. Water moderation was also considered in the package area that contains the vertical carbon steel stiffeners (e.g., square tubing and support angles) and further above the payload within the containment boundary. Also, interspersed water moderation was considered between packages. Due to the higher k_{eff} results for the in-homogeneous modeled configurations, additional region dependent cases are analyzed individually for the payload, payload containment insulation, inner/outer liners, top/bottom insulation, and the package exterior.

The analysis results, as further presented, show that increasing the interspersed moderation from 0.0001 g/cc in all moderator regions causes an increase in the single package multiplication factor and further causes a reduction in the multiplication factor for arrays of packages.

6.3.4.5 Package Array Configurations

Several different shipment package array configurations were evaluated to determine the most reactive arrangement. The package was evaluated using both square-pitched close-packed arrays and triangular-pitched close-packed arrays. The triangular-pitched arrays provide slightly more interaction between packages and yield the higher system k_{eff}.

The homogeneously distributed fissile mass systems, as indicated in Section 6.3.4.1, only considered the triangular-pitch close-packaged array. Square-pitched close-packed array calculations were not performed with the homogeneously distributed fissile mass since the k_{eff} results for these calculations were low and the results were significantly lower than the lumped fissile mass sytems.

However, the lumped fissile mass systems, as indicated in Section 6.3.4.2, considered both square-pitched close-packed arrays and triangular-pitched close-packed arrays. These calculations further considered the fissile mass as both spheres and cylinders. Both spheres and cylinders were considered in the array calculations due to the lower than expected differences noted in the k_{eff} results.

6.4 Single Package Evaluation

6.4.1 Configuration

The single package evaluation considered both the distributed fissile mass and a lumped fissile mass. The package geometry was considered in the distributed fissile mass calculations for the single package. Variations in the fissile mass moderator density and interspersed moderation were also considered in these calculations. A single model was constructed as previously indicated based on the HAC test results which is further bounding of the NCT configuration.

A lumped fissile mass is further evaluated without considering the package geometry since the mass could be essentially fully reflected with flooding of the package. Only variations in the fissile mass poly-moderator density were considered in these calculations since the lumped fissile mass is modeled with full boundary water reflection.

The HAC model would in general have the higher k_{eff} results when compared to a similar NCT model due to the reduced exterior package dimensions resulting from the required performance testing. However, the lumped spherical fissile mass with full boundary reflection bounds both NCT and HAC models in all cases since it is independent of the package modeled geometry. Therefore, the single package safety can be assessed with the use of a single very conservative model.

6.4.2 Results

The single package results are summarized in Table 6-5. All results are less than the conservative administrative Upper Subcritical Limit of 0.95 minus any code bias and uncertainty. Table 6-5 provides a summary of the multiplication factors for all calculations for the single package configurations. Figures 6-2 through 6-5 graphically display the results of the calculations.

The fully poly-moderated and reflected lumped spherical fissile mass provides the most reactive arrangement, Figure 6-5. However, the single package with distributed fissile mass is most reactive when the drum is filled to about 20%, Figures 6-2 and 6-4. Increasing the interspersed water moderation (within the package) density to about 1.0 g/cc maximizes the k_{eff} result (Figure 6-4) while reducing the poly-moderator density decreases the k_{eff} result (Figure 6-3).

Due to their simplicity, single package input cases are not provided in Section 6.9. However input cases can be constructed using the provided array input cases with modification of the array boundaries.

6.5 Evaluation of Package Arrays Under Normal Conditions of Transport

6.5.1 Configuration

The Normal Transport condition postulates a group of 5N Century Versa-Pac Shipping Containers (5(50)=250), optimized as discussed in Section 6.3.4. Close full water reflection is applied at the array boundary. Table 6-1 summarizes the evaluated fuel loadings and conditions for the Hypothetical Accident Conditions. Tables 6-6 through 6-9 provide summaries of the multiplication factors for all calculations for the Hypothetical Accident Condition package configuration including sensitivity studies.

A single model was constructed as previously indicated based on the HAC test results which is further bounding of the NCT configuration. The HAC model would in general have higher k_{eff} results when compared to a similar NCT model due to the more extensive damage resulting from testing. Therefore, the package array safety can be assessed with the use of a single very conservative model.

The package array evaluation considered both the distributed fissile mass and a lumped fissile mass. The package geometry was considered in the distributed fissile mass calculations for the package array evaluation. Variations in the fissile mass moderator density and interspersed moderation were also considered in these calculations.

6.5.2 Results

As discussed in Section 6.5.1, the package array safety can be assessed with the use of a single very conservative (HAC) model.The results of these bounding HAC calculations are further detailed in Section 6.6.2.

6.6 *Evaluation of Package Arrays Under Hypothetical Accident Conditions*

6.6.1 Configuration

Regulation requires that a minimum of 2N damaged packages (2(125)=250), arranged in the most reactive array, be evaluated for Hypothetical Accident Conditions (HAC). However, since a single model is used for both NCT and HAC, the more limiting NCT 5N criterion is used in the determination of the appropriate CSI. Additionally, the evaluation includes optimum interspersed moderation, optimum fissile mass moderation, and close full reflection by water at the boundaries. Also, the fissile payload contents are arranged within the package in support of the most reactive array determination.

The package bottom offers the lowest amount of carbon steel interms of amount and thicknesses and further provides the shortest distance to the boundary of the package. Therefore, the most reactive package orientation occurs when the fissile mass is oriented at the base of the package with the bottom package further inverted and the top package stacked in its normal orientation. This places the lumped fissile mass within two contiguous packages in their closest proximity. The packages are then evaluated in both square and triangular configurations with the lumped fissile mass further oriented to achieve maximum interaction between contiguous drums. Large package arrays are then constructed with duplication of the inverted and normal package arrangement. Figures 6-16 and 6-17 illustrate the package arrangement with lumped fissile mass for the triangular and square configurations, respectively. By comparison of both Figures 6-16 and 6-17 it is evident that more packages can be placed within a triangular array. Figure 6-18 illustrates the original stacked package configuration, hereafter refered to as the MOD0 array, with inverted bottom package and normally positioned top package and further shows the duplicated stack in a 4-high package array.

Figures 6-19, 6-20, and 6-21 illustrate additional array configurations (X-Z view) used in the criticality analysis. The MOD1 array as shown in Figure 6-19 is similar to the MOD0 array however only a central cluster is modeled with the remaining lumped spherical masses moved to the opposite extents of the package. The MOD2 array as shown in Figure 6-20 is similary to the MOD1 array however all lumped spherical masses are moved to the opposite extents of the package thereby eliminating the central cluster. The MOD3 array is similar to MOD1 however the spherical masses are centered on the package bottom thereby eliminating the triangular cluster of spheres. A fourth configuration MOD4 is shown in Figure 6-22. MOD4 is similar to MOD0 and MOD1 however the central clustered is moved to the lower region of the package array.

The results of the drop tests reported in Section 2 were used as a basis for determining the structural damage to the package under HAC. The overall OD and height of the package are modeled at 21.1875” and 33.625”, respectively, per the configuration, conservatisms and approximations discussed in Section 6.3. This reduction in package diameter conservatively encompasses the damage resulting from both the side and top impact tests (see Section 2).

The density for each material used in the models is provided in Table 6-4. The default atomic number densities from the SCALE library were used for all materials and mixtures. Specific package orientations are further discussed.

6.6.1.1 Homogeneous Model

Two homogeneous model configuarations are investigated. The first model is similar to the single package array model but imployes specular reflection in a triangular array to produce an infinite array of packages. For the second model, the 350 gram U-235 fissile mass is evenly distributed in the base of the package with two packages oriented with one inverted such that the fissile mass within the two stacked drums are in a closer proximity. A finite model is constructed of this double stacked arrangement with specular boundary reflection applied to generate an infinite 3D array of packages. The packages are modeled in both a square and triangular configuration. The effect of interspersed moderation and variations in the fissile mass moderation density are further investigated.

The calculation results are significantly lower than that for the in-homogeneous models as further discussed in Section 6.6.1.2. The results are further presented in Section 6.6.2.

6.6.1.2 In-Homogeneous Model

Similar to the homogeneous model discussed in Section 6.6.1.1, the 350 gram U-235 fissile mass is lumped in the base of the containment region of the package with two packages oriented with one inverted such that the fissile mass within the two stacked packages are in close proximity. A finite model is constructed of this double stacked arrangement with placement of additional packages (drums) in a similar arrangement with their lumped fissile mass further placed in a similar fashion. A finite array of packages are then configured with explicitly modeled full water boundary reflection. The packages are modeled in both a square and triangular configuration with the lumped fissile masses further oriented in their respective packages to optimize interaction between the lumped masses of adjacent packages. The effect of interspersed moderation and variations in the fissile mass poly-moderation density are further investigated.

Figures 6-16 and 6-17 display the modeled drum arrays in both the triangular and square lattice, respectively. Figure 6-18 further shows the X-Z view of the model which in this case shows the sphere placement. A cylinder, with an H/D of 1.0, would occupy the same region as the sphere allowing easy conversion of the model from either sphere to cylinder and visa-versa. The package model places the fissile lump in the bottom of the package since the package bottom recognizies the shortest distance to a neibhoring lump in an adjacent package. The bottom portion of the package also has the least amount of carbon steel as the bottom plate is ¼" and the top containment closure is ½". The bottom package is then inverted, with the lump further in the bottom, with a normally oriented package above also with the fissile lump positioned in the base of the package containment region.

The calculated results for the lumped spherical and cylindrical results are anticipated to be very close. Additional sensitivity studies will be performed for the most reactive lumped configuration within the Century Versa-Pac Shipping Containers. Further sensitivity calculations consider different cross section libraries, an increased fissile mass, further reductions in the minimum modeled carbon steel thicknesses, an increased poly-moderation density, and lumped spherical mass placement within the package.

The results are further discussed in Section 6.6.2.

6.6.2 Results

The maximum $k_{eff} + 2\sigma$ evaluated for an array of 272 packages for HAC is less than 0.94. This result is based on a fissile mass of 350 grams U-235 with poly-moderation at an increased density of 0.98 g/cc, which corresponds to a Hydrogen density of 0.141 g/cc. The arrangement models about 50% of the carbon steel of the package with those selected components modeled at their minimum values based on standard manufacturing tolerances.

The maximum result occurs with a finite arrangement of Century Versa-Pac Shipping Containers oriented in a triangular configuration with the fissile mass modeled as spheres and further oriented within the package to achieve optimum interaction. A fully poly-moderated sphere of 12.0-cm diameter produces the maximum k_{eff} result for the evaluated package array. The MOD0 and MOD1 configurations for the lumped spherical mass appear to interchangeably produce the higher k_{eff} results as dependent on the number of stacked packages. Sensitivity calculations as discussed in Section 6.6.1.2 are further provided.

Table 6-1 summarizes the evaluated fuel loadings and conditions for the most reactive Hypothetical Accident Condition model. However, Tables 6-6 through 6-9 provide summaries of the multiplication factors for all calculations for the Hypothetical Accident Condition package configuration.

6.6.2.1 Homogeneous Model

The infinite array calculations for the model discussed in Section 6.6.1.1 produced a maximum $k_{eff} + 2\sigma$ of 0.7175 with a 10% volume fill level for a homogeneously distributed 350 gram U-235 mass. Little difference is observed between packages modeled in a triangular and square lattice but the triangular lattice does yield the higher k_{eff} by a difference of 0.0016. Reductions in the poly-moderation density cause the k_{eff} to be reduced. Likewise, increasing the interspersed water moderation also causes the keff to be reduced. Table 6-6 provides a summary of the multiplication factors for all calculations for the homogneous model Hypothetical Accident Condition package configuration.

Figure 6-6 displays the results of the homogeneously distributed fissile mass calculations for the inverted bottom/top package model in both triangular and square configurations as a function of the package fill percentage. Packages with a 10% fill volume appear to produce the higher k_{eff} results for this modeled configuration. Although not shown the the figure, the normally oriented packages have lower k_{eff} results and appear to have a maximum value also corresponding to a 10% fill volume. The results of both modeled configurations appear to be consistent.

Figure 6-7 displays the calculation results for conditions with reduced poly-moderation. The array k_{eff} is reduced with reduced poly-moderation density. The array k_{eff} is also reduced with increased interspersed moderation.

The maximum $k_{eff} + 2\sigma$ for this modeled configuration is 0.7175 and results in an EALF of 3.46E-02 eV. Due to the low k_{eff} results further sensitivity studies are not performed for the homogeneous model.

A reduction in the modeled diameter of the package slightly increases k_{eff} for the homogeneously modeled system. Table 6-6 summarizes the result for the homogeneous case in which the package radius is reduced from 19.2088-cm to 19.05-cm. A reduction in the radius of 0.1588-cm (~$^1/_{16}$") results in an increase in k_{eff} for the homogeneous case of 0.0129, however the maximum k_{eff} for the homogeneous model of 0.7304 is significantly low such that additional reductions in the diameter will not challenge the USL. Thus, with a further reduction in the diameter of ~$^1/_{16}$" the k_{eff} for the homogeneously modeled system is not expected to exceed a k_{eff} of 0.75.[4]

Two input cases are provided in Section 6.9. Case Versa_HAC_INFH_10_A represents an infinite (INF) array of packages with their fissile mass content occupying the bottom 10 volume percent of the inner package (containment). The package is modeled in a hexagonal (H) lattice arrangement with full fissile mass poly-moderation (A). Case Versa_HAC_INFH2_10_A represents an infinite (INF) array of packages with their fissile mass content occupying the bottom 10 volume percent of the inner package (containment). The packages are stacked in an array with the bottom package being inverted to achieve maximum interaction with a top package in its normal orientation. The package is modeled in a hexagonal (H) lattice arrangement as the second evaluated model (2) with full fissile mass poly-moderation (A). The results of these cases are presented in Table 6-6. These input cases can be modified to produce other input cases as referenced in Table 6-6.

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[4] Section 2.12.4 indicates that the inner diameter of a VP-55 package was slightly reduced by $^1/_{16}$" after the 30-ft slap-down test.

6.6.2.2 In-Homogeneous Model

Both spheres and cylinders are evaluated in the lumped fissile mass model for the Century Versa-Pac Shipping Containers. Sphere and cylinder diameters ranging from 8-cm to 14-cm are modeled with cylinders further modeled by varying their height-to-diameter H/D ratios. Since the fissile mass is fixed at 350 grams U-235, cylinders modeled with a high H/D ratio will have a lower U-235 density when compared to cylinders with a lower H/D ratio. Thus, as the cylinder height is increased to further increase interaction between cylinders in adjacent packages the single unit reactivity is reduced with the reduction in the fissile mass density. The drums are arranged in both a triangular and square lattice. Calculations are initially performed with expansion of a 2x2x2 drum array to a final array size of 10x10x8. Drum arrays are initially modeled consisting of 8, 64, 144, 216, 384, 512, and 800 packages in the MOD0 sphere placement configuration.

The 12.0-cm diameter sphere consistently produces the higher k_{eff} results in both triangular and square arrays with the triangular arrays consistently producing the highest result. The results of the lumped spherical mass calculations indicate that the triangular configuration is more reactive than the square arrays with an optimum sphere diameter of 12.0-cm. The triangular array is more reactive with increased sphere diameters of 14.0-cm, however reducing the sphere diameter to 10.0-cm causes the square array to become slightly more reactive. The lumped cylindrical fissile mass calculations are further described below. The cylindrical mass calculations will only consider arrangement in a triangular configuration since these arrays produced the higher k_{eff} results in the spherical model calculations.

The 10.0-cm and 12.0-cm diameter cylinders consistently produce the higher k_{eff} results. The 10.0-cm diameter cylinder produces a maximum value at an H/D of 1.0 while the 12.0-cm diameter cylinder produces a maximum value at an H/D of 0.80 with the k_{eff} results differing by only 0.0005. The results of the lumped spherical mass calculations for the 12.0-cm diameter sphere produce higher k_{eff} results with a k_{eff} difference of about 0.02. Therefore, sensitivity studies as indicated in Section 6.6.1.2 will be performed with the lumped spherical mass model.

The results of these cases are summarized in Table 6-7. Table 6-8 summarizes the results of increased poly-moderation density studies. Table 6-9 provides the sensitivity studies for the lumped spherical mass models as indicated in the preceding paragraph.

A reduction in the modeled diameter of the package will have little or no effect on the more reactive in-homogeneous (lumped fissile mass) modeled system since the reduced diameter does not otherwise limit placement of the modeled spherical mass.[5]

Two input cases are provided in Section 6.9. Case Versa_HAC_FINS_12S_A7

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[5] Section 2.12.4 indicates that the inner diameter of a VP-55 package was slightly reduced by $^{1}/_{16}$” after the 30-ft slap-down test.

and Versa_HAC_FINH_12S_A7 represent finite (FIN) arrays of packages in square (S) and hexagonal lattices (H). The fissile mass is modeled as a 12-cm radius sphere in both cases (12S) with full fissile mass poly-moderation (A). The modeled array size is 800 packages (7) in an 10x10x8 array. Corresponding cases A1 through A6, as indicated in Table 6-7, can be reproduced with modification of the array parameters. Likewise, the cylindrical fissile mass models can be duplicated by changing the modeled sphere to a cylinder with further indication of the cylindrical height.

6.6.2.2.1 Expanded Array Analysis

The lumped 12.0-cm diameter spherical mass is used in an expanded array interaction analysis with sphere placement as shown in Figure 6-18 for the MOD0 configuration. Poly-moderation with a density of 0.92 g/cc is used in this analysis. The purpose of the analysis being to evaluate arrays of at least 400 packages starting with a single layer (Z=1) and continuing to a multiple stacked layer (Z=10). The object being to stack 400 packages in layers until the USL is exceeded and then reduce the number of packages in each layer and proceed with additional stacking. Stacked layers with a Z>10 were not modeled due to the decreased k_{eff} trend with the same package array size as the Z is increased from 8 to 10.

The calculation results are combined with the initial package array calculations as show in Figure 6-14. The initial results are indicated by “Trend 1” while the latter results are shown as “Trend 2”. The results of these calculations indicate that package arrays consisting of 400, each containing a lumped fissile mass, has a $k_{eff} + 2\sigma$ of 0.94.

The results of these cases are further summarized in Table 6-8. A single input case is provided in Section 6.9. Case Versa_HAC_FINH_12S_10x064, representing an 8x8x10 package array. The nomenclature is similar to that described for other array input cases, however the 10x064 designation represents a modeled array with 10 packages stacked in the Z direction with a single layer of 64 packages modeled in the X-Y direction (an 8x8 array). Other cases, as indicated in Table 6-8, can be reproduced with modification of the array parameters. Likewise, the cylindrical fissile mass models can be duplicated by changing the modeled sphere to a cylinder with further indication of the cylindrical height.

6.6.2.2.2 Increased Poly-Moderation Density

The calculations performed in Section 6.6.2.2.1 were duplicated with an increased poly-moderation density from 0.92 to 0.98 g/cc. The results, shown in Figures 6-14 and 6-15, indicate that an increase in the poly-moderation density causes a reduction in the drum array size from 400 to 300 while maintaining a $k_{eff} + 2\sigma$ of 0.94.

Increasing the evaluated poly-moderation density to 0.98 g/cc bounds other carbon-hydrogen based moderators (paraffin) with sufficient margin. The k_{eff} for cases with paraffin moderation are greater than cases with poly-moderation at a density of 0.92 g/cc however these same cases are all lower than cases with an increased poly-moderation density of 0.98 g/cc. Therefore, poly-moderation with a density of 0.98 g/cc is bounding for this analysis.[6]

Replacing the poly-moderation with graphite causes the array k_{eff}'s to decrease significantly. A single calculation for an 10x10x8 package array with the 12.0-cm diameter lumped 350 gram U-235 fissile mass moderated with graphite reported a k_{eff} of 0.1554. Therefore, the package array reactivity is dictated exclusively by the presence of hydrogen based moderation.

The results of these cases are summarized in Table 6-8. The single calculation with only graphite moderation is provided in Table 6-9. The input cases provided in Section 6.9 can be modified to duplicate the cases described in this section by changing the poly-moderation density from 0.92 to 0.98 and by further substitution of the poly-moderation input with graphite or paraffin at their respective material densities.

6.6.2.2.3 Interspersed Moderation

The initial array calculation model involving 800 drums with a 12.0-cm diameter sphere with an interspersed moderation volume fraction (VF) of 0.0001 were duplicated with the interspersed moderation values of 0.001, 0.01, 0.1, 0.5, and 1.0. The results, provided in Table 6-9, show that increasing the interspersed moderation consistently within all regions causes the array k_{eff} to be reduced. With full interspersed moderation the k_{eff} result approaches the value of a single fully reflected sphere.

Input cases can be duplicated by changing mixture 5 in the provided input cases to the desired value.

Additional interspersed moderation calculations as a function of each modeled package region are documented in Section 6.6.2.2.9.

6.6.2.2.4 Fissile Moderation Density

The initial array calculation model involving 800 drums with a fully poly-moderated (VF=1.0) 12.0-cm diameter sphere with an interspersed moderation volume fraction (VF) of 0.0001 were duplicated with reduced poly-moderation values (VF) of 0.90, 0.80, 0.70, 0.60, and 0.50. The results, provided in Table 6-9, show that decreasing the poly-moderation volume fraction causes the array k_{eff} to be reduced.

Input cases can be duplicated by changing the poly-moderation in mixture 1 in the provided input cases to the desired value.

6.6.2.2.5 Carbon Steel Reduction

The drum arrays initially modeled consisting of 8, 64, 144, 216, 384, 512, and 800 packages, as presented in Section 6.6.2.2, were duplicated by changing the Material and Volume Fraction for Carbon Steel to Water with a Volume Fraction of 0.0001. The

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[6] The Hydrogen density associated with high density polyethylene (HDPE) is 0.141 g/cc. Moderators with a Hydrogen density exceeding 0.141 g/cc are expected to produce higher k_{eff} results.

results, provided in Table 6-9, show that eliminating the minimum modeled carbon steel causes the array k_{eff} to be increased. By comparison, the analysis involving the minimum modeled carbon steel thicknesses supported an array size of 400 drums.

A reduction of the minimum fabricated carbon steel thicknesses to values below the manufacturing tolerances causes a significant impact on the results. The original analysis essentially considered approximately 50% of the carbon steel of the package. Eliminating the minimum carbon steel in the modeled configuration decreases the array size from 400 to about 216. Further reductions may be necessary when considering a cylindrical lumped fissile mass. Therefore, the minimum modeled carbon steel thicknesses are not only required for structural integrity but also needed to ensure that the USL is not exceeded.

Input cases can be duplicated by changing the volume fraction of mixture 3 in the provided input cases to 0.50.

6.6.2.2.6 Cross Section and Neutron Histories

The initial array calculation model involving 800 drums is executed again by changing the modeled cross sections from the 44-Group Standard Cross Section Library to the 238 group. The case is executed with 600 generations and 1000 neutrons per group (600,000 neutron histories). The results differ by 0.0001 with the 44-Group generating the larger value.

To determine the sensitivity to the magnitude of the neutron histories the case is again executed with the 238-group cross sections with 600 generations and the neutrons per group increased from 1000 to 2000 (1,200,000 neutron histories). Although the $k_{eff} + 2\sigma$ for the case increases by 0.0017 the result is within 2σ of the original result. For comparison, the case using the 44-group cross sections is executed with 600 generations and 2000 neutrons per group. The raw k_{eff} for this case increases by 0.0010 however with reduction in the uncertainty the final $k_{eff} + 2\sigma$ result remains the same.

The use of differenct cross sections and increasing the neutron histories did not change the final result. Therefore, the cases used in the original analysis are sufficient and properly converged. There is also no observed benefit with migration of a larger group cross section library as the 44-group produces consistent results. The results are further summarized in Table 6-9.

Input cases can be duplicated by changing the cross section input, neutron generations and neutrons per group to their desired values.

6.6.2.2.7 Increased Fissile Mass

The drum arrays initially modeled consisting of 8, 64, 144, 216, 384, 512, and 800 packages, as presented in Section 6.6.2.2, were each duplicated by increasing the fissile mass from 350 grams U-235 to 375 and 400 grams U-235. The results, provided in Table 6-9, show that increasing the fissile mass by 25 grams requires that the drum array size be reduced. The 350 gram U-235 model, as originally evaluated, could potentially support a 550 package array and remain below a $k_{eff} + 2\sigma$ of 0.94. The 375 and 400 gram

U-235 models require that the array, using the original array models, be reduced to 350 and 275 packages to remain below a $k_{eff} + 2\sigma$ of 0.94, respectively.

Increasing the fissile mass above 350 grams U-235 requires additional sensitivity analysis as it is quite possible that a larger or smaller fissile lump could become more reactive than the 12.0-cm diameter sphere as modeled in the above cases. Therefore, a fissile mass content no greater than 350 grams U-235 is recommended for the Century Versa-Pac Shipping Containers.

Input cases can be duplicated from those provided in Section 6.9 by changing the fissile constituent volume fraction of mixture 1 to correspond to the increased fissile mass.

6.6.2.2.8 Lumped Spherical Mass Placement Sensitivity

The array configuration illustrated in Figure 6-18 (MOD0) was anticipated to produce the higher k_{eff} results for the lumped spherical mass calculations due to the modeled cluster configuration of fissile mass within the array. The results of the original MOD0 calculations indicate that the USL is less than 0.94 for package arrays of 300 within high density poly-moderation. To demonstrate that the MOD0 array is more, or less, reactive, four additional array configurations are chosen as further illustrated in Figures 6-19, 6-20, 6-21, 6-22 for array configurations defined as MOD1, MOD2, MOD3, and MOD4, respectively. For reference, the results of additional calculations for the MOD0 configuration for arrays of 300 packages are shown in Table 6-10.

The MOD1 array is identical to the MOD0 array for stacked package heights ranging from 1 to 3. The arrays are further similar inthat the MOD1 array has a central clustered sphere array however the remaining spheres are positioned in the opposite ends of the packages. The MOD1 configuration places more spheres in the vicinity of the array full water boundary reflection. The results of the MOD1 calculations with high density poly-moderation are shown in Table 6-10. The MOD0 and MOD1 results interchange as to the higher k_{eff} results however the majority of the results with the exception of two are not stastically different. When compared to the MOD0 array, the MOD1 array produced stastically different and higher k_{eff} results for package array heights of 4 and 6 on the order of 4σ. The maximum observed k_{eff} differences for these package array heights were 0.0071 and 0.0072, respectively. The modeled package arrays for the 4 and 6 high stacks were 308 and 312, respectively. Since the USL of 0.94 is also exceeded for these two calculations, the maximum modeled array size for the 4 and 6 high package stacks are reduced to 272 and 288 packages, respectively. For the reduced package array size (272) the k_{eff} is less than the USL of 0.94.

The MOD2 array is similar to the MOD1 array however the central cluster of spheres as modeled in the MOD1 array are further positioned in the opposite ends of the packages. The MOD2 array eliminates the central cluster of spheres with sphere migration more toward the array bondary reflection. These calculations demonstrate which is more important, the clustering of the spheres or the presence of full water boundary reflection. The results of the MOD2 calculations with high density poly-moderation are shown in Table 6-10. In all cases, the MOD2 results are significant lower that the MOD0 and MOD1 results. All results are within the USL of 0.94 for package arrays of 300.

The MOD3 array is similar to the MOD1 array however the spheres are centered about the package base as opposed to being clustered. The results of the MOD3 calculations with high density poly-moderation are shown in Table 6-10. In all cases, the MOD3 results are significant lower that the MOD1 results. Centralization of the main cluster within the package array appears to produce the most reactive case by comparison of the MOD1 and MOD3 case results.

The maximum k_{eff} interchanges in comparison of MOD1 and MOD0 results. The MOD1 array is more reactive for the package heights of 4, 6, 7 and 8 with MOD0 being more reactive with package heights of 5 and 9 through 12. However, only the results for package heights of 10 and 12 are stastically different. All results are within the USL of 0.94 for package arrays of 272.

A final sensitivity series of calculations are performed using a variation of the MOD1 configuration with the central cluster of spheres being moved to the bottom of the array. These calculations for the MOD4 array are only performed for the configurations with package heights of 4 and 6. The MOD4 configuration is shown in Figure 6-22. The results are shown in Table 6-10. For the modeled cases, the MOD1 configuration yields the higher k_{eff} results. The MOD4 results are not stastically different from the original MOD0 calculations for the same package stack heights. All results are within the USL of 0.94 for package arrays of 300 in the MOD4 configuration.

Table 6-11 summarizes the results of the sphere sensitivity studies with the maximum k_{eff} result high-lighted for each configuration. The calculations demonstrate that arrays of 272 packages is within the USL of 0.94.

6.6.2.2.9 Interspersed Moderation with Modeled Package Region

The input cases for the MOD1 array are modified to allow different moderator volume fractions to be specified for five different package regions, including the payload region (Mixture 5), payload insulation region (Mixture 6), inner/outer liners (Mixture 8), top/bottom insulation regions (Mixture 7), and the exterior region between packages (Mixture 9). The MOD1 calculations presented in Section 6.6.2.2.9 are duplicated with modified input cases with the volume fractions of each designated moderator region of 0.001, 0.01, 0.1, 0.5 and 1.0. The results of these calculations are presented in Table 6-12. The calculations indicated that the MOD1 configurations with moderator volume fractions of 0.0001, 0.001, and 0.01 produce the higher k_{eff} results. All results are with the USL of 0.94.

It is noted that, since the k_{eff} has been shown to increase with region varied moderator volume fractions that, the larger 300-400 package arrays of the MOD0 configuration (Section 6.6.2.2.4) could have potentially exceeded the USL had the moderating regions been modeled separately. Modeling the MOD0 configuration in a similar fashion is expected to produce similar results. However, necessary reductions in the modeled array size due to the more reactive MOD1 array would also result in lower

k_{eff} results for the MOD0 array configuration. To confirm this, the arrays with package heights ranging from 1 through 5 are executed using the same modeled configuration as presented above with the MOD0 array configuration. The MOD0 configuration with package heights of 4 and 5 were less reactive than the MOD1 array for the same package height. For package heights ranging from 1 to 3 the array configurations for MOD0 and MOD1 are identical. The results are also presented in Table 6-12. The calculations indicated that the MOD0 configurations with moderator volume fractions of 0.0001, 0.001, and 0.01 also produce the higher k_{eff} results similar to the MOD1 configuration with the exception of the single package height model which has a maximum k_{eff} with full moderation within the payload (Region 5). All results are within the USL of 0.94.

It is further noted that the majority of results are statistically indeterminate such that a correlation of the modeled array (MOD0 and MOD1) to the modeled interspersed moderation with the k_{eff} result is difficult to produce. In many cases, the next highest k_{eff} result is within 0.0001 of the maximum result. A summary (essentially of Tables 6-11 and 6-12) of the maximum k_{eff} results is provided in Table 6-1.

An input case of the revised base model is provided in Section 6.9.

6.7 Fissile Material Packages for Air Transport

The Century Versa-Pac Shipping Container is not authorized for air transport.

6.8 Benchmark Evaluations

6.8.1 Benchmark Experiments and Applicability

Reference 6-1 documents 161 critical experiments modeled using the SCALE 4.4a code (KENO VI) with the 44 Group Standard Cross Section Library. Uranium compounds used in the experiments include uranyl nitrate, uranium fluoride, uranium dioxide, uranium-aluminum alloys, and uranium metal. Moderators included water, alcohol, nitric acid, hydrofluoric acid, beryllium, aluminum and silicon oxides, water, D_2O, iron, tungsten, plastics and graphite. Reflectors included aluminum, steel, concrete, water, D_2O, titanium, tungsten, lead, iron, and graphite. Enrichments ranged from 62.4 to 97.68 wt% U-235. The H/X ratio ranged from 0 to 1,837. ALCF (eV) ranged from 3.0E-02 to 9.14E+05. The fuel density ranged from 0.014 to 18.6 gU-235/cc.

The HEU experiments were selected and categorized into four distinct groups. These groupings consisted of:

Group 1: All experiments (161) used in this validation,

Group 2: Experiments (81) with ALCF $\leq 10^{-2}$ eV, data sets 1-82, and

Group 3: Experiments (56) with ALCF $> 10^{-2}$ eV and $\leq 10^{5}$ eV, data sets 83-138, and

Group 4: Experiments (24) with ALCF $> 10^{5}$ eV, data sets 139-162.

The cases evaluated for the Century Versa-Pac Shipping Container include uranium metal, water, graphite, steel, and plastic moderation/reflection. The Century Versa-Pac Shipping Container cases were evaluated at an enrichment of 100 wt% ^{235}U, and the H/X ratio ranged from 0 to 1,011. The ALCF for the Century Versa-Pac Shipping Container cases ranged from 3.00E-02 to 9.90E-02. The fuel density ranged from 0.00160 to 0.020 gU-235/cc. Although the evaluated higher enrichment falls very slightly outside the validated range, the benchmark results for Group 2 and Group 3 are directly applicable to the Century Versa-Pac Shipping Container cases.

6.8.2 Bias Determination

Details of the benchmark calculations are provided in Reference 6-1. In order to validate the SCALE 4.4a code for use with high-enriched uranium systems, it is necessary to determine if KENO predicts the multiplication factor in an accurate and precise manner throughout the range of fission energies of interest. To evaluate the accuracy of the code, the mean of each Group of experiments was compared to the mean of the experimental results. A t-test was performed for each Group to determine whether or not the average result of a KENO calculation (the mean calculated k_{eff} for each Group) is statistically the same as the experimental result (unity). Passing the t-test affirms that the KENO code predicts multiplication factors accurately for the Group being tested, without bias. Failure of the t-test indicates that the mean KENO k_{eff} is statistically different from the experimental mean, and that a bias exists in the data. Groups that failed the t-test were further evaluated for bias and uncertainty, and these parameters applied to provide an upper limit subcritical multiplication factor for the Group.

Each Group of KENO-calculated k_{eff}s are also graphed against key system parameters (Energy of the Average Lethargy Causing Fission (ALCF), Hydrogen-to-Fissile Atom Ratio (H/^{235}U), enrichment, and fissile material density (g ^{235}U/cc)) to identify trends within the data that may indicate inaccurate cross-sections or instabilities in the code. The normality of residuals is also tested using the Anderson-Darling method. The null hypothesis of a normality test is that there is no significant departure from normality. When the probability level, ρ is greater than 0.05, it fails to reject the null hypothesis and thus the assumption holds. Histogram, skewness and kurtosis plots are also provided for each group.

Jaech's[7] method for bias determination is applied, and the upper subcritical limit is calculated based upon NUREG/CR-6361.[8]

6.8.3 Benchmark Results

For the groups of interest for the Century Versa-Pac Shipping Container, the

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[7] Jaech, J., *Statistical Methods in Nuclear Material Control,* Exxon Nuclear Company, Richland, WA (1973).

[8] *Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages*, NUREG/CR-6361 (ORNL/TM-13211), (March 1997).

bounding combined bias and bias uncertainty was reported as 0.0026 (Group 3). Thus, including a conservative 5% administrative margin, the applicable upper subcritical limit for the Century Versa-Pac Shipping Container is 0.9466 for the calculated k_{eff} $+2\sigma$. For conservatism, a USL of 0.94 is further adopted.

6.9 List of Appendices

6.9.1 Selected SCALE 4.4a Input Cases

6.9.2 Reference [6-1]

6.10 References

[6-1] Montgomery, Richard D. Validation of SCALE-PC for High Enriched Uranium (HEU) Systems, MTS423, Rev. 1, 5/30/09.

Table 6-1 Summary of Results for the Most Reactive Case

Case ID	Package Array Size	Material	Modeled Configuration	Poly-Moderation Density (g/cc)	^{235}U Mass (kg)	Interspersed Moderation (water volume fraction)/ Package Region Note 1	Close Water Reflection	H/X Note 2	EALF (eV)	k_{eff}	σ	$k_{eff} + 2\sigma$	Applicable USL
VERSAPAK_HAC_FINH_12S_1x324Pf MOD0/R5	324	U-Metal, 12.0-cm Dia. Sphere	MOD0 MOD1	0.98	0.350	1.0 Region 5	Yes	636	3.63E-02	0.8988	0.0011	0.9010	0.94
VERSAPAK_HAC_FINH_12S_2x338Pc MOD0/R5	338	U-Metal, 12.0-cm Dia. Sphere	MOD0 MOD1	0.98	0.350	0.01 Region 5	Yes	636	3.83E-02	0.9189	0.0012	0.9213	0.94
VERSAPAK_HAC_FINH_12S_3x300Pb MOD0/R5	300	U-Metal, 12.0-cm Dia. Sphere	MOD0 MOD1	0.98	0.350	0.001 Region 5	Yes	636	3.83E-02	0.9347	0.0012	0.9371	0.94
VERSAPAK_HAC_FINH_12S_3x300Pc MOD0/R8	300	U-Metal, 12.0-cm Dia. Sphere	MOD0 MOD1	0.98	0.350	0.01 Region 8	Yes	636	3.84E-02	0.9345	0.0013	0.9371	0.94
VERSAPAK_HAC_FINH_12S_4x272P	272	U-Metal, 12.0-cm Dia. Sphere	MOD1	0.98	0.350	0.0001 All	Yes	636	3.84E-02	0.9378	0.0010	0.9398	0.94
VERSAPAK_HAC_FINH_12S_4x272Pb MOD1/R5	272	U-Metal, 12.0-cm Dia. Sphere	MOD1	0.98	0.350	0.001 Region 5	Yes	636	3.84E-02	0.9374	0.0012	0.9398	0.94
VERSAPAK_HAC_FINH_12S_4x272Pb MOD1/R8	272	U-Metal, 12.0-cm Dia. Sphere	MOD1	0.98	0.350	0.001 Region 8	Yes	636	3.84E-02	0.9374	0.0012	0.9398	0.94
VERSAPAK_HAC_FINH_12S_5x280P MOD1/R6	280	U-Metal, 12.0-cm Dia. Sphere	MOD1	0.98	0.350	0.001 Region 6	Yes	636	3.83E-02	0.9376	0.0012	0.9400	0.94
VERSAPAK_HAC_FINH_12S_6X288Pb MOD1/R6	288	U-Metal, 12.0-cm Dia. Sphere	MOD1	0.98	0.350	0.001 Region 6	Yes	636	3.843-02	0.9373	0.0012	0.9397	0.94
VERSAPAK_HAC_FINH_12S_7X322Pb MOD1/R6	322	U-Metal, 12.0-cm Dia. Sphere	MOD1	0.98	0.350	0.001 Region 6	Yes	636	3.83E-02	0.9361	0.0012	0.9385	0.94
VERSAPAK_HAC_FINH_12S_8X312Pb MOD1/R7	312	U-Metal, 12.0-cm Dia. Sphere	MOD1	0.98	0.350	0.001 Region 7	Yes	636	3.83E-02	0.9277	0.0013	0.9303	0.94
VERSAPAK_HAC_FINH_12S_9X324Pb MOD1/R5	324	U-Metal, 12.0-cm Dia. Sphere	MOD1	0.98	0.350	0.001 Region 5	Yes	636	3.83E-02	0.9250	0.0012	0.9274	0.94

Table 6-1 Summary of Results for the Most Reactive Case

Case ID	Package Array Size	Material	Modeled Configuration	Poly-Moderation Density (g/cc)	^{235}U Mass (kg)	Interspersed Moderation (water volume fraction)/ Package Region Note 1	Close Water Reflection	H/X Note 2	EALF (eV)	k_{eff}	σ	$k_{eff} + 2\sigma$	Applicable USL
VERSAPAK_HAC_FINH_12S_10X300Pb MOD1/R9	300	U-Metal, 12.0-cm Dia. Sphere	MOD1	0.98	0.350	0.001 Region 9	Yes	636	3.83E-02	0.9145	0.0012	0.9169	0.94
VERSAPAK_HAC_FINH_12S_12X300Pb MOD1/R5	300	U-Metal, 12.0-cm Dia. Sphere	MOD1	0.98	0.350	0.001 Region 5	Yes	636	3.83E-02	0.9039	0.0012	0.9063	0.94
VERSAPAK_HAC_FINH_12S_12X300Pb MOD1/R9	300	U-Metal, 12.0-cm Dia. Sphere	MOD1	0.98	0.350	0.001 Region 9	Yes	636	3.83E-02	0.9035	0.0014	0.9063	0.94

Notes on Table 6-1:

1. Package region refers to the modeled regions of the package containing water moderation. “All” indicates that the package regions 5, 6, 7, 8, and 9 are modeled at the indicated volume fraction. Regions not indicated are modeled at a volume fraction of 0.0001, unless otherwise specified
2. X in this case refers to U-235; since the modeled enrichment is 100 Wt%.

Table 6-2 Century Versa-Pac Shipping Container – Test Package Dimensional Changes

Location	Description	Package 10550	Package 10551	Package 10552
A-C	Inner Container Inner Diameter	+ 1/8	NC	+ 1/16
A-C	Outer Container Outer Diameter	+ 1/16	NC	- 3/16
A	Drum Height	+ 1/8	+ 1/16	- 3/16
A	Wall – In/Out	+ 1/8	- 1/16	+ 1/8
A	Inside Height	NC	NC	NC
A	Top Rim – Inside Flange	+ 1/8	+ 1/8	- 3/8
B	Drum Height	+ 1/16	NC	- 1/4
B	Top Rim – Inside Flange	+ 1/16	NC	- 1/4
B	Wall – In/Out	- 1/8	NC	+ 1/8
B-D	Inner Container Inner Diameter	+ 1/16	NC	NC
B-D	Outer Container Outer Diameter	- 1/16	+ 1/8	- 5/16
C	Drum Height	NC	NC	NC
C	Wall – In/Out	+ 3/16	+ 1/16	- 11/16
C	Inside Height	NC	+ 5/16	- 1/8
C	Top Rim – Inside Flange	- 1/16	NC	- 1/4
D	Drum Height	NC	NC	NC
D	Top Rim – Inside Flange	NC	+ 1/16	- 1/16
D	Wall – In/Out	- 1/16	+ 1/16	- 7/16
D	Inner Container	+ 7/16	- 1/8	NC

NC – Denotes No Change (Dimensional) with tested orientation

Table 6-3 Century Versa-Pac Shipping Container Dimensions and Materials

Component	Actual Dimension		Modeled Dimension		Actual Material	Modeled Material/Notes
	(in)	(cm)	(in)	(cm)		
Radial Direction						
Payload vessel Inner diameter	15.0	38.1	15.0 – 15.125	38.1 – 38.4175	Payload – Containment Boundary	The fissile material is initially modeled in a defined volume with the remaining interstitial volume completely filled with poly-moderation. In this case, the sum of the volume fractions of both fissile material and poly-moderation are equal to unity. Subsequent calculations reduce the poly-moderation volume fraction to demonstrate that the system is not over moderated (or not more reactive with partial poly-moderation). In the latter case, the mixture is then comprised of fissile material, poly-moderation, and void. Void is technically modeled within the mixture under conditions in which the summed fissile material and poly-moderation volume fractions are less than unity. Both homogeneous and in-homogeneous (lumped) fissile masses are modeled.
Payload vessel Wall thickness	0.1345 (10 ga)	0.3416	0.1211	0.3076	Carbon steel	Carbon steel modeled with reduced manufacturing tolerance
Insulation thickness	3.0	7.62	2.5	6.35	Insulation	Optimum interspersed moderator
Inner liner wall thickness	0.0598 (16 ga)	0.1518	0.0533	0.1354	Carbon steel	Carbon steel modeled with reduced manufacturing tolerance
Outer insulation, vertical and horizonal tubing and angles	1.25	3.175	1.25 NCT 0.25 HAC	3.175 NCT 0.6356 HAC	Carbon Steel & Insulation	Optimum interspersed moderator. Carbon steel tubing and angles are neglected for conservatism.
Outer liner wall thickness	0.0598 (16 ga)	0.1518	0.0533	0.1354	Carbon steel	Carbon steel modeled with reduced manufacturing tolerance
Drum wall thickness	0.0598 (16 ga)	0.1518	0.0533	0.1354	Carbon steel	Carbon steel modeled with reduced manufacturing tolerance
Drum outer radius	11.531 [Note 1]	29.2887	11.250 NCT [Note 2] 10.593 HAC	28.575 NCT 26.908 HAC	N/A	The outer radius of the 55 gallon package is 23". Neglicting the drum stiffeners and bolt ring reduces the outer diameter to 22-1/2". For the bounding HAC/NCT model, the 55-gallon drum is further modeled with a reduced outer diameter of 1.313" which significantly bounds the maximum reduced dimension resulting from the tests of 0.313" (5/16") as indicated in Section 2. The outer radius of the 55 gallon package HAC model is then 21.1875".
Axial Direction From Bottom of Package						
Drum bottom thickness	0.0598 (16 ga)	0.1518	0.0533	0.1354	Carbon steel	Carbon steel modeled with reduced manufacturing tolerance
Bottom reinforcing plate	0.25	0.635	0.24	0.6096	Carbon steel	Carbon steel modeled with reduced manufacturing tolerance

Bottom insulation layer thickness	2.5	6.35	2.5	6.35	Insulation	Optimum interspersed moderator
Payload vessel Bottom wall thickness	0.1345 (10 ga)	0.3416	0.1211	0.3076	Carbon steel	Carbon steel modeled with reduced manufacturing tolerance
Payload vessel Inner height	27.0625	68.7387	27.0625 – 27.1875	68.7387 – 69.0562	Payload – Containment Boundary	Fissile material, same as payload vessel inner diameter.
Payload vessel Closure lid wall thickness	0.50	1.27	0.49	1.2446	Carbon steel	Carbon steel modeled with reduced manufacturing tolerance
Lid-to-plug gap	0.9065	2.3025	0.4265	1.0833	Gasket, Carbon steel bolts, Air	Clearance for gasket and inner fasteners. Modeled as optimum interspersed moderator
Inner plug liner	0.0598 (16 ga)	0.1518	0.0533	0.1354	Carbon steel	Carbon steel modeled with reduced manufacturing tolerance
Top insulation layer thickness	2.5	6.35	2.5	6.35	Insulation	Optimum interspersed moderator
Drum lid	0.0598 (16 ga)	0.1518	0.0533	0.1354	Carbon steel	Carbon steel modeled with reduced manufacturing tolerance
Drum outer height	34.5 Note 3	87.63	34.0 NCT Note 4 33.625 HAC	86.36 NCT 85.4075 HAC	N/A	The outer height of the 55 gallon package is 34-1/2”. Neglicting the drum bottom chime reduces the outer height to 34”. For the bounding HAC model, the 55-gallon drum is modeled with a reduced outer height of 0.875” which bounds the maximum reduced dimension resulting from the tests of 0.250” (1/4”) as indicated in Section 2. The outer height of the 55 gallon package HAC model is then 33.625”.

Notes on Table 6-3:

1. Dimension includes the drum ring stiffeners, lid, chime, and lock ring.
2. Dimension does not include the drum ring stiffeners, lid, chime, or lock ring.
3. Dimension includes the drum bottom chime.
4. Dimension does not include the drum bottom chime.

Table 6-4 Package and Material Regional Densities

Material	Maximum Material Density (g/cc) at 21°C	Material Hydrogen Density (g/cc)
UO_2	10.96	N/A
U-metal	19.05	N/A
UNX at 1,274 gU/L	2.705	N/A
H_2O	0.9982	0.1117
Carbon Steel (CS)	7.8212	N/A
Polyethylene (LDPE) – CH_2	0.92	0.1323
Polyethylene (HDPE) – CH_2	0.98	0.1409
Pariffin – $C_{25}H_{52}$	0.90	0.1338
Carbon (graphite)	2.300	N/A

Table 6-5 Summary of Single Package Results

Case ID	Drum Fill Percent	Poly-Moderation	^{235}U Mass (kg)	Interspersed Moderation (water volume fraction)	Close Water Reflection	k_{eff}	σ	$k_{eff} + 2\sigma$	EALF (eV)	Comments
Homogeneous Fissile Material as a Function of Drum Fill Percentage										
VERSAPAK_HAC_SIN_5_A	5	100	0.350	0.0001	Yes	0.1546	0.0006	0.1558	4.87E-02	
VERSAPAK_HAC_SIN_10_A	10	100	0.350	0.0001	Yes	0.3155	0.0007	0.3169	3.45E-02	
VERSAPAK_HAC_SIN_15_A	15	100	0.350	0.0001	Yes	0.3950	0.0006	0.3962	3.11E-02	
VERSAPAK_HAC_SIN_20_A Note 1	20	100	0.350	0.0001	Yes	0.4193	0.0006	0.4205	2.97E-02	
VERSAPAK_HAC_SIN_30_A	30	100	0.350	0.0001	Yes	0.3993	0.0007	0.4007	2.84E-02	
VERSAPAK_HAC_SIN_40_A	40	100	0.350	0.0001	Yes	0.3591	0.0005	0.3601	2.79E-02	
VERSAPAK_HAC_SIN_60_A	60	100	0.350	0.0001	Yes	0.2849	0.0003	0.2855	2.74E-02	
VERSAPAK_HAC_SIN_80_A	80	100	0.350	0.0001	Yes	0.2318	0.0002	0.2322	2.71E-02	
VERSAPAK_HAC_SIN_100_A	100	100	0.350	0.0001	Yes	0.1946	0.0002	0.1950	2.70E-02	
Homogeneous Fissile Material as a Function of Poly-Moderation Density										
VERSAPAK_HAC_SIN_20_A Note 1	20	100	0.350	0.0001	Yes	0.4193	0.0006	0.4205	2.97E-02	**k_{eff} decreases with reduced poly-moderation density**
VERSAPAK_HAC_SIN_20_B	20	90	0.350	0.0001	Yes	0.4003	0.0007	0.4017	3.02E-02	
VERSAPAK_HAC_SIN_20_C	20	80	0.350	0.0001	Yes	0.3741	0.0007	0.3755	3.09E-02	
VERSAPAK_HAC_SIN_20_D	20	70	0.350	0.0001	Yes	0.3385	0.0006	0.3397	3.19E-02	
VERSAPAK_HAC_SIN_20_E	20	60	0.350	0.0001	Yes	0.2936	0.0006	0.2948	3.33E-02	
VERSAPAK_HAC_SIN_20_F	20	50	0.350	0.0001	Yes	0.2397	0.0006	0.2409	3.54E-02	
Homogeneous Fissile Material as a Function of Interspersed-Moderator Density										
VERSAPAK_HAC_SIN_20_A Note 1	20	100	0.350	0.0001	Yes	0.4193	0.0006	0.4205	2.97E-02	**k_{eff} increases with increased interspersed moderation density**
VERSAPAK_HAC_SIN_20_Aa	20	100	0.350	0.001	Yes	0.4195	0.0006	0.4207	2.97E-02	
VERSAPAK_HAC_SIN_20_Ab	20	100	0.350	0.01	Yes	0.4215	0.0006	0.4227	2.96E-02	
VERSAPAK_HAC_SIN_20_Ac	20	100	0.350	0.1	Yes	0.4335	0.0006	0.4347	2.95E-02	
VERSAPAK_HAC_SIN_20_Ad	20	100	0.350	0.5	Yes	0.4708	0.0007	0.4722	2.91E-02	
VERSAPAK_HAC_SIN_20_Ae	20	100	0.350	1.0	Yes	0.4839	0.0006	0.4851	2.90E-02	**Maximum Homogeneous Result**

Case ID	Sphere Radius, cm	Poly-Moderation	^{235}U Mass (kg)	Interspersed Moderation (water volume fraction)	Close Water Reflection	k_{eff}	σ	$k_{eff} + 2\sigma$	EALF (eV)	Comments
Single Lumped Fissile Mass										
VERSAPAK_HAC_SIN_6S_A	6	100	0.350	0.0001	Yes	0.6471	0.0012	0.6495	1.45E-01	
VERSAPAK_HAC_SIN_8S_A	8	100	0.350	0.0001	Yes	0.7927	0.0012	0.7951	6.55E-02	
VERSAPAK_HAC_SIN_10S_A	10	100	0.350	0.0001	Yes	0.8683	0.0012	0.8707	4.47E-02	
VERSAPAK_HAC_SIN_12S_A $^{\text{Note 2}}$	12	100	0.350	0.0001	Yes	0.8814	0.0012	0.8838	3.66E-02	**Maximum Lumped Result**
VERSAPAK_HAC_SIN_14S_A	14	100	0.350	0.0001	Yes	0.8429	0.0011	0.8451	3.27E-02	
Single Lumped Fissile Mass as a Function of Poly-Moderation Density										
VERSAPAK_HAC_SIN_12S_A $^{\text{Note 2}}$	12	100	0.350	0.0001	Yes	0.8814	0.0012	0.8838	3.66E-02	**k_{eff} decreases with reduced poly-moderation density**
VERSAPAK_HAC_SIN_12S_B	12	90	0.350	0.0001	Yes	0.8431	0.0012	0.8455	3.77E-02	
VERSAPAK_HAC_SIN_12S_C	12	80	0.350	0.0001	Yes	0.7952	0.0011	0.7974	3.90E-02	
VERSAPAK_HAC_SIN_12S_D	12	70	0.350	0.0001	Yes	0.7411	0.0011	0.7433	4.07E-02	
VERSAPAK_HAC_SIN_12S_E	12	60	0.350	0.0001	Yes	0.6800	0.0012	0.6824	4.27E-02	

Notes on Table 6-5:

1. Duplicate entry for observance of trend.
2. Duplicate entry for observance of trend.

Table 6-6 Summary of Hypothetical Accident Condition Package Results for Homogeneous Models

Case ID	Drum Fill Percent	Poly-Moderation	^{235}U Mass (kg)	Interspersed Moderation (water volume fraction)	Close Water Reflection	k_{eff}	σ	k_{eff} + 2σ	EALF (eV)	Comments
Infinite Triangular Package Array - Homogeneous Fissile Material as a Function of Drum Fill Percentage – Bottom Filled Package Model										
VERSAPAK_HAC_INFH_5_A	5	100	0.350	0.0001	Yes	0.6807	0.0008	0.6823	4.77E-02	
VERSAPAK_HAC_INFH_10_A Note 1	10	100	0.350	0.0001	Yes	0.7158	0.0006	0.7170	3.46E-02	
VERSAPAK_HAC_INFH_15_A	15	100	0.350	0.0001	Yes	0.6673	0.0005	0.6683	3.14E-02	
VERSAPAK_HAC_INFH_20_A	20	100	0.350	0.0001	Yes	0.6104	0.0005	0.6114	3.00E-02	
Infinite Triangular Package Array - Homogeneous Fissile Material as a Function of Poly-Moderation Density – Bottom Filled Package Model										
VERSAPAK_HAC_INFH_10_A Note 1	10	100	0.350	0.0001	Yes	0.7158	0.0006	0.7170	3.46E-02	**k_{eff} decreases with reduced poly-moderation density**
VERSAPAK_HAC_INFH_10_B	10	90	0.350	0.0001	Yes	0.7149	0.0006	0.7161	3.58E-02	
VERSAPAK_HAC_INFH_10_C	10	80	0.350	0.0001	Yes	0.7082	0.0006	0.7094	3.76E-02	
Infinite Triangular Package Array - Homogeneous Fissile Material as a Function of Interspersed Moderator Density – Bottom Filled Package Model										
VERSAPAK_HAC_INFH_10_Aa	10	100	0.350	0.001	Yes	0.7083	0.0006	0.7095	3.45E-02	**k_{eff} decreases with increased interspersed moderator density**
VERSAPAK_HAC_INFH_10_Ba	10	90	0.350	0.001	Yes	0.7063	0.0006	0.7075	3.58E-02	
VERSAPAK_HAC_INFH_10_Ca	10	80	0.350	0.001	Yes	0.7002	0.0007	0.7016	3.75E-02	
VERSAPAK_HAC_INFH_10_Ab	10	100	0.350	0.01	Yes	0.6420	0.0006	0.6432	3.42E-02	
VERSAPAK_HAC_INFH_10_Bb	10	90	0.350	0.01	Yes	0.6347	0.0006	0.6359	3.54E-02	
VERSAPAK_HAC_INFH_10_Cb	10	80	0.350	0.01	Yes	0.6209	0.0007	0.6223	3.70E-02	
VERSAPAK_HAC_INFH_10_Ac	10	100	0.350	0.1	Yes	0.4959	0.0007	0.4973	3.30E-02	
VERSAPAK_HAC_INFH_10_Bc	10	90	0.350	0.1	Yes	0.4780	0.0007	0.4794	3.39E-02	
VERSAPAK_HAC_INFH_10_Cc	10	80	0.350	0.1	Yes	0.4551	0.0007	0.4565	3.49E-02	
Infinite Triangular Package Array - Homogeneous Fissile Material as a Function of Drum Fill Percentage – Bottom Filled Inverted Bottom Package Model										
VERSAPAK_HAC_INFH2_5_A	5	100	0.350	0.0001	Yes	0.6817	0.0007	0.6831	4.77E-02	**Bottom filled inverted model (H2) is more reactive than previous bottom filled (H) model**
VERSAPAK_HAC_INFH2_5_B	5	90	0.350	0.0001	Yes	0.6625	0.0006	0.6637	5.15E-02	
VERSAPAK_HAC_INFH2_5_C	5	80	0.350	0.0001	Yes	0.6374	0.0006	0.6386	5.70E-02	
VERSAPAK_HAC_INFH2_5_D	5	70	0.350	0.0001	Yes	0.608	0.0007	0.6094	6.50E-02	
VERSAPAK_HAC_INFH2_5_E	5	60	0.350	0.0001	Yes	0.5727	0.0006	0.5739	7.74E-02	
VERSAPAK_HAC_INFH2_5_F	5	50	0.350	0.0001	Yes	0.5317	0.0006	0.5329	9.90E-02	
VERSAPAK_HAC_INFH2_10_A	10	100	0.350	0.0001	Yes	0.7161	0.0007	0.7175	3.46E-02	

VERSAPAK_HAC_INFH2_10_B	10	90	0.350	0.0001	Yes	0.7141	0.0006	0.7153	3.58E-02	**k_{eff} decreases with reduced poly-moderation density**
VERSAPAK_HAC_INFH2_10_C	10	80	0.350	0.0001	Yes	0.7082	0.0006	0.7094	3.76E-02	
VERSAPAK_HAC_INFH2_10_D	10	70	0.350	0.0001	Yes	0.697	0.0007	0.6984	3.99E-02	
VERSAPAK_HAC_INFH2_10_E	10	60	0.350	0.0001	Yes	0.6769	0.0007	0.6783	4.34E-02	
VERSAPAK_HAC_INFH2_10_F	10	50	0.350	0.0001	Yes	0.6465	0.0007	0.6479	4.91E-02	
VERSAPAK_HAC_INFH2_15_A	15	100	0.350	0.0001	Yes	0.6664	0.0006	0.6676	3.15E-02	
VERSAPAK_HAC_INFH2_15_B	15	90	0.350	0.0001	Yes	0.6773	0.0005	0.6783	3.22E-02	
VERSAPAK_HAC_INFH2_15_C	15	80	0.350	0.0001	Yes	0.6829	0.0006	0.6841	3.32E-02	
VERSAPAK_HAC_INFH2_15_D	15	70	0.350	0.0001	Yes	0.6874	0.0006	0.6886	3.45E-02	
VERSAPAK_HAC_INFH2_15_E	15	60	0.350	0.0001	Yes	0.6824	0.0006	0.6836	3.65E-02	
VERSAPAK_HAC_INFH2_15_F	15	50	0.350	0.0001	Yes	0.6707	0.0006	0.6719	3.94E-02	
VERSAPAK_HAC_INFH2_20_A	20	100	0.350	0.0001	Yes	0.6089	0.0005	0.6099	3.00E-02	
Infinite Triangular Package Array - Homogeneous Fissile Material as a Function of Poly-Moderation Density – Bottom Filled Inverted Bottom Package Model										
VERSAPAK_HAC_INFH2_10_Aa	10	100	0.350	0.001	Yes	0.7090	0.0006	0.7102	3.45E-02	**k_{eff} decreases with reduced poly-moderation density and with increased interspersed moderator density**
VERSAPAK_HAC_INFH2_10_Ba	10	90	0.350	0.001	Yes	0.7060	0.0006	0.7072	3.58E-02	
VERSAPAK_HAC_INFH2_10_Ca	10	80	0.350	0.001	Yes	0.6990	0.0006	0.7002	3.75E-02	
VERSAPAK_HAC_INFH2_10_Ab	10	100	0.350	0.01	Yes	0.6431	0.0007	0.6445	3.42E-02	
VERSAPAK_HAC_INFH2_10_Bb	10	90	0.350	0.01	Yes	0.6325	0.0007	0.6339	3.54E-02	
VERSAPAK_HAC_INFH2_10_Cb	10	80	0.350	0.01	Yes	0.6197	0.0007	0.6211	3.70E-02	
VERSAPAK_HAC_INFH2_10_Ac	10	100	0.350	0.1	Yes	0.4956	0.0008	0.4972	3.30E-02	
VERSAPAK_HAC_INFH2_10_Bc	10	90	0.350	0.1	Yes	0.4762	0.0007	0.4776	3.39E-02	
VERSAPAK_HAC_INFH2_10_Cc	10	80	0.350	0.1	Yes	0.4530	0.0007	0.4544	3.50E-02	
Infinite Square Package Array - Homogeneous Fissile Material as a Function of Drum Fill Percentage – Bottom Filled Inverted Bottom Package Model										
VERSAPAK_HAC_INFS2_5_A	5	100	0.350	0.0001	Yes	0.6800	0.0007	0.6814	4.77E-02	**k_{eff} decreases for square array**
VERSAPAK_HAC_INFS2_10_A	10	100	0.350	0.0001	Yes	0.7145	0.0007	0.7159	3.46E-02	
VERSAPAK_HAC_INFS2_15_A	15	100	0.350	0.0001	Yes	0.6663	0.0005	0.6673	3.14E-02	
VERSAPAK_HAC_INFS2_20_A	20	100	0.350	0.0001	Yes	0.6082	0.0005	0.6092	3.01E-02	
VERSAPAK_HAC_INFS2_30_A	30	100	0.350	0.0001	Yes	0.5063	0.0004	0.5071	2.88E-02	
Infinite Triangular Package Array - Homogeneous Fissile Material as a Function of Drum Fill Percentage – Bottom Filled Inverted Bottom Package Model – Reduced Containment Cavity Radius										
VERSAPAK_HAC_INFH2_10M_A	10	100	0.350	0.0001	Yes	0.7292	0.0006	0.7304	3.46E-02	**Containment radius reduced from 19.2088 to 19.05-cm**

Notes on Table 6-6:

1. Duplicate entry for observance of trend.

Table 6-7 Summary of Hypothetical Accident Condition Package Results for Lumped Fissile Mass Models

Case ID	Radius (cm) of Sphere or Cylinder (H/D)	Modeled Package Array	Poly-Moderation	^{235}U Mass (kg)	Interspersed Moderation (water volume fraction)	Close Water Reflection	k_{eff}	σ	k_{eff} + 2σ	EALF (eV)	Comments
Triangular Package Arrays – Lumped Spherical Fissile Mass – Initial Array Sensitivity Study											
VERSAPAK_HAC_FINH_8S_A1	8	2x2x2=8	100	0.350	0.0001	Yes	0.5932	0.0013	0.5958	8.89E-02	
VERSAPAK_HAC_FINH_8S_A2	8	4x4x4=64	100	0.350	0.0001	Yes	0.6311	0.0013	0.6337	8.84E-02	
VERSAPAK_HAC_FINH_8S_A3	8	6x6x4=144	100	0.350	0.0001	Yes	0.6672	0.0014	0.6700	8.82E-02	
VERSAPAK_HAC_FINH_8S_A4	8	6x6x6=216	100	0.350	0.0001	Yes	0.6827	0.0014	0.6855	8.79E-02	
VERSAPAK_HAC_FINH_8S_A5	8	8x8x6=384	100	0.350	0.0001	Yes	0.7182	0.0014	0.7210	8.79E-02	
VERSAPAK_HAC_FINH_8S_A6	8	8x8x8=512	100	0.350	0.0001	Yes	0.7282	0.0013	0.7308	8.76E-02	
VERSAPAK_HAC_FINH_8S_A7	8	10x10x8=800	100	0.350	0.0001	Yes	0.7695	0.0014	0.7723	8.74E-02	
VERSAPAK_HAC_FINH_10S_A1	10	2x2x2=8	100	0.350	0.0001	Yes	0.7381	0.0014	0.7409	5.11E-02	
VERSAPAK_HAC_FINH_10S_A2	10	4x4x4=64	100	0.350	0.0001	Yes	0.7804	0.0012	0.7828	5.11E-02	
VERSAPAK_HAC_FINH_10S_A3	10	6x6x4=144	100	0.350	0.0001	Yes	0.8214	0.0012	0.8238	5.10E-02	
VERSAPAK_HAC_FINH_10S_A4	10	6x6x6=216	100	0.350	0.0001	Yes	0.8346	0.0011	0.8368	5.12E-02	
VERSAPAK_HAC_FINH_10S_A5	10	8x8x6=384	100	0.350	0.0001	Yes	0.8712	0.0015	0.8742	5.11E-02	
VERSAPAK_HAC_FINH_10S_A6	10	8x8x8=512	100	0.350	0.0001	Yes	0.8841	0.0014	0.8869	5.10E-02	
VERSAPAK_HAC_FINH_10S_A7	10	10x10x8=800	100	0.350	0.0001	Yes	0.9210	0.0013	0.9236	5.11E-02	
VERSAPAK_HAC_FINH_12S_A1	12	2x2x2=8	100	0.350	0.0001	Yes	0.7973	0.0011	0.7995	3.92E-02	
VERSAPAK_HAC_FINH_12S_A2	12	4x4x4=64	100	0.350	0.0001	Yes	0.8403	0.0012	0.8427	3.93E-02	
VERSAPAK_HAC_FINH_12S_A3	12	6x6x4=144	100	0.350	0.0001	Yes	0.8791	0.0012	0.8815	3.94E-02	
VERSAPAK_HAC_FINH_12S_A4	12	6x6x6=216	100	0.350	0.0001	Yes	0.8889	0.0013	0.8915	3.94E-02	
VERSAPAK_HAC_FINH_12S_A5	12	8x8x6=384	100	0.350	0.0001	Yes	0.9220	0.0011	0.9242	3.94E-02	
VERSAPAK_HAC_FINH_12S_A6	12	8x8x8=512	100	0.350	0.0001	Yes	0.9341	0.0012	0.9365	3.94E-02	
VERSAPAK_HAC_FINH_12S_A7	12	10x10x8=800	100	0.350	0.0001	Yes	0.9623	0.0013	0.9649	3.95E-02	
VERSAPAK_HAC_FINH_14S_A1	14	2x2x2=8	100	0.350	0.0001	Yes	0.7929	0.0010	0.7949	3.41E-02	
VERSAPAK_HAC_FINH_14S_A2	14	4x4x4=64	100	0.350	0.0001	Yes	0.8359	0.0010	0.8379	3.41E-02	
VERSAPAK_HAC_FINH_14S_A3	14	6x6x4=144	100	0.350	0.0001	Yes	0.8662	0.0011	0.8684	3.42E-02	
VERSAPAK_HAC_FINH_14S_A4	14	6x6x6=216	100	0.350	0.0001	Yes	0.8762	0.0010	0.8782	3.42E-02	
VERSAPAK_HAC_FINH_14S_A5	14	8x8x6=384	100	0.350	0.0001	Yes	0.9037	0.0011	0.9059	3.43E-02	

VERSAPAK_HAC_FINH_14S_A6	14	8x8x8=512	100	0.350	0.0001	Yes	0.9084	0.0010	0.9104	3.43E-02	
VERSAPAK_HAC_FINH_14S_A7	14	10x10x8=800	100	0.350	0.0001	Yes	0.9314	0.0010	0.9334	3.43E-02	
Square Package Arrays – Lumped Spherical Fissile Mass – Initial Array Sensitivity Study											
VERSAPAK_HAC_FINS_10S_A1	10	2x2x2=8	100	0.350	0.0001	Yes	0.7348	0.0012	0.7372	5.11E-02	
VERSAPAK_HAC_FINS_10S_A2	10	4x4x4=64	100	0.350	0.0001	Yes	0.7780	0.0012	0.7804	5.12E-02	
VERSAPAK_HAC_FINS_10S_A3	10	6x6x4=144	100	0.350	0.0001	Yes	0.8118	0.0012	0.8142	5.12E-02	
VERSAPAK_HAC_FINS_10S_A4	10	6x6x6=216	100	0.350	0.0001	Yes	0.8241	0.0012	0.8265	5.11E-02	
VERSAPAK_HAC_FINS_10S_A5	10	8x8x6=384	100	0.350	0.0001	Yes	0.8583	0.0014	0.8611	5.12E-02	
VERSAPAK_HAC_FINS_10S_A6	10	8x8x8=512	100	0.350	0.0001	Yes	0.8706	0.0014	0.8734	5.13E-02	
VERSAPAK_HAC_FINS_10S_A7	10	10x10x8=800	100	0.350	0.0001	Yes	0.9056	0.0014	0.9084	5.11E-02	
VERSAPAK_HAC_FINS_12S_A1	12	2x2x2=8	100	0.350	0.0001	Yes	0.7923	0.0012	0.7947	3.92E-02	
VERSAPAK_HAC_FINS_12S_A2	12	4x4x4=64	100	0.350	0.0001	Yes	0.8381	0.0014	0.8409	3.93E-02	
VERSAPAK_HAC_FINS_12S_A3	12	6x6x4=144	100	0.350	0.0001	Yes	0.8720	0.0011	0.8742	3.93E-02	
VERSAPAK_HAC_FINS_12S_A4	12	6x6x6=216	100	0.350	0.0001	Yes	0.8814	0.0012	0.8838	3.93E-02	
VERSAPAK_HAC_FINS_12S_A5	12	8x8x6=384	100	0.350	0.0001	Yes	0.9154	0.0012	0.9178	3.94E-02	
VERSAPAK_HAC_FINS_12S_A6	12	8x8x8=512	100	0.350	0.0001	Yes	0.9219	0.0012	0.9243	3.94E-02	
VERSAPAK_HAC_FINS_12S_A7	12	10x10x8=800	100	0.350	0.0001	Yes	0.9505	0.0012	0.9529	3.95E-02	
VERSAPAK_HAC_FINS_14S_A1	14	2x2x2=8	100	0.350	0.0001	Yes	0.7926	0.0010	0.7946	3.41E-02	
VERSAPAK_HAC_FINS_14S_A2	14	4x4x4=64	100	0.350	0.0001	Yes	0.8331	0.0011	0.8353	3.42E-02	
VERSAPAK_HAC_FINS_14S_A3	14	6x6x4=144	100	0.350	0.0001	Yes	0.8573	0.0010	0.8593	3.42E-02	
VERSAPAK_HAC_FINS_14S_A4	14	6x6x6=216	100	0.350	0.0001	Yes	0.8713	0.0010	0.8733	3.42E-02	
VERSAPAK_HAC_FINS_14S_A5	14	8x8x6=384	100	0.350	0.0001	Yes	0.8962	0.0010	0.8982	3.43E-02	
VERSAPAK_HAC_FINS_14S_A6	14	8x8x8=512	100	0.350	0.0001	Yes	0.9047	0.0010	0.9067	3.43E-02	
VERSAPAK_HAC_FINS_14S_A7	14	10x10x8=800	100	0.350	0.0001	Yes	0.9236	0.0010	0.9256	3.43E-02	
Triangular Package Arrays – Lumped Cylindrical Fissile Mass – Initial Array Sensitivity Study											
VERSAPAK_HAC_FINH_8C_A1	8 (1.0)	2x2x2=8	100	0.350	0.0001	Yes	0.6623	0.0012	0.6647	6.18E-02	
VERSAPAK_HAC_FINH_8C_A2	8 (1.0)	4x4x4=64	100	0.350	0.0001	Yes	0.7005	0.0012	0.7029	6.18E-02	
VERSAPAK_HAC_FINH_8C_A3	8 (1.0)	6x6x4=144	100	0.350	0.0001	Yes	0.7433	0.0014	0.7461	6.20E-02	
VERSAPAK_HAC_FINH_8C_A4	8 (1.0)	6x6x6=216	100	0.350	0.0001	Yes	0.7562	0.0013	0.7588	6.18E-02	
VERSAPAK_HAC_FINH_8C_A5	8 (1.0)	8x8x6=384	100	0.350	0.0001	Yes	0.7955	0.0013	0.7981	6.19E-02	
VERSAPAK_HAC_FINH_8C_A6	8 (1.0)	8x8x8=512	100	0.350	0.0001	Yes	0.8075	0.0013	0.8101	6.17E-02	
VERSAPAK_HAC_FINH_8C_A7	8 (1.0)	10x10x8=800	100	0.350	0.0001	Yes	0.8462	0.0013	0.8488	6.19E-02	
VERSAPAK_HAC_FINH_10C_A1	10 (1.0)	2x2x2=8	100	0.350	0.0001	Yes	0.7741	0.0011	0.7763	4.17E-02	
VERSAPAK_HAC_FINH_10C_A2	10 (1.0)	4x4x4=64	100	0.350	0.0001	Yes	0.8179	0.0013	0.8205	4.18E-02	
VERSAPAK_HAC_FINH_10C_A3	10 (1.0)	6x6x4=144	100	0.350	0.0001	Yes	0.8546	0.0013	0.8572	4.19E-02	
VERSAPAK_HAC_FINH_10C_A4	10 (1.0)	6x6x6=216	100	0.350	0.0001	Yes	0.8657	0.0012	0.8681	4.19E-02	

VERSAPAK_HAC_FINH_10C_A5	10 (1.0)	8x8x6=384	100	0.350	0.0001	Yes	0.9033	0.0012	0.9057	4.19E-02	
VERSAPAK_HAC_FINH_10C_A6	10 (1.0)	8x8x8=512	100	0.350	0.0001	Yes	0.9126	0.0013	0.9152	4.20E-02	
VERSAPAK_HAC_FINH_10C_A7	10 (1.0)	10x10x8=800	100	0.350	0.0001	Yes	0.9427	0.0014	0.9455	4.21E-02	
VERSAPAK_HAC_FINH_12C_A1	12 (1.0)	2x2x2=8	100	0.350	0.0001	Yes	0.7854	0.0010	0.7874	3.47E-02	
VERSAPAK_HAC_FINH_12C_A2	12 (1.0)	4x4x4=64	100	0.350	0.0001	Yes	0.8248	0.0011	0.8270	3.48E-02	
VERSAPAK_HAC_FINH_12C_A3	12 (1.0)	6x6x4=144	100	0.350	0.0001	Yes	0.8592	0.0010	0.8612	3.49E-02	
VERSAPAK_HAC_FINH_12C_A4	12 (1.0)	6x6x6=216	100	0.350	0.0001	Yes	0.8674	0.0011	0.8696	3.49E-02	
VERSAPAK_HAC_FINH_12C_A5	12 (1.0)	8x8x6=384	100	0.350	0.0001	Yes	0.8958	0.0010	0.8978	3.49E-02	
VERSAPAK_HAC_FINH_12C_A6	12 (1.0)	8x8x8=512	100	0.350	0.0001	Yes	0.9000	0.0010	0.9020	3.50E-02	
VERSAPAK_HAC_FINH_12C_A7	12 (1.0)	10x10x8=800	100	0.350	0.0001	Yes	0.9227	0.0010	0.9247	3.50E-02	
VERSAPAK_HAC_FINH_14C_A1	14 (1.0)	2x2x2=8	100	0.350	0.0001	Yes	0.7377	0.0009	0.7395	3.15E-02	
VERSAPAK_HAC_FINH_14C_A2	14 (1.0)	4x4x4=64	100	0.350	0.0001	Yes	0.7737	0.0011	0.7759	3.16E-02	
VERSAPAK_HAC_FINH_14C_A3	14 (1.0)	6x6x4=144	100	0.350	0.0001	Yes	0.7985	0.0009	0.8003	3.17E-02	
VERSAPAK_HAC_FINH_14C_A4	14 (1.0)	6x6x6=216	100	0.350	0.0001	Yes	0.8057	0.0008	0.8073	3.17E-02	
VERSAPAK_HAC_FINH_14C_A5	14 (1.0)	8x8x6=384	100	0.350	0.0001	Yes	0.8247	0.0009	0.8265	3.17E-02	
VERSAPAK_HAC_FINH_14C_A6	14 (1.0)	8x8x8=512	100	0.350	0.0001	Yes	0.8296	0.0008	0.8312	3.17E-02	
VERSAPAK_HAC_FINH_14C_A7	14 (1.0)	10x10x8=800	100	0.350	0.0001	Yes	0.8436	0.0009	0.8454	3.17E-02	
Triangular Package Arrays – Lumped Cylindrical Fissile Mass – Initial Array Sensitivity Study – 10.0" Cylinder Height-to-Diameter Sensitivity											
VERSAPAK_HAC_FINH_10C12_A1	10 (1.2)	2x2x2=8	100	0.350	0.0001	Yes	0.7777	0.0013	0.7803	3.88E-02	
VERSAPAK_HAC_FINH_10C12_A2	10 (1.2)	4x4x4=64	100	0.350	0.0001	Yes	0.8204	0.0012	0.8228	3.89E-02	
VERSAPAK_HAC_FINH_10C12_A3	10 (1.2)	6x6x4=144	100	0.350	0.0001	Yes	0.8587	0.0010	0.8607	3.91E-02	
VERSAPAK_HAC_FINH_10C12_A4	10 (1.2)	6x6x6=216	100	0.350	0.0001	Yes	0.8711	0.0010	0.8731	3.90E-02	
VERSAPAK_HAC_FINH_10C12_A5	10 (1.2)	8x8x6=384	100	0.350	0.0001	Yes	0.9041	0.0011	0.9063	3.91E-02	
VERSAPAK_HAC_FINH_10C12_A6	10 (1.2)	8x8x8=512	100	0.350	0.0001	Yes	0.9130	0.0011	0.9152	3.91E-02	
VERSAPAK_HAC_FINH_10C12_A7	10 (1.2)	10x10x8=800	100	0.350	0.0001	Yes	0.9428	0.0012	0.9452	3.92E-02	
VERSAPAK_HAC_FINH_10C11_A1	10 (1.1)	2x2x2=8	100	0.350	0.0001	Yes	0.8229	0.0012	0.8253	4.34E-02	
VERSAPAK_HAC_FINH_10C11_A2	10 (1.1)	4x4x4=64	100	0.350	0.0001	Yes	0.8202	0.0011	0.8224	4.03E-02	
VERSAPAK_HAC_FINH_10C11_A3	10 (1.1)	6x6x4=144	100	0.350	0.0001	Yes	0.8570	0.0014	0.8598	4.03E-02	
VERSAPAK_HAC_FINH_10C11_A4	10 (1.1)	6x6x6=216	100	0.350	0.0001	Yes	0.8723	0.0011	0.8745	4.03E-02	
VERSAPAK_HAC_FINH_10C11_A5	10 (1.1)	8x8x6=384	100	0.350	0.0001	Yes	0.9038	0.0012	0.9062	4.04E-02	
VERSAPAK_HAC_FINH_10C11_A6	10 (1.1)	8x8x8=512	100	0.350	0.0001	Yes	0.9131	0.0014	0.9159	4.04E-02	
VERSAPAK_HAC_FINH_10C11_A7	10 (1.1)	10x10x8=800	100	0.350	0.0001	Yes	0.9430	0.0012	0.9454	4.05E-02	
VERSAPAK_HAC_FINH_10C9_A1	10 (0.9)	2x2x2=8	100	0.350	0.0001	Yes	0.7676	0.0013	0.7702	4.37E-02	
VERSAPAK_HAC_FINH_10C9_A2	10 (0.9)	4x4x4=64	100	0.350	0.0001	Yes	0.8099	0.0012	0.8123	4.38E-02	
VERSAPAK_HAC_FINH_10C9_A3	10 (0.9)	6x6x4=144	100	0.350	0.0001	Yes	0.8485	0.0012	0.8509	4.39E-02	

VERSAPAK_HAC_FINH_10C9_A4	10 (0.9)	6x6x6=216	100	0.350	0.0001	Yes	0.8581	0.0012	0.8605	4.39E-02	
VERSAPAK_HAC_FINH_10C9_A5	10 (0.9)	8x8x6=384	100	0.350	0.0001	Yes	0.8954	0.0013	0.8980	4.40E-02	
VERSAPAK_HAC_FINH_10C9_A6	10 (0.9)	8x8x8=512	100	0.350	0.0001	Yes	0.9035	0.0013	0.9061	4.41E-02	
VERSAPAK_HAC_FINH_10C9_A7	10 (0.9)	10x10x8=800	100	0.350	0.0001	Yes	0.9373	0.0013	0.9399	4.41E-02	
Triangular Package Arrays – Lumped Cylindrical Fissile Mass – Initial Array Sensitivity Study – 12.0” Cylinder Height-to-Diameter Sensitivity											
VERSAPAK_HAC_FINH_12C11_A1	12 (1.1)	2x2x2=8	100	0.350	0.0001	Yes	0.7787	0.0010	0.7807	3.39E-02	
VERSAPAK_HAC_FINH_12C11_A2	12 (1.1)	4x4x4=64	100	0.350	0.0001	Yes	0.8178	0.0009	0.8196	3.40E-02	
VERSAPAK_HAC_FINH_12C11_A3	12 (1.1)	6x6x4=144	100	0.350	0.0001	Yes	0.8481	0.0010	0.8501	3.41E-02	
VERSAPAK_HAC_FINH_12C11_A4	12 (1.1)	6x6x6=216	100	0.350	0.0001	Yes	0.8568	0.0011	0.8590	3.41E-02	
VERSAPAK_HAC_FINH_12C11_A5	12 (1.1)	8x8x6=384	100	0.350	0.0001	Yes	0.8819	0.0010	0.8839	3.41E-02	
VERSAPAK_HAC_FINH_12C11_A6	12 (1.1)	8x8x8=512	100	0.350	0.0001	Yes	0.8904	0.0010	0.8924	3.42E-02	
VERSAPAK_HAC_FINH_12C11_A7	12 (1.1)	10x10x8=800	100	0.350	0.0001	Yes	0.9103	0.0010	0.9123	3.42E-02	
VERSAPAK_HAC_FINH_12C9_A1	12 (0.9)	2x2x2=8	100	0.350	0.0001	Yes	0.7917	0.0011	0.7939	3.57E-02	
VERSAPAK_HAC_FINH_12C9_A2	12 (0.9)	4x4x4=64	100	0.350	0.0001	Yes	0.8308	0.0010	0.8328	3.58E-02	
VERSAPAK_HAC_FINH_12C9_A3	12 (0.9)	6x6x4=144	100	0.350	0.0001	Yes	0.8661	0.0009	0.8679	3.59E-02	
VERSAPAK_HAC_FINH_12C9_A4	12 (0.9)	6x6x6=216	100	0.350	0.0001	Yes	0.8769	0.0010	0.8789	3.59E-02	
VERSAPAK_HAC_FINH_12C9_A5	12 (0.9)	8x8x6=384	100	0.350	0.0001	Yes	0.9043	0.0011	0.9065	3.60E-02	
VERSAPAK_HAC_FINH_12C9_A6	12 (0.9)	8x8x8=512	100	0.350	0.0001	Yes	0.9125	0.0009	0.9143	3.60E-02	
VERSAPAK_HAC_FINH_12C9_A7	12 (0.9)	10x10x8=800	100	0.350	0.0001	Yes	0.9391	0.0009	0.9409	3.60E-02	
VERSAPAK_HAC_FINH_12C8_A1	12 (0.8)	2x2x2=8	100	0.350	0.0001	Yes	0.7908	0.0011	0.7930	3.70E-02	
VERSAPAK_HAC_FINH_12C8_A2	12 (0.8)	4x4x4=64	100	0.350	0.0001	Yes	0.8317	0.0012	0.8341	3.71E-02	
VERSAPAK_HAC_FINH_12C8_A3	12 (0.8)	6x6x4=144	100	0.350	0.0001	Yes	0.8657	0.0011	0.8679	3.72E-02	
VERSAPAK_HAC_FINH_12C8_A4	12 (0.8)	6x6x6=216	100	0.350	0.0001	Yes	0.8794	0.0011	0.8816	3.72E-02	
VERSAPAK_HAC_FINH_12C8_A5	12 (0.8)	8x8x6=384	100	0.350	0.0001	Yes	0.9061	0.0010	0.9081	3.73E-02	
VERSAPAK_HAC_FINH_12C8_A6	12 (0.8)	8x8x8=512	100	0.350	0.0001	Yes	0.9158	0.0011	0.9180	3.73E-02	
VERSAPAK_HAC_FINH_12C8_A7	12 (0.8)	10x10x8=800	100	0.350	0.0001	Yes	0.9426	0.0012	0.9450	3.73E-02	
VERSAPAK_HAC_FINH_12C6_A1	12 (0.6)	2x2x2=8	100	0.350	0.0001	Yes	0.7631	0.0013	0.7657	4.13E-02	
VERSAPAK_HAC_FINH_12C6_A2	12 (0.6)	4x4x4=64	100	0.350	0.0001	Yes	0.8088	0.0011	0.8110	4.13E-02	
VERSAPAK_HAC_FINH_12C6_A3	12 (0.6)	6x6x4=144	100	0.350	0.0001	Yes	0.8469	0.0010	0.8489	4.14E-02	
VERSAPAK_HAC_FINH_12C6_A4	12 (0.6)	6x6x6=216	100	0.350	0.0001	Yes	0.8471	0.0013	0.8497	4.14E-02	
VERSAPAK_HAC_FINH_12C6_A5	12 (0.6)	8x8x6=384	100	0.350	0.0001	Yes	0.8913	0.0012	0.8937	4.16E-02	
VERSAPAK_HAC_FINH_12C6_A6	12 (0.6)	8x8x8=512	100	0.350	0.0001	Yes	0.9029	0.0015	0.9059	4.15E-02	
VERSAPAK_HAC_FINH_12C6_A7	12 (0.6)	10x10x8=800	100	0.350	0.0001	Yes	0.9336	0.0012	0.9360	4.16E-02	

Table 6-8 Summary of Hypothetical Accident Condition Package Results for Lumped Fissile Mass Models – Increased Array Size and Increased Poly-Moderation Sensitivity

Case ID	Radius (cm) of Sphere	Modeled Package Array	Poly-Moderation Density	^{235}U Mass (kg)	Interspersed Moderation (water volume fraction)	Close Water Reflection	k_{eff}	σ	k_{eff} + 2σ	EALF (eV)	Comments
Triangular Package Arrays – Lumped Spherical Fissile Mass – Normal Density Poly-Moderation Sensitivity Study											
VERSAPAK_HAC_FINH_12S_1X400	12	16x25x1=400	0.92	0.350	0.0001	Yes	0.8240	0.0011	0.8262	3.92E-02	
VERSAPAK_HAC_FINH_12S_1x416	12	16x26x1=416	0.92	0.350	0.0001	Yes	0.8273	0.0012	0.8297	3.92E-02	
VERSAPAK_HAC_FINH_12S_1x468	12	18x26x1=468	0.92	0.350	0.0001	Yes	0.8249	0.0012	0.8273	3.93E-02	
VERSAPAK_HAC_FINH_12S_2X324	12	20x18x2=720	0.92	0.350	0.0001	Yes	0.9077	0.0011	0.9099	3.95E-02	
VERSAPAK_HAC_FINH_12S_2x400	12	16x25x2=800	0.92	0.350	0.0001	Yes	0.9076	0.0010	0.9096	3.94E-02	
VERSAPAK_HAC_FINH_12S_2x416	12	16x26x2=832	0.92	0.350	0.0001	Yes	0.9074	0.0013	0.9100	3.94E-02	
VERSAPAK_HAC_FINH_12S_2x468	12	18x26x2=936	0.92	0.350	0.0001	Yes	0.9110	0.0012	0.9134	3.94E-02	
VERSAPAK_HAC_FINH_12S_3X120	12	10x12x3=360	0.92	0.350	0.0001	Yes	0.9202	0.0012	0.9226	3.94E-02	
VERSAPAK_HAC_FINH_12S_3X144	12	12x12x3=432	0.92	0.350	0.0001	Yes	0.9253	0.0011	0.9275	3.94E-02	
VERSAPAK_HAC_FINH_12S_3X224	12	14x16x3=672	0.92	0.350	0.0001	Yes	0.9371	0.0013	0.9397	3.95E-02	
VERSAPAK_HAC_FINH_12S_3X324	12	20x18x3=1080	0.92	0.350	0.0001	Yes	0.9500	0.0011	0.9522	3.95E-02	
VERSAPAK_HAC_FINH_12S_3x400	12	16x25x3=1200	0.92	0.350	0.0001	Yes	0.9491	0.0012	0.9515	3.95E-02	
VERSAPAK_HAC_FINH_12S_3x416	12	16x26x3=1248	0.92	0.350	0.0001	Yes	0.9504	0.0011	0.9526	3.94E-02	
VERSAPAK_HAC_FINH_12S_3x468	12	18x26x3=1404	0.92	0.350	0.0001	Yes	0.9548	0.0011	0.9570	3.94E-02	
VERSAPAK_HAC_FINS_12_A3	12	6x6x4=144	0.92	0.350	0.0001	Yes	0.8720	0.0011	0.8742	3.93E-02	
VERSAPAK_HAC_FINH_12S_4X120	12	10x12x4=480	0.92	0.350	0.0001	Yes	0.9359	0.0011	0.9381	3.95E-02	
VERSAPAK_HAC_FINH_12S_4x400	12	16x25x4=1600	0.92	0.350	0.0001	Yes	0.9779	0.0010	0.9799	3.95E-02	
VERSAPAK_HAC_FINH_12S_4x416	12	16x26x4=1664	0.92	0.350	0.0001	Yes	0.9754	0.0011	0.9776	3.95E-02	
VERSAPAK_HAC_FINH_12S_4x468	12	18x26x4=1872	0.92	0.350	0.0001	Yes	0.9825	0.0012	0.9849	3.95E-02	
VERSAPAK_HAC_FINH_12S_5X080	12	8x10x5=400	0.92	0.350	0.0001	Yes	0.9322	0.0012	0.9346	3.95E-02	
VERSAPAK_HAC_FINH_12S_5X120	12	10x12x5=600	0.92	0.350	0.0001	Yes	0.9554	0.0012	0.9578	3.94E-02	
VERSAPAK_HAC_FINS_12_A4	12	6x6x6=216	0.92	0.350	0.0001	Yes	0.8814	0.0012	0.8838	3.93E-02	
VERSAPAK_HAC_FINS_12_A5	12	8x8x6=384	0.92	0.350	0.0001	Yes	0.9154	0.0012	0.9178	3.94E-02	
VERSAPAK_HAC_FINH_12S_6X080	12	8x10x6=480	0.92	0.350	0.0001	Yes	0.9373	0.0012	0.9397	3.94E-02	
VERSAPAK_HAC_FINH_12S_7X064	12	8x8x7=448	0.92	0.350	0.0001	Yes	0.9319	0.0012	0.9343	3.94E-02	

VERSAPAK_HAC_FINH_12S_7X080	12	8x10x7=560	0.92	0.350	0.0001	Yes	0.9436	0.0012	0.9460	3.95E-02	
VERSAPAK_HAC_FINS_12_A6	12	8x8x8=512	0.92	0.350	0.0001	Yes	0.9219	0.0012	0.9243	3.94E-02	
VERSAPAK_HAC_FINH_12S_8X080	12	8x10x8=640	0.92	0.350	0.0001	Yes	0.9507	0.0012	0.9531	3.94E-02	
VERSAPAK_HAC_FINS_12_A7	12	10x10x8=800	0.92	0.350	0.0001	Yes	0.9505	0.0012	0.9529	3.95E-02	
VERSAPAK_HAC_FINH_12S_8X064	12	8x8x10=640	0.92	0.350	0.0001	Yes	0.9380	0.0011	0.9402	3.94E-02	
Triangular Package Arrays – Lumped Spherical Fissile Mass – Increased Density Poly-Moderation Sensitivity Study											
VERSAPAK_HAC_FINH_12S_1X400PM	12	16x25x1=400	0.98	0.350	0.0001	Yes	0.8572	0.0013	0.8598	3.82E-02	**Increasing the poly-moderation density from 0.92 to 0.98 g/cc results in an average increase in the k_{eff} + 2σ of 0.0221. This results in an array reduction from 400 to 300 packages to remain within the established USL of 0.94.**
VERSAPAK_HAC_FINH_12S_1x416PM	12	16x26x1=416	0.98	0.350	0.0001	Yes	0.8520	0.0012	0.8544	3.82E-02	
VERSAPAK_HAC_FINH_12S_1x468PM	12	18x26x1=468	0.98	0.350	0.0001	Yes	0.8542	0.0011	0.8564	3.83E-02	
VERSAPAK_HAC_FINH_12S_2X324PM	12	20x18x2=720	0.98	0.350	0.0001	Yes	0.9270	0.0012	0.9294	3.84E-02	
VERSAPAK_HAC_FINH_12S_2x400PM	12	16x25x2=800	0.98	0.350	0.0001	Yes	0.9313	0.0011	0.9335	3.84E-02	
VERSAPAK_HAC_FINH_12S_2x416PM	12	16x26x2=832	0.98	0.350	0.0001	Yes	0.9301	0.0012	0.9325	3.84E-02	
VERSAPAK_HAC_FINH_12S_2x468PM	12	18x26x2=936	0.98	0.350	0.0001	Yes	0.9317	0.0011	0.9339	3.84E-02	
VERSAPAK_HAC_FINH_12S_3X120PM	12	10x12x3=360	0.98	0.350	0.0001	Yes	0.9413	0.0010	0.9433	3.84E-02	
VERSAPAK_HAC_FINH_12S_3X144PM	12	12x12x3=432	0.98	0.350	0.0001	Yes	0.9460	0.0011	0.9482	3.84E-02	
VERSAPAK_HAC_FINH_12S_3X224PM	12	14x16x3=672	0.98	0.350	0.0001	Yes	0.9574	0.0012	0.9598	3.84E-02	
VERSAPAK_HAC_FINH_12S_3X324PM	12	20x18x3=1080	0.98	0.350	0.0001	Yes	0.9694	0.0011	0.9716	3.84E-02	
VERSAPAK_HAC_FINH_12S_3x400PM	12	16x25x3=1200	0.98	0.350	0.0001	Yes	0.9703	0.0011	0.9725	3.84E-02	
VERSAPAK_HAC_FINH_12S_3x416PM	12	16x26x3=1248	0.98	0.350	0.0001	Yes	0.9672	0.0011	0.9694	3.84E-02	
VERSAPAK_HAC_FINH_12S_3x468PM	12	18x26x3=1404	0.98	0.350	0.0001	Yes	0.9728	0.0010	0.9748	3.85E-02	
VERSAPAK_HAC_FINS_12_A3PM	12	6x6x4=144	0.98	0.350	0.0001	Yes	0.9026	0.0013	0.9052	3.83E-02	
VERSAPAK_HAC_FINH_12S_4X120PM	12	10x12x4=480	0.98	0.350	0.0001	Yes	0.9532	0.0012	0.9556	3.84E-02	
VERSAPAK_HAC_FINH_12S_4x400PM	12	16x25x4=1600	0.98	0.350	0.0001	Yes	0.9937	0.0011	0.9959	3.85E-02	
VERSAPAK_HAC_FINH_12S_4x416PM	12	16x26x4=1664	0.98	0.350	0.0001	Yes	0.9957	0.0012	0.9981	3.85E-02	
VERSAPAK_HAC_FINH_12S_4x468PM	12	18x26x4=1872	0.98	0.350	0.0001	Yes	0.9984	0.0011	1.0006	3.85E-02	
VERSAPAK_HAC_FINH_12S_5X080PM	12	8x10x5=400	0.98	0.350	0.0001	Yes	0.9523	0.0012	0.9547	3.84E-02	
VERSAPAK_HAC_FINH_12S_5X120PM	12	10x12x5=600	0.98	0.350	0.0001	Yes	0.9722	0.0012	0.9746	3.84E-02	
VERSAPAK_HAC_FINS_12_A4PM	12	6x6x6=216	0.98	0.350	0.0001	Yes	0.9101	0.0012	0.9125	3.83E-02	
VERSAPAK_HAC_FINS_12_A5PM	12	8x8x6=384	0.98	0.350	0.0001	Yes	0.9434	0.0011	0.9456	3.84E-02	
VERSAPAK_HAC_FINH_12S_6X080PM	12	8x10x6=480	0.98	0.350	0.0001	Yes	0.9571	0.0012	0.9595	3.84E-02	
VERSAPAK_HAC_FINH_12S_7X064PM	12	8x8x7=448	0.98	0.350	0.0001	Yes	0.9514	0.0012	0.9538	3.84E-02	
VERSAPAK_HAC_FINH_12S_7X080PM	12	8x10x7=560	0.98	0.350	0.0001	Yes	0.9648	0.0012	0.9672	3.84E-02	
VERSAPAK_HAC_FINS_12_A6PM	12	8x8x8=512	0.98	0.350	0.0001	Yes	0.9540	0.0011	0.9562	3.84E-02	
VERSAPAK_HAC_FINH_12S_8X080PM	12	8x10x8=640	0.98	0.350	0.0001	Yes	0.9672	0.0011	0.9694	3.84E-02	
VERSAPAK_HAC_FINS_12_A7PM	12	10x10x8=800	0.98	0.350	0.0001	Yes	0.9815	0.0015	0.9845	3.84E-02	
VERSAPAK_HAC_FINH_12S_8X064PM	12	8x8x10=640	0.98	0.350	0.0001	Yes	0.9579	0.0012	0.9603	3.84E-02	

Triangular Package Arrays – Lumped Spherical Fissile Mass – Paraffin Moderation Sensitivity Study											
VERSAPAK_HAC_FINH_12S_1X400PF	12	16x25x1=400	0.90	0.350	0.0001	Yes	0.8266	0.0012	0.8290	3.91E-02	**All poly-moderation cases with density of 0.98 g/cc are higher than the paraffin cases with an average increase in the k_{eff} + 2σ of 0.0194.**
VERSAPAK_HAC_FINH_12S_1X416PF	12	16x26x1=416	0.90	0.350	0.0001	Yes	0.8272	0.0011	0.8294	3.91E-02	
VERSAPAK_HAC_FINH_12S_1X468PF	12	18x26x1=468	0.90	0.350	0.0001	Yes	0.8281	0.0011	0.8303	3.90E-02	
VERSAPAK_HAC_FINH_12S_2X324PF	12	20x18x2=720	0.90	0.350	0.0001	Yes	0.9075	0.0013	0.9101	3.93E-02	
VERSAPAK_HAC_FINH_12S_2X400PF	12	16x25x2=800	0.90	0.350	0.0001	Yes	0.9099	0.0010	0.9119	3.93E-02	
VERSAPAK_HAC_FINH_12S_2X416 PF	12	16x26x2=832	0.90	0.350	0.0001	Yes	0.9107	0.0011	0.9129	3.92E-02	
VERSAPAK_HAC_FINH_12S_2X468 PF	12	18x26x2=936	0.90	0.350	0.0001	Yes	0.9118	0.0011	0.9140	3.93E-02	
VERSAPAK_HAC_FINH_12S_3X120 PF	12	10x12x3=360	0.90	0.350	0.0001	Yes	0.9202	0.0012	0.9226	3.93E-02	
VERSAPAK_HAC_FINH_12S_3X144 PF	12	12x12x3=432	0.90	0.350	0.0001	Yes	0.9256	0.0011	0.9278	3.93E-02	
VERSAPAK_HAC_FINH_12S_3X224 PF	12	14x16x3=672	0.90	0.350	0.0001	Yes	0.9410	0.0012	0.9434	3.92E-02	
VERSAPAK_HAC_FINH_12S_3X324 PF	12	20x18x3=1080	0.90	0.350	0.0001	Yes	0.9502	0.0011	0.9524	3.93E-02	
VERSAPAK_HAC_FINH_12S_3X400 PF	12	16x25x3=1200	0.90	0.350	0.0001	Yes	0.9531	0.0010	0.9551	3.93E-02	
VERSAPAK_HAC_FINH_12S_3X416 PF	12	16x26x3=1248	0.90	0.350	0.0001	Yes	0.9519	0.0012	0.9543	3.93E-02	
VERSAPAK_HAC_FINH_12S_3X468 PF	12	18x26x3=1404	0.90	0.350	0.0001	Yes	0.9530	0.0010	0.9550	3.93E-02	
VERSAPAK_HAC_FINH_12S_4X120 PF	12	10x12x4=480	0.90	0.350	0.0001	Yes	0.9382	0.0010	0.9402	3.93E-02	
VERSAPAK_HAC_FINH_12S_4X400 PF	12	16x25x4=1600	0.90	0.350	0.0001	Yes	0.9770	0.0013	0.9796	3.93E-02	
VERSAPAK_HAC_FINH_12S_4X416 PF	12	16x26x4=1664	0.90	0.350	0.0001	Yes	0.9790	0.0013	0.9816	3.93E-02	
VERSAPAK_HAC_FINH_12S_4X468 PF	12	18x26x4=1872	0.90	0.350	0.0001	Yes	0.9842	0.0010	0.9862	3.93E-02	
VERSAPAK_HAC_FINH_12S_5X080 PF	12	8x10x5=400	0.90	0.350	0.0001	Yes	0.9315	0.0010	0.9335	3.93E-02	
VERSAPAK_HAC_FINH_12S_5X120 PF	12	10x12x5=600	0.90	0.350	0.0001	Yes	0.9541	0.0011	0.9563	3.93E-02	
VERSAPAK_HAC_FINH_12S_6X080 PF	12	6x6x6=216	0.90	0.350	0.0001	Yes	0.9384	0.0012	0.9408	3.93E-02	
VERSAPAK_HAC_FINH_12S_7X064 PF	12	8x10x6=480	0.90	0.350	0.0001	Yes	0.9313	0.0013	0.9339	3.92E-02	
VERSAPAK_HAC_FINH_12S_7X080 PF	12	8x10x7=560	0.90	0.350	0.0001	Yes	0.9458	0.0011	0.9480	3.93E-02	
VERSAPAK_HAC_FINH_12S_8X080 PF	12	8x10x8=640	0.90	0.350	0.0001	Yes	0.9488	0.0011	0.9510	3.93E-02	
VERSAPAK_HAC_FINH_12S_10X064 PF	12	8x8x10=640	0.90	0.350	0.0001	Yes	0.9389	0.0013	0.9415	3.92E-02	

Table 6-9 Summary of Hypothetical Accident Condition Package Results for Lumped Fissile Mass Models – Cross Section, Fissile Mass, Interspersed Moderation, Fissile Moderator Density, Package Carbon Steel Sensitivity, and Graphite Moderation

Case ID	Radius (cm) of Sphere	Modeled Package Array	Poly-Moderation	^{235}U Mass (kg)	Interspersed Moderation (water volume fraction)	Close Water Reflection	k_{eff}	σ	k_{eff} + 2σ	EALF (eV)	Comments
Triangular Package Arrays – Lumped Spherical Fissile Mass – Normal Density Poly-Moderation - Cross Section Sensitivity Study											
VERSAPAK_HAC_FINH_12S_A7	12	10x10x8=800	100	0.350	0.0001	Yes	0.9623	0.0013	0.9649	3.95E-02	**44 Group**
VERSAPAK_HAC_FINH_12S_A7X	12	10x10x8=800	100	0.350	0.0001	Yes	0.9624	0.0012	0.9648	4.12E-02	**238 Group**
VERSAPAK_HAC_FINH_12S_A7X1	12	10x10x8=800	100	0.350	0.0001	Yes	0.9650	0.0008	0.9666	4.11E-02	**238 Group Increased Histories**
VERSAPAK_HAC_FINH_12S_A7XN	12	10x10x8=800	100	0.350	0.0001	Yes	0.9633	0.0008	0.9649	3.95E-02	**44 Group Increased Histories**
Triangular Package Arrays – Lumped Spherical Fissile Mass – Normal Density Poly-Moderation – Increased Fissile Mass Sensitivity Study											
VERSAPAK_HAC_FINH_12S_A1_375	12	2x2x2=8	100	0.375	0.0001	Yes	0.8135	0.0012	0.8159	4.01E-02	**Increasing the fissile mass above 350 gcarbon steel content requires array size reduction**
VERSAPAK_HAC_FINH_12S_A2_375	12	4x4x4=64	100	0.375	0.0001	Yes	0.8585	0.0011	0.8607	4.02E-02	
VERSAPAK_HAC_FINH_12S_A3_375	12	6x6x4=144	100	0.375	0.0001	Yes	0.8957	0.0011	0.8979	4.03E-02	
VERSAPAK_HAC_FINH_12S_A4_375	12	6x6x6=216	100	0.375	0.0001	Yes	0.9094	0.0014	0.9122	4.03E-02	
VERSAPAK_HAC_FINH_12S_A5_375	12	8x8x6=384	100	0.375	0.0001	Yes	0.9416	0.0012	0.9440	4.04E-02	
VERSAPAK_HAC_FINH_12S_A6_375	12	8x8x8=512	100	0.375	0.0001	Yes	0.9502	0.0011	0.9524	4.04E-02	
VERSAPAK_HAC_FINH_12S_A7_375	12	10x10x8=800	100	0.375	0.0001	Yes	0.9818	0.0010	0.9838	4.04E-02	
VERSAPAK_HAC_FINH_12S_A1_400	12	2x2x2=8	100	0.400	0.0001	Yes	0.8276	0.0012	0.8300	4.11E-02	
VERSAPAK_HAC_FINH_12S_A2_400	12	4x4x4=64	100	0.400	0.0001	Yes	0.8741	0.0013	0.8767	4.12E-02	
VERSAPAK_HAC_FINH_12S_A3_400	12	6x6x4=144	100	0.400	0.0001	Yes	0.9118	0.0012	0.9142	4.13E-02	
VERSAPAK_HAC_FINH_12S_A4_400	12	6x6x6=216	100	0.400	0.0001	Yes	0.9258	0.0012	0.9282	4.12E-02	
VERSAPAK_HAC_FINH_12S_A5_400	12	8x8x6=384	100	0.400	0.0001	Yes	0.9594	0.0012	0.9618	4.14E-02	
VERSAPAK_HAC_FINH_12S_A6_400	12	8x8x8=512	100	0.400	0.0001	Yes	0.9704	0.0013	0.9730	4.14E-02	
VERSAPAK_HAC_FINH_12S_A7_400	12	10x10x8=800	100	0.400	0.0001	Yes	1.0043	0.0011	1.0065	4.13E-02	
Triangular Package Arrays – Lumped Spherical Fissile Mass – Normal Density Poly-Moderation – Interspersed Moderation Sensitivity Study											
VERSAPAK_HAC_FINH_12S_A7	12	10x10x8=800	100	0.350	0.0001	Yes	0.9623	0.0013	0.9649	3.95E-02	**Increased interspersed moderation**
VERSAPAK_HAC_FINH_12S_A7a	12	10x10x8=800	100	0.350	0.001	Yes	0.9621	0.0011	0.9643	3.94E-02	
VERSAPAK_HAC_FINH_12S_A7b	12	10x10x8=800	100	0.350	0.01	Yes	0.9405	0.0012	0.9429	3.93E-02	

VERSAPAK_HAC_FINH_12S_A7c	12	10x10x8=800	100	0.350	0.1	Yes	0.8527	0.0012	0.8551	3.83E-02	**reduces k_{ef}**
VERSAPAK_HAC_FINH_12S_A7d	12	10x10x8=800	100	0.350	0.5	Yes	0.8517	0.0013	0.8543	3.72E-02	
VERSAPAK_HAC_FINH_12S_A7e	12	10x10x8=800	100	0.350	1.0	Yes	0.8793	0.0016	0.8825	3.67E-02	
Triangular Package Arrays – Lumped Spherical Fissile Mass – Normal Density Poly-Moderation – Reduced Poly-Moderation Sensitivity Study											
VERSAPAK_HAC_FINH_12S_A7	12	10x10x8=800	100	0.350	0.0001	Yes	0.9623	0.0013	0.9649	3.95E-02	**Reduced poly-moderation reduces k_{eff}**
VERSAPAK_HAC_FINH_12S_A7B	12	10x10x8=800	90	0.350	0.0001	Yes	0.9315	0.0012	0.9339	4.14E-02	
VERSAPAK_HAC_FINH_12S_A7C	12	10x10x8=800	80	0.350	0.0001	Yes	0.8906	0.0013	0.8932	4.40E-02	
VERSAPAK_HAC_FINH_12S_A7D	12	10x10x8=800	70	0.350	0.0001	Yes	0.8358	0.0012	0.8382	4.76E-02	
VERSAPAK_HAC_FINH_12S_A7E	12	10x10x8=800	60	0.350	0.0001	Yes	0.7677	0.0014	0.7705	5.30E-02	
VERSAPAK_HAC_FINH_12S_A7F	12	10x10x8=800	50	0.350	0.0001	Yes	0.6809	0.0012	0.6833	6.15E-02	
Triangular Package Arrays – Lumped Spherical Fissile Mass – Normal Density Poly-Moderation – No Carbon Steel Sensitivity Study											
VERSAPAK_HAC_FINH_12S_A1NS	12	2x2x2=8	100	0.350	0.0001	Yes	0.8046	0.0010	0.8066	3.81E-02	**Not crediting the minimum carbon steel content requires array size reduction**
VERSAPAK_HAC_FINH_12S_A2NS	12	4x4x4=64	100	0.350	0.0001	Yes	0.8666	0.0011	0.8688	3.76E-02	
VERSAPAK_HAC_FINH_12S_A3NS	12	6x6x4=144	100	0.350	0.0001	Yes	0.9097	0.0012	0.9121	3.73E-02	
VERSAPAK_HAC_FINH_12S_A4NS	12	6x6x6=216	100	0.350	0.0001	Yes	0.9276	0.0012	0.9300	3.72E-02	
VERSAPAK_HAC_FINH_12S_A5NS	12	8x8x6=384	100	0.350	0.0001	Yes	0.9677	0.0013	0.9703	3.69E-02	
VERSAPAK_HAC_FINH_12S_A6NS	12	8x8x8=512	100	0.350	0.0001	Yes	0.9793	0.0011	0.9815	3.69E-02	
VERSAPAK_HAC_FINH_12S_A7NS	12	10x10x8=800	100	0.350	0.0001	Yes	1.0168	0.0010	1.0188	3.69E-02	
Triangular Package Arrays – Lumped Spherical Fissile Mass – Graphite Moderation Sensitivity Study											
VERSAPAK_HAC_FINH_12S_A7G	12	10x10x8=800	100	0.350	0.0001	Yes	0.1544	0.0005	0.1554	3.43E+00	

Table 6-10 Summary of Sphere Sensitivity Placement Calculations for MOD0, MOD1, MOD2, MOD3, and MOD4 Arrays

(note values exceeding the USL of 0.94 are high-lighted yellow)

CASE ID	ARRAY HEIGHT	# PACKAGES	k_{eff}	σ	$k_{eff} + 2\sigma$	EALF (eV)
MOD0 - INITIAL ARRAY STUDY						
VERSAPAK_HAC_FINH_12S_1X306P	1	306	0.8514	0.0012	0.8538	3.82E-02
VERSAPAK_HAC_FINH_12S_1x315P	1	315	0.8541	0.0013	0.8567	3.82E-02
VERSAPAK_HAC_FINH_12S_1x324P	1	324	0.8536	0.0012	0.8560	3.82E-02
VERSAPAK_HAC_FINH_12S_2X312P	2	312	0.9162	0.0011	0.9184	3.83E-02
VERSAPAK_HAC_FINH_12S_2X326P	2	326	0.9172	0.0013	0.9198	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338P	2	338	0.9184	0.0010	0.9204	3.84E-02
VERSAPAK_HAC_FINH_12S_3X300P	3	300	0.9333	0.0011	0.9355	3.84E-02
VERSAPAK_HAC_FINH_12S_4X272P	4	272	0.9298	0.0012	0.9322	3.84E-02
VERSAPAK_HAC_FINH_12S_4X308P	4	308	0.9360	0.0011	0.9382	3.84E-02
VERSAPAK_HAC_FINH_12S_5X260P	5	260	0.9299	0.0012	0.9323	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280P	5	280	0.9364	0.0011	0.9386	3.83E-02
VERSAPAK_HAC_FINH_12S_5x300P	5	300	0.9361	0.0012	0.9385	3.84E-02
VERSAPAK_HAC_FINH_12S_6X312P	6	312	0.9341	0.0011	0.9363	3.83E-02
VERSAPAK_HAC_FINH_12S_6X336P	6	336	0.9376	0.0012	0.9400	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322P	7	322	0.9303	0.0011	0.9325	3.83E-02
VERSAPAK_HAC_FINH_12S_7X343P	7	343	0.9360	0.0011	0.9382	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312P	8	312	0.9212	0.0010	0.9232	3.84E-02
VERSAPAK_HAC_FINH_12S_8X336P	8	336	0.9280	0.0011	0.9302	3.83E-02
VERSAPAK_HAC_FINH_12S_8X368P	8	368	0.9313	0.0011	0.9335	3.83E-02
VERSAPAK_HAC_FINH_12S_8X392P	8	392	0.9370	0.0012	0.9394	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324P	9	324	0.9224	0.0012	0.9248	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300P	10	300	0.9121	0.0013	0.9147	3.83E-02
VERSAPAK_HAC_FINH_12S_10X330P	10	330	0.9153	0.0014	0.9181	3.83E-02

VERSAPAK_HAC_FINH_12S_10X360P	10	360	0.9220	0.0010	0.9240	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300P	12	300	0.9028	0.0013	0.9054	3.83E-02
MOD1						
VERSAPAK_HAC_FINH_12S_4x272P	4	272	0.9378	0.0010	0.9398	3.84E-02
VERSAPAK_HAC_FINH_12S_4x288P	4	288	0.9390	0.0013	0.9416	3.84E-02
VERSAPAK_HAC_FINH_12S_4x308P	4	308	0.9431	0.0011	0.9453	3.84E-02
VERSAPAK_HAC_FINH_12S_5x280P	5	280	0.9358	0.0011	0.9380	3.84E-02
VERSAPAK_HAC_FINH_12S_6x288P	6	288	0.9345	0.0012	0.9369	3.84E-02
VERSAPAK_HAC_FINH_12S_6x312P	6	312	0.9409	0.0013	0.9435	3.84E-02
VERSAPAK_HAC_FINH_12S_7x322P	7	322	0.9330	0.0015	0.9360	3.83E-02
VERSAPAK_HAC_FINH_12S_8x312P	8	312	0.9246	0.0012	0.9270	3.83E-02
VERSAPAK_HAC_FINH_12S_9x324P	9	324	0.9214	0.0012	0.9238	3.83E-02
VERSAPAK_HAC_FINH_12S_10x300P	10	300	0.9114	0.0011	0.9136	3.83E-02
VERSAPAK_HAC_FINH_12S_12x300P	12	300	0.9032	0.0011	0.9054	3.83E-02
MOD2						
VERSAPAK_HAC_FINH_12S_4x272P	4	272	0.9076	0.0013	0.9102	3.83E-02
VERSAPAK_HAC_FINH_12S_4x288P	4	288	0.9088	0.0011	0.9110	3.83E-02
VERSAPAK_HAC_FINH_12S_4x308P	4	308	0.9118	0.0013	0.9144	3.83E-02
VERSAPAK_HAC_FINH_12S_5x280P	5	280	0.9115	0.0012	0.9139	3.83E-02
VERSAPAK_HAC_FINH_12S_6x288P	6	288	0.9063	0.0010	0.9083	3.83E-02
VERSAPAK_HAC_FINH_12S_6x312P	6	312	0.9152	0.0012	0.9176	3.83E-02
VERSAPAK_HAC_FINH_12S_7x322P	7	322	0.9121	0.0010	0.9141	3.83E-02
VERSAPAK_HAC_FINH_12S_8x312P	8	312	0.9070	0.0011	0.9092	3.83E-02
VERSAPAK_HAC_FINH_12S_9x324P	9	324	0.9054	0.0012	0.9078	3.83E-02
VERSAPAK_HAC_FINH_12S_10x300P	10	300	0.8972	0.0011	0.8994	3.83E-02
VERSAPAK_HAC_FINH_12S_12x300P	12	300	0.8900	0.0012	0.8924	3.83E-02
MOD3						
VERSAPAK_HAC_FINH_12S_4x272P	4	272	0.9353	0.0012	0.9377	3.84E-02
VERSAPAK_HAC_FINH_12S_4x288P	4	288	0.9372	0.0012	0.9396	3.84E-02
VERSAPAK_HAC_FINH_12S_4x308P	4	308	0.9377	0.0010	0.9397	3.84E-02
VERSAPAK_HAC_FINH_12S_5x280P	5	280	0.9347	0.0011	0.9369	3.84E-02

VERSAPAK_HAC_FINH_12S_6x288P	6	288	0.9318	0.0012	0.9342	3.84E-02
VERSAPAK_HAC_FINH_12S_6x312P	6	312	0.9358	0.0012	0.9382	3.84E-02
VERSAPAK_HAC_FINH_12S_7x322P	7	322	0.9302	0.0012	0.9326	3.84E-02
VERSAPAK_HAC_FINH_12S_8x312P	8	312	0.9234	0.0012	0.9258	3.83E-02
VERSAPAK_HAC_FINH_12S_9x324P	9	324	0.9214	0.0010	0.9234	3.83E-02
VERSAPAK_HAC_FINH_12S_10x300P	10	300	0.9092	0.0012	0.9116	3.83E-02
VERSAPAK_HAC_FINH_12S_12x300P	12	300	0.8985	0.0013	0.9011	3.83E-02
MOD4						
VERSAPAK_HAC_FINH_12S_4x272P	4	272	0.9323	0.0012	0.9347	3.84E-02
VERSAPAK_HAC_FINH_12S_4x288P	4	288	0.9367	0.0011	0.9389	3.84E-02
VERSAPAK_HAC_FINH_12S_4x308P	4	308	0.9370	0.0011	0.9392	3.84E-02
VERSAPAK_HAC_FINH_12S_6x288P	6	288	0.9258	0.0013	0.9284	3.84E-02
VERSAPAK_HAC_FINH_12S_6x312P	6	312	0.9314	0.0013	0.9340	3.84E-02

Table 6-11 Summary of Sphere Sensitivity Placement Calculations for MOD0, MOD1, MOD2, MOD3, and MOD4 Arrays(note: yellow high-lighted cells represent the bounding case, interspersed moderator VF=0.0001, poly-moderation density=0.98 g/cc)

CASE ID	ARRAY HEIGHT	# PACKAGES	$k_{eff} + 2\sigma$				
			MOD0	MOD1	MOD2	MOD3	MOD4
VERSAPAK_HAC_FINH_12S_1x324P	1	324	0.8560	0.8560	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_2X338P	2	338	0.9204	0.9204	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_3X300P	3	300	0.9355	0.9355	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_4x272P	4	272	0.9322	0.9398	0.9102	0.9377	0.9347
VERSAPAK_HAC_FINH_12S_4x288P	4	288	n/a	0.9416	0.9110	0.9396	0.9389
VERSAPAK_HAC_FINH_12S_4X308P	4	308	0.9382	0.9453	0.9144	0.9397	0.9392
VERSAPAK_HAC_FINH_12S_5X260P	5	260	0.9323	n/a	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_5X280P	5	280	0.9386	0.9380	0.9139	0.9369	n/a
VERSAPAK_HAC_FINH_12S_5x300P	5	300	0.9385	n/a	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_6x288P	6	288	n/a	0.9369	0.9083	0.9342	0.9284
VERSAPAK_HAC_FINH_12S_6X312P	6	312	0.9363	0.9435	0.9176	0.9382	0.9340
VERSAPAK_HAC_FINH_12S_6X336P	6	336	0.9400	n/a	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_7X322P	7	322	0.9325	0.9360	0.9141	0.9326	n/a
VERSAPAK_HAC_FINH_12S_7X343P	7	343	0.9382	n/a	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_8X312P	8	312	0.9232	0.9270	0.9092	0.9258	n/a
VERSAPAK_HAC_FINH_12S_8X336P	8	336	0.9302	n/a	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_8X368P	8	368	0.9335	n/a	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_8X392P	8	392	0.9394	n/a	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_9X324P	9	324	0.9248	0.9238	0.9078	0.9234	n/a
VERSAPAK_HAC_FINH_12S_10X300P	10	300	0.9147	0.9136	0.8994	0.9116	n/a
VERSAPAK_HAC_FINH_12S_10X330P	10	330	0.9181	n/a	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_10X360P	10	360	0.9240	n/a	n/a	n/a	n/a
VERSAPAK_HAC_FINH_12S_12X300P	12	300	0.9054	0.9054	0.8924	0.9011	n/a

Table 6-12 Summary of Region Dependent Interspersed Moderation Calculations for MOD0 and MOD1 Array Configurations (note: yellow high-lighted cells represent the bounding case)

CASE ID	Region/Mixture Moderator Volume Fraction	k_{eff}	σ	$k_{eff} + 2\sigma$	EALF (eV)
MOD1 – Region/Mixture 5 – Payload Region					
VERSAPAK_HAC_FINH_12S_1x324P	0.0001	0.8536	0.0012	0.8560	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pb	0.001	0.8531	0.0012	0.8555	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pc	0.01	0.8532	0.0012	0.8556	3.81E-02
VERSAPAK_HAC_FINH_12S_1X324Pd	0.1	0.8565	0.0013	0.8591	3.77E-02
VERSAPAK_HAC_FINH_12S_1X324Pe	0.5	0.8780	0.0012	0.8804	3.67E-02
VERSAPAK_HAC_FINH_12S_1X324Pf	1	0.8988	0.0011	0.9010	3.63E-02
VERSAPAK_HAC_FINH_12S_2X338P	0.0001	0.9184	0.0010	0.9204	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338Pb	0.001	0.9174	0.0012	0.9198	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338Pc	0.01	0.9189	0.0012	0.9213	3.83E-02
VERSAPAK_HAC_FINH_12S_2X338Pd	0.1	0.9101	0.0011	0.9123	3.77E-02
VERSAPAK_HAC_FINH_12S_2X338Pe	0.5	0.9067	0.0012	0.9091	3.67E-02
VERSAPAK_HAC_FINH_12S_2X338Pf	1	0.9153	0.0011	0.9175	3.62E-02
VERSAPAK_HAC_FINH_12S_3X300P	0.0001	0.9333	0.0011	0.9355	3.84E-02
VERSAPAK_HAC_FINH_12S_3X300Pb	0.001	0.9347	0.0012	0.9371	3.83E-02
VERSAPAK_HAC_FINH_12S_3X300Pc	0.01	0.9329	0.0011	0.9351	3.83E-02
VERSAPAK_HAC_FINH_12S_3X300Pd	0.1	0.9163	0.0012	0.9187	3.77E-02
VERSAPAK_HAC_FINH_12S_3X300Pe	0.5	0.9035	0.0011	0.9057	3.66E-02
VERSAPAK_HAC_FINH_12S_3X300Pf	1	0.9136	0.0011	0.9158	3.62E-02
VERSAPAK_HAC_FINH_12S_4x272P	0.0001	0.9378	0.0010	0.9398	3.84E-02
VERSAPAK_HAC_FINH_12S_4x272Pb	0.001	0.9374	0.0012	0.9398	3.84E-02
VERSAPAK_HAC_FINH_12S_4x272Pc	0.01	0.9374	0.0010	0.9394	3.83E-02
VERSAPAK_HAC_FINH_12S_4x272Pd	0.1	0.9167	0.0011	0.9189	3.77E-02
VERSAPAK_HAC_FINH_12S_4x272Pe	0.5	0.9071	0.0013	0.9097	3.66E-02
VERSAPAK_HAC_FINH_12S_4x272Pf	1.0	0.9142	0.0012	0.9166	3.62E-02
VERSAPAK_HAC_FINH_12S_5x280P	0.0001	0.9358	0.0011	0.9380	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pb	0.001	0.9358	0.0011	0.9380	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pc	0.01	0.9345	0.0013	0.9371	3.83E-02

VERSAPAK_HAC_FINH_12S_5X280Pd	0.1	0.9144	0.0012	0.9168	3.76E-02
VERSAPAK_HAC_FINH_12S_5X280Pe	0.5	0.8629	0.0012	0.8653	3.80E-02
VERSAPAK_HAC_FINH_12S_5X280Pf	1.0	0.9163	0.0011	0.9185	3.62E-02
VERSAPAK_HAC_FINH_12S_6x288P	0.0001	0.9345	0.0012	0.9369	3.84E-02
VERSAPAK_HAC_FINH_12S_6X288Pb	0.001	0.9348	0.0013	0.9374	3.84E-02
VERSAPAK_HAC_FINH_12S_6X288Pc	0.01	0.9326	0.0013	0.9352	3.83E-02
VERSAPAK_HAC_FINH_12S_6X288Pd	0.1	0.9117	0.0012	0.9141	3.76E-02
VERSAPAK_HAC_FINH_12S_6X288Pe	0.5	0.9050	0.0013	0.9076	3.66E-02
VERSAPAK_HAC_FINH_12S_6X288Pf	1.0	0.9132	0.0012	0.9156	3.63E-02
VERSAPAK_HAC_FINH_12S_7x322P	0.0001	0.9330	0.0015	0.9360	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pb	0.001	0.9327	0.0011	0.9349	3.84E-02
VERSAPAK_HAC_FINH_12S_7X322Pc	0.01	0.9306	0.0011	0.9328	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pd	0.1	0.9124	0.0012	0.9148	3.76E-02
VERSAPAK_HAC_FINH_12S_7X322Pe	0.5	0.9045	0.0013	0.9071	3.66E-02
VERSAPAK_HAC_FINH_12S_7X322Pf	1.0	0.9133	0.0013	0.9159	3.62E-02
VERSAPAK_HAC_FINH_12S_8x312P	0.0001	0.9246	0.0012	0.9270	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pb	0.001	0.9246	0.0013	0.9272	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pc	0.01	0.9263	0.0011	0.9285	3.82E-02
VERSAPAK_HAC_FINH_12S_8X312Pd	0.1	0.9049	0.0011	0.9071	3.76E-02
VERSAPAK_HAC_FINH_12S_8X312Pe	0.5	0.9034	0.0013	0.9060	3.66E-02
VERSAPAK_HAC_FINH_12S_8X312Pf	1.0	0.9162	0.0011	0.9184	3.62E-02
VERSAPAK_HAC_FINH_12S_9x324P	0.0001	0.9214	0.0012	0.9238	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pb	0.001	0.9250	0.0012	0.9274	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pc	0.01	0.9232	0.0012	0.9256	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pd	0.1	0.9055	0.0015	0.9085	3.77E-02
VERSAPAK_HAC_FINH_12S_9X324Pe	0.5	0.9060	0.0011	0.9082	3.66E-02
VERSAPAK_HAC_FINH_12S_9X324Pf	1.0	0.9026	0.0012	0.9050	3.63E-02
VERSAPAK_HAC_FINH_12S_10x300P	0.0001	0.9114	0.0011	0.9136	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pb	0.001	0.9142	0.0013	0.9168	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pc	0.01	0.9119	0.0012	0.9143	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pd	0.1	0.8974	0.0013	0.9000	3.76E-02
VERSAPAK_HAC_FINH_12S_10X300Pe	0.5	0.8985	0.0013	0.9011	3.67E-02
VERSAPAK_HAC_FINH_12S_10X300Pf	1.0	0.9112	0.0010	0.9132	3.62E-02

VERSAPAK_HAC_FINH_12S_12x300P	0.0001	0.9032	0.0011	0.9054	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pb	0.001	0.9039	0.0012	0.9063	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pc	0.01	0.8994	0.0011	0.9016	3.82E-02
VERSAPAK_HAC_FINH_12S_12X300Pd	0.1	0.8962	0.0013	0.8988	3.76E-02
VERSAPAK_HAC_FINH_12S_12X300Pe	0.5	0.8995	0.0013	0.9021	3.67E-02
VERSAPAK_HAC_FINH_12S_12X300Pf	1.0	0.9084	0.0013	0.9110	3.63E-02
MOD0 – Region/Mixture 5 – Payload Region					
VERSAPAK_HAC_FINH_12S_4X272P	0.0001	0.9298	0.0012	0.9322	3.84E-02
VERSAPAK_HAC_FINH_12S_4X272Pb	0.001	0.9342	0.0012	0.9366	3.83E-02
VERSAPAK_HAC_FINH_12S_4X272Pc	0.01	0.9302	0.0013	0.9328	3.83E-02
VERSAPAK_HAC_FINH_12S_4X272Pd	0.1	0.9110	0.0011	0.9132	3.76E-02
VERSAPAK_HAC_FINH_12S_4X272Pe	0.5	0.9037	0.0011	0.9059	3.66E-02
VERSAPAK_HAC_FINH_12S_4X272Pf	1.0	0.9158	0.0013	0.9184	3.63E-02
VERSAPAK_HAC_FINH_12S_5X280P	0.0001	0.9364	0.0011	0.9386	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pb	0.001	0.9349	0.0011	0.9371	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pc	0.01	0.9320	0.0013	0.9346	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pd	0.1	0.9118	0.0012	0.9142	3.77E-02
VERSAPAK_HAC_FINH_12S_5X280Pe	0.5	0.8996	0.0013	0.9022	3.66E-02
VERSAPAK_HAC_FINH_12S_5X280Pf	1.0	0.9159	0.0013	0.9185	3.63E-02
MOD1 – Region/Mixture 6 – Payload Radial Insulation Region					
VERSAPAK_HAC_FINH_12S_1x324P	0.0001	0.8536	0.0012	0.8560	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pb	0.001	0.8529	0.0013	0.8555	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pc	0.01	0.8530	0.0013	0.8556	3.81E-02
VERSAPAK_HAC_FINH_12S_1X324Pd	0.1	0.8398	0.0010	0.8418	3.80E-02
VERSAPAK_HAC_FINH_12S_1X324Pe	0.5	0.8153	0.0012	0.8177	3.77E-02
VERSAPAK_HAC_FINH_12S_1X324Pf	1	0.8081	0.0013	0.8107	3.77E-02
VERSAPAK_HAC_FINH_12S_2X338P	0.0001	0.9184	0.0010	0.9204	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338Pb	0.001	0.9174	0.0011	0.9196	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338Pc	0.01	0.9176	0.0012	0.9200	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338Pd	0.1	0.8919	0.0011	0.8941	3.81E-02
VERSAPAK_HAC_FINH_12S_2X338Pe	0.5	0.8495	0.0013	0.8521	3.77E-02
VERSAPAK_HAC_FINH_12S_2X338Pf	1	0.8296	0.0012	0.8320	3.77E-02
VERSAPAK_HAC_FINH_12S_3X300P	0.0001	0.9333	0.0011	0.9355	3.84E-02

VERSAPAK_HAC_FINH_12S_3X300Pb	0.001	0.9341	0.0010	0.9361	3.83E-02
VERSAPAK_HAC_FINH_12S_3X300Pc	0.01	0.9288	0.0010	0.9308	3.83E-02
VERSAPAK_HAC_FINH_12S_3X300Pd	0.1	0.8983	0.0012	0.9007	3.81E-02
VERSAPAK_HAC_FINH_12S_3X300Pe	0.5	0.8476	0.0012	0.8500	3.77E-02
VERSAPAK_HAC_FINH_12S_3X300Pf	1	0.8290	0.0012	0.8314	3.77E-02
VERSAPAK_HAC_FINH_12S_4x272P	0.0001	0.9378	0.0010	0.9398	3.84E-02
VERSAPAK_HAC_FINH_12S_4x272Pb	0.001	0.9370	0.0011	0.9392	3.84E-02
VERSAPAK_HAC_FINH_12S_4x272Pc	0.01	0.9316	0.0013	0.9342	3.84E-02
VERSAPAK_HAC_FINH_12S_4x272Pd	0.1	0.9017	0.0011	0.9039	3.81E-02
VERSAPAK_HAC_FINH_12S_4x272Pe	0.5	0.8468	0.0016	0.8500	3.77E-02
VERSAPAK_HAC_FINH_12S_4x272Pf	1.0	0.8315	0.0012	0.8339	3.77E-02
VERSAPAK_HAC_FINH_12S_5x280P	0.0001	0.9358	0.0011	0.9380	3.84E-02
VERSAPAK_HAC_FINH_12S_5x280Pb	0.001	0.9376	0.0012	0.9400	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pc	0.01	0.9330	0.0015	0.9360	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pd	0.1	0.9007	0.0012	0.9031	3.80E-02
VERSAPAK_HAC_FINH_12S_5X280Pe	0.5	0.8465	0.0012	0.8489	3.77E-02
VERSAPAK_HAC_FINH_12S_5X280Pf	1.0	0.8318	0.0012	0.8342	3.77E-02
VERSAPAK_HAC_FINH_12S_6x288P	0.0001	0.9345	0.0012	0.9369	3.84E-02
VERSAPAK_HAC_FINH_12S_6X288Pb	0.001	0.9373	0.0012	0.9397	3.83E-02
VERSAPAK_HAC_FINH_12S_6X288Pc	0.01	0.9310	0.0014	0.9338	3.83E-02
VERSAPAK_HAC_FINH_12S_6X288Pd	0.1	0.8973	0.0013	0.8999	3.81E-02
VERSAPAK_HAC_FINH_12S_6X288Pe	0.5	0.8473	0.0010	0.8493	3.77E-02
VERSAPAK_HAC_FINH_12S_6X288Pf	1.0	0.8295	0.0011	0.8317	3.76E-02
VERSAPAK_HAC_FINH_12S_7x322P	0.0001	0.9330	0.0015	0.9360	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pb	0.001	0.9361	0.0012	0.9385	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pc	0.01	0.9312	0.0012	0.9336	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pd	0.1	0.8965	0.0012	0.8989	3.80E-02
VERSAPAK_HAC_FINH_12S_7X322Pe	0.5	0.8437	0.0011	0.8459	3.77E-02
VERSAPAK_HAC_FINH_12S_7X322Pf	1.0	0.8287	0.0014	0.8315	3.77E-02
VERSAPAK_HAC_FINH_12S_8x312P	0.0001	0.9246	0.0012	0.9270	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pb	0.001	0.9265	0.0012	0.9289	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pc	0.01	0.9223	0.0012	0.9247	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pd	0.1	0.8970	0.0013	0.8996	3.80E-02

VERSAPAK_HAC_FINH_12S_8X312Pe	0.5	0.8429	0.0012	0.8453	3.77E-02
VERSAPAK_HAC_FINH_12S_8X312Pf	1.0	0.8288	0.0011	0.8310	3.77E-02
VERSAPAK_HAC_FINH_12S_9x324P	0.0001	0.9214	0.0012	0.9238	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pb	0.001	0.9235	0.0011	0.9257	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pc	0.01	0.9202	0.0013	0.9228	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pd	0.1	0.8940	0.0012	0.8964	3.80E-02
VERSAPAK_HAC_FINH_12S_9X324Pe	0.5	0.8468	0.0011	0.8490	3.77E-02
VERSAPAK_HAC_FINH_12S_9X324Pf	1.0	0.8293	0.0012	0.8317	3.77E-02
VERSAPAK_HAC_FINH_12S_10x300P	0.0001	0.9114	0.0011	0.9136	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pb	0.001	0.9119	0.0012	0.9143	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pc	0.01	0.9115	0.0012	0.9139	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pd	0.1	0.8867	0.0013	0.8893	3.80E-02
VERSAPAK_HAC_FINH_12S_10X300Pe	0.5	0.8464	0.0013	0.8490	3.76E-02
VERSAPAK_HAC_FINH_12S_10X300Pf	1.0	0.8279	0.0012	0.8303	3.77E-02
VERSAPAK_HAC_FINH_12S_12x300P	0.0001	0.9032	0.0011	0.9054	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pb	0.001	0.9020	0.0010	0.9040	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pc	0.01	0.9030	0.0012	0.9054	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pd	0.1	0.8809	0.0012	0.8833	3.81E-02
VERSAPAK_HAC_FINH_12S_12X300Pe	0.5	0.8419	0.0012	0.8443	3.77E-02
VERSAPAK_HAC_FINH_12S_12X300Pf	1.0	0.8305	0.0012	0.8329	3.77E-02
MOD0 – Region/Mixture 6 – Payload Radial Insulation Region					
VERSAPAK_HAC_FINH_12S_4X272P	0.0001	0.9298	0.0012	0.9322	3.84E-02
VERSAPAK_HAC_FINH_12S_4X272Pb	0.001	0.9304	0.0012	0.9328	3.84E-02
VERSAPAK_HAC_FINH_12S_4X272Pc	0.01	0.9281	0.0012	0.9305	3.83E-02
VERSAPAK_HAC_FINH_12S_4X272Pd	0.1	0.8973	0.0011	0.8995	3.80E-02
VERSAPAK_HAC_FINH_12S_4X272Pe	0.5	0.8468	0.0012	0.8492	3.77E-02
VERSAPAK_HAC_FINH_12S_4X272Pf	1.0	0.8306	0.0011	0.8328	3.77E-02
VERSAPAK_HAC_FINH_12S_5X280P	0.0001	0.9364	0.0011	0.9386	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pb	0.001	0.9332	0.0012	0.9356	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pc	0.01	0.931	0.001	0.9330	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pd	0.1	0.8991	0.0015	0.9021	3.81E-02
VERSAPAK_HAC_FINH_12S_5X280Pe	0.5	0.8465	0.0013	0.8491	3.77E-02
VERSAPAK_HAC_FINH_12S_5X280Pf	1.0	0.8295	0.0011	0.8317	3.77E-02

MOD1 – Region/Mixture 7 – Top/Bottom Insulation Region					
VERSAPAK_HAC_FINH_12S_1x324P	0.0001	0.8536	0.0012	0.8560	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pb	0.001	0.8525	0.0015	0.8555	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pc	0.01	0.8569	0.0011	0.8591	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pd	0.1	0.8537	0.0012	0.8561	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pe	0.5	0.8540	0.0012	0.8564	3.81E-02
VERSAPAK_HAC_FINH_12S_1X324Pf	1	0.8536	0.0011	0.8558	3.80E-02
VERSAPAK_HAC_FINH_12S_2X338P	0.0001	0.9184	0.0010	0.9204	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338Pb	0.001	0.9158	0.0011	0.9180	3.83E-02
VERSAPAK_HAC_FINH_12S_2X338Pc	0.01	0.9156	0.0012	0.9180	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338Pd	0.1	0.9046	0.0012	0.9070	3.82E-02
VERSAPAK_HAC_FINH_12S_2X338Pe	0.5	0.8719	0.0012	0.8743	3.80E-02
VERSAPAK_HAC_FINH_12S_2X338Pf	1	0.8579	0.0013	0.8605	3.80E-02
VERSAPAK_HAC_FINH_12S_3X300P	0.0001	0.9333	0.0011	0.9355	3.84E-02
VERSAPAK_HAC_FINH_12S_3X300Pb	0.001	0.9328	0.0012	0.9352	3.84E-02
VERSAPAK_HAC_FINH_12S_3X300Pc	0.01	0.9347	0.0011	0.9369	3.84E-02
VERSAPAK_HAC_FINH_12S_3X300Pd	0.1	0.9132	0.0011	0.9154	3.82E-02
VERSAPAK_HAC_FINH_12S_3X300Pe	0.5	0.8695	0.0011	0.8717	3.79E-02
VERSAPAK_HAC_FINH_12S_3X300Pf	1	0.8544	0.0011	0.8566	3.80E-02
VERSAPAK_HAC_FINH_12S_4x272P	0.0001	0.9378	0.0010	0.9398	3.84E-02
VERSAPAK_HAC_FINH_12S_4x272Pb	0.001	0.9371	0.0012	0.9395	3.84E-02
VERSAPAK_HAC_FINH_12S_4x272Pc	0.01	0.9371	0.0012	0.9395	3.83E-02
VERSAPAK_HAC_FINH_12S_4x272Pd	0.1	0.9172	0.0012	0.9196	3.82E-02
VERSAPAK_HAC_FINH_12S_4x272Pe	0.5	0.8670	0.0012	0.8694	3.80E-02
VERSAPAK_HAC_FINH_12S_4x272Pf	1.0	0.8522	0.0012	0.8546	3.80E-02
VERSAPAK_HAC_FINH_12S_5x280P	0.0001	0.9358	0.0011	0.9380	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pb	0.001	0.9351	0.0012	0.9375	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pc	0.01	0.9359	0.0012	0.9383	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pd	0.1	0.9158	0.0011	0.9180	3.82E-02
VERSAPAK_HAC_FINH_12S_5X280Pe	0.5	0.8629	0.0012	0.8653	3.80E-02
VERSAPAK_HAC_FINH_12S_5X280Pf	1.0	0.8489	0.0012	0.8513	3.80E-02
VERSAPAK_HAC_FINH_12S_6x288P	0.0001	0.9345	0.0012	0.9369	3.84E-02
VERSAPAK_HAC_FINH_12S_6X288Pb	0.001	0.9351	0.0014	0.9379	3.83E-02

VERSAPAK_HAC_FINH_12S_6X288Pc	0.01	0.9335	0.0012	0.9359	3.83E-02
VERSAPAK_HAC_FINH_12S_6X288Pd	0.1	0.9122	0.0011	0.9144	3.82E-02
VERSAPAK_HAC_FINH_12S_6X288Pe	0.5	0.8641	0.0012	0.8665	3.80E-02
VERSAPAK_HAC_FINH_12S_6X288Pf	1.0	0.8492	0.0012	0.8516	3.80E-02
VERSAPAK_HAC_FINH_12S_7x322P	0.0001	0.9330	0.0015	0.9360	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pb	0.001	0.9345	0.0012	0.9369	3.84E-02
VERSAPAK_HAC_FINH_12S_7X322Pc	0.01	0.9328	0.0011	0.9350	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pd	0.1	0.9093	0.0014	0.9121	3.82E-02
VERSAPAK_HAC_FINH_12S_7X322Pe	0.5	0.8639	0.0012	0.8663	3.79E-02
VERSAPAK_HAC_FINH_12S_7X322Pf	1.0	0.8465	0.0013	0.8491	3.80E-02
VERSAPAK_HAC_FINH_12S_8x312P	0.0001	0.9246	0.0012	0.9270	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pb	0.001	0.9277	0.0013	0.9303	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pc	0.01	0.9239	0.0013	0.9265	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pd	0.1	0.9037	0.0013	0.9063	3.82E-02
VERSAPAK_HAC_FINH_12S_8X312Pe	0.5	0.8589	0.0011	0.8611	3.80E-02
VERSAPAK_HAC_FINH_12S_8X312Pf	1.0	0.8443	0.0012	0.8467	3.80E-02
VERSAPAK_HAC_FINH_12S_9x324P	0.0001	0.9214	0.0012	0.9238	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pb	0.001	0.9229	0.0011	0.9251	3.84E-02
VERSAPAK_HAC_FINH_12S_9X324Pc	0.01	0.9227	0.0012	0.9251	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pd	0.1	0.9022	0.0011	0.9044	3.82E-02
VERSAPAK_HAC_FINH_12S_9X324Pe	0.5	0.8501	0.0012	0.8525	3.79E-02
VERSAPAK_HAC_FINH_12S_9X324Pf	1.0	0.8441	0.0011	0.8463	3.80E-02
VERSAPAK_HAC_FINH_12S_10x300P	0.0001	0.9114	0.0011	0.9136	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pb	0.001	0.9118	0.0012	0.9142	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pc	0.01	0.9110	0.0014	0.9138	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pd	0.1	0.8953	0.0014	0.8981	3.81E-02
VERSAPAK_HAC_FINH_12S_10X300Pe	0.5	0.8527	0.0011	0.8549	3.80E-02
VERSAPAK_HAC_FINH_12S_10X300Pf	1.0	0.8415	0.0013	0.8441	3.80E-02
VERSAPAK_HAC_FINH_12S_12x300P	0.0001	0.9032	0.0011	0.9054	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pb	0.001	0.9014	0.0011	0.9036	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pc	0.01	0.9026	0.0012	0.9050	3.82E-02
VERSAPAK_HAC_FINH_12S_12X300Pd	0.1	0.8862	0.0011	0.8884	3.81E-02
VERSAPAK_HAC_FINH_12S_12X300Pe	0.5	0.8533	0.0013	0.8559	3.80E-02

VERSAPAK_HAC_FINH_12S_12X300Pf	1.0	0.8392	0.0012	0.8416	3.80E-02
MOD0 – Region/Mixture 7 – Top/Bottom Insulation Region					
VERSAPAK_HAC_FINH_12S_4X272P	0.0001	0.9298	0.0012	0.9322	3.84E-02
VERSAPAK_HAC_FINH_12S_4X272Pb	0.001	0.9258	0.0012	0.9282	3.83E-02
VERSAPAK_HAC_FINH_12S_4X272Pc	0.01	0.9290	0.0012	0.9314	3.83E-02
VERSAPAK_HAC_FINH_12S_4X272Pd	0.1	0.9110	0.0013	0.9136	3.82E-02
VERSAPAK_HAC_FINH_12S_4X272Pe	0.5	0.8688	0.0011	0.8710	3.80E-02
VERSAPAK_HAC_FINH_12S_4X272Pf	1.0	0.8507	0.0013	0.8533	3.80E-02
VERSAPAK_HAC_FINH_12S_5X280P	0.0001	0.9364	0.0011	0.9386	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pb	0.001	0.9330	0.0012	0.9354	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pc	0.01	0.9314	0.0010	0.9334	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pd	0.1	0.9112	0.0010	0.9132	3.82E-02
VERSAPAK_HAC_FINH_12S_5X280Pe	0.5	0.8626	0.0014	0.8654	3.80E-02
VERSAPAK_HAC_FINH_12S_5X280Pf	1.0	0.8512	0.0012	0.8536	3.80E-02
MOD1 – Region/Mixture 8 – Payload Radial Inner/Outer Liner Insulation Region					
VERSAPAK_HAC_FINH_12S_1x324P	0.0001	0.8536	0.0012	0.8560	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pb	0.001	0.8539	0.0011	0.8561	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pc	0.01	0.8530	0.0012	0.8554	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pd	0.1	0.8523	0.0013	0.8549	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pe	0.5	0.8459	0.0012	0.8483	3.81E-02
VERSAPAK_HAC_FINH_12S_1X324Pf	1	0.8357	0.0011	0.8379	3.80E-02
VERSAPAK_HAC_FINH_12S_2X338P	0.0001	0.9184	0.0010	0.9204	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338Pb	0.001	0.9172	0.0011	0.9194	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338Pc	0.01	0.9184	0.0011	0.9206	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338Pd	0.1	0.9140	0.0012	0.9164	3.83E-02
VERSAPAK_HAC_FINH_12S_2X338Pe	0.5	0.8962	0.0011	0.8984	3.82E-02
VERSAPAK_HAC_FINH_12S_2X338Pf	1	0.8802	0.0013	0.8828	3.81E-02
VERSAPAK_HAC_FINH_12S_3X300P	0.0001	0.9333	0.0011	0.9355	3.84E-02
VERSAPAK_HAC_FINH_12S_3X300Pb	0.001	0.9342	0.0012	0.9366	3.84E-02
VERSAPAK_HAC_FINH_12S_3X300Pc	0.01	0.9345	0.0013	0.9371	3.84E-02
VERSAPAK_HAC_FINH_12S_3X300Pd	0.1	0.9286	0.0011	0.9308	3.83E-02
VERSAPAK_HAC_FINH_12S_3X300Pe	0.5	0.9046	0.0012	0.9070	3.82E-02
VERSAPAK_HAC_FINH_12S_3X300Pf	1	0.8842	0.0011	0.8864	3.80E-02

VERSAPAK_HAC_FINH_12S_1x324P	0.0001	0.8536	0.0012	0.8560	3.82E-02
VERSAPAK_HAC_FINH_12S_4x272P	0.0001	0.9378	0.0010	0.9398	3.84E-02
VERSAPAK_HAC_FINH_12S_4x272Pb	0.001	0.9374	0.0012	0.9398	3.84E-02
VERSAPAK_HAC_FINH_12S_4x272Pc	0.01	0.9373	0.0011	0.9395	3.83E-02
VERSAPAK_HAC_FINH_12S_4x272Pd	0.1	0.9315	0.0013	0.9341	3.83E-02
VERSAPAK_HAC_FINH_12S_4x272Pe	0.5	0.9075	0.0013	0.9101	3.82E-02
VERSAPAK_HAC_FINH_12S_4x272Pf	1.0	0.8833	0.0012	0.8857	3.81E-02
VERSAPAK_HAC_FINH_12S_5x280P	0.0001	0.9358	0.0011	0.9380	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pb	0.001	0.9363	0.0012	0.9387	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pc	0.01	0.9364	0.0012	0.9388	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pd	0.1	0.9306	0.0011	0.9328	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pe	0.5	0.9061	0.0013	0.9087	3.82E-02
VERSAPAK_HAC_FINH_12S_5X280Pf	1.0	0.8835	0.0011	0.8857	3.80E-02
VERSAPAK_HAC_FINH_12S_6x288P	0.0001	0.9345	0.0012	0.9369	3.84E-02
VERSAPAK_HAC_FINH_12S_6X288Pb	0.001	0.9347	0.0011	0.9369	3.83E-02
VERSAPAK_HAC_FINH_12S_6X288Pc	0.01	0.9338	0.0013	0.9364	3.83E-02
VERSAPAK_HAC_FINH_12S_6X288Pd	0.1	0.9285	0.0011	0.9307	3.83E-02
VERSAPAK_HAC_FINH_12S_6X288Pe	0.5	0.9061	0.0011	0.9083	3.81E-02
VERSAPAK_HAC_FINH_12S_6X288Pf	1.0	0.8836	0.0013	0.8862	3.80E-02
VERSAPAK_HAC_FINH_12S_7x322P	0.0001	0.9330	0.0015	0.9360	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pb	0.001	0.9329	0.0013	0.9355	3.84E-02
VERSAPAK_HAC_FINH_12S_7X322Pc	0.01	0.9326	0.0012	0.9350	3.84E-02
VERSAPAK_HAC_FINH_12S_7X322Pd	0.1	0.9275	0.0011	0.9297	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pe	0.5	0.9025	0.0012	0.9049	3.81E-02
VERSAPAK_HAC_FINH_12S_7X322Pf	1.0	0.8804	0.0011	0.8826	3.80E-02
VERSAPAK_HAC_FINH_12S_8x312P	0.0001	0.9246	0.0012	0.9270	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pb	0.001	0.9266	0.0012	0.9290	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pc	0.01	0.9249	0.0012	0.9273	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pd	0.1	0.9213	0.0012	0.9237	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pe	0.5	0.9004	0.0013	0.9030	3.82E-02
VERSAPAK_HAC_FINH_12S_8X312Pf	1.0	0.8777	0.0012	0.8801	3.80E-02
VERSAPAK_HAC_FINH_12S_9x324P	0.0001	0.9214	0.0012	0.9238	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pb	0.001	0.9238	0.0012	0.9262	3.83E-02

VERSAPAK_HAC_FINH_12S_9X324Pc	0.01	0.9252	0.0012	0.9276	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pd	0.1	0.9208	0.0012	0.9232	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pe	0.5	0.8991	0.0011	0.9013	3.81E-02
VERSAPAK_HAC_FINH_12S_9X324Pf	1.0	0.8777	0.0012	0.8801	3.80E-02
VERSAPAK_HAC_FINH_12S_10x300P	0.0001	0.9114	0.0011	0.9136	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pb	0.001	0.9130	0.0013	0.9156	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pc	0.01	0.9126	0.0012	0.9150	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pd	0.1	0.9101	0.0011	0.9123	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pe	0.5	0.8905	0.0016	0.8937	3.82E-02
VERSAPAK_HAC_FINH_12S_10X300Pf	1.0	0.8726	0.0012	0.8750	3.80E-02
VERSAPAK_HAC_FINH_12S_12x300P	0.0001	0.9032	0.0011	0.9054	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pb	0.001	0.9012	0.0013	0.9038	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pc	0.01	0.9018	0.0013	0.9044	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pd	0.1	0.9001	0.0012	0.9025	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pe	0.5	0.8817	0.0012	0.8841	3.82E-02
VERSAPAK_HAC_FINH_12S_12X300Pf	1.0	0.8647	0.0013	0.8673	3.80E-02
MOD0 – Region/Mixture 8 – Payload Radial Inner/Outer Liner Insulation Region					
VERSAPAK_HAC_FINH_12S_4X272P	0.0001	0.9298	0.0012	0.9322	3.84E-02
VERSAPAK_HAC_FINH_12S_4X272Pb	0.001	0.9341	0.0012	0.9365	3.83E-02
VERSAPAK_HAC_FINH_12S_4X272Pc	0.01	0.9301	0.0011	0.9323	3.83E-02
VERSAPAK_HAC_FINH_12S_4X272Pd	0.1	0.9237	0.0011	0.9259	3.83E-02
VERSAPAK_HAC_FINH_12S_4X272Pe	0.5	0.9009	0.0012	0.9033	3.81E-02
VERSAPAK_HAC_FINH_12S_4X272Pf	1.0	0.881	0.0013	0.8836	3.80E-02
VERSAPAK_HAC_FINH_12S_5X280P	0.0001	0.9364	0.0011	0.9386	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pb	0.001	0.9339	0.0011	0.9361	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pc	0.01	0.9336	0.0011	0.9358	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pd	0.1	0.9267	0.0011	0.9289	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pe	0.5	0.9049	0.0015	0.9079	3.82E-02
VERSAPAK_HAC_FINH_12S_5X280Pf	1.0	0.8814	0.0012	0.8838	3.80E-02
MOD1 – Region/Mixture 9 – Exterior Package Region					
VERSAPAK_HAC_FINH_12S_1x324P	0.0001	0.8536	0.0012	0.8560	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pb	0.001	0.8538	0.0011	0.8560	3.82E-02
VERSAPAK_HAC_FINH_12S_1X324Pc	0.01	0.8535	0.0012	0.8559	3.81E-02

VERSAPAK_HAC_FINH_12S_1X324Pd	0.1	0.8510	0.0012	0.8534	3.81E-02
VERSAPAK_HAC_FINH_12S_1X324Pe	0.5	0.8319	0.0014	0.8347	3.81E-02
VERSAPAK_HAC_FINH_12S_1X324Pf	1	0.8248	0.0011	0.8270	3.80E-02
VERSAPAK_HAC_FINH_12S_2X338P	0.0001	0.9184	0.0010	0.9204	3.84E-02
VERSAPAK_HAC_FINH_12S_2X338Pb	0.001	0.9184	0.0012	0.9208	3.83E-02
VERSAPAK_HAC_FINH_12S_2X338Pc	0.01	0.9171	0.0011	0.9193	3.83E-02
VERSAPAK_HAC_FINH_12S_2X338Pd	0.1	0.9104	0.0012	0.9128	3.83E-02
VERSAPAK_HAC_FINH_12S_2X338Pe	0.5	0.8790	0.0011	0.8812	3.80E-02
VERSAPAK_HAC_FINH_12S_2X338Pf	1	0.8559	0.0011	0.8581	3.80E-02
VERSAPAK_HAC_FINH_12S_3X300P	0.0001	0.9333	0.0011	0.9355	3.84E-02
VERSAPAK_HAC_FINH_12S_3X300Pb	0.001	0.9324	0.0011	0.9346	3.84E-02
VERSAPAK_HAC_FINH_12S_3X300Pc	0.01	0.9323	0.0011	0.9345	3.84E-02
VERSAPAK_HAC_FINH_12S_3X300Pd	0.1	0.9216	0.0011	0.9238	3.83E-02
VERSAPAK_HAC_FINH_12S_3X300Pe	0.5	0.8826	0.0011	0.8848	3.80E-02
VERSAPAK_HAC_FINH_12S_3X300Pf	1	0.8577	0.0010	0.8597	3.80E-02
VERSAPAK_HAC_FINH_12S_4x272P	0.0001	0.9378	0.0010	0.9398	3.84E-02
VERSAPAK_HAC_FINH_12S_4X272Pb	0.001	0.9367	0.0011	0.9389	3.84E-02
VERSAPAK_HAC_FINH_12S_4x272Pc	0.01	0.9353	0.0011	0.9375	3.84E-02
VERSAPAK_HAC_FINH_12S_4x272Pd	0.1	0.9247	0.0011	0.9269	3.83E-02
VERSAPAK_HAC_FINH_12S_4x272Pe	0.5	0.8839	0.0011	0.8861	3.81E-02
VERSAPAK_HAC_FINH_12S_4x272Pf	1.0	0.8602	0.0013	0.8628	3.80E-02
VERSAPAK_HAC_FINH_12S_5x280P	0.0001	0.9358	0.0011	0.9380	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pb	0.001	0.9352	0.0012	0.9376	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pc	0.01	0.9354	0.0013	0.9380	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pd	0.1	0.9235	0.0010	0.9255	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pe	0.5	0.8831	0.0011	0.8853	3.80E-02
VERSAPAK_HAC_FINH_12S_5X280Pf	1.0	0.8580	0.0012	0.8604	3.80E-02
VERSAPAK_HAC_FINH_12S_6x288P	0.0001	0.9345	0.0012	0.9369	3.84E-02
VERSAPAK_HAC_FINH_12S_6X288Pb	0.001	0.9353	0.0011	0.9375	3.83E-02
VERSAPAK_HAC_FINH_12S_6X288Pc	0.01	0.9337	0.0011	0.9359	3.84E-02
VERSAPAK_HAC_FINH_12S_6X288Pd	0.1	0.9211	0.0012	0.9235	3.83E-02
VERSAPAK_HAC_FINH_12S_6X288Pe	0.5	0.8802	0.0012	0.8826	3.80E-02
VERSAPAK_HAC_FINH_12S_6X288Pf	1.0	0.8567	0.0011	0.8589	3.80E-02

VERSAPAK_HAC_FINH_12S_7x322P	0.0001	0.9330	0.0015	0.9360	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pb	0.001	0.9345	0.0013	0.9371	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pc	0.01	0.9340	0.0011	0.9362	3.83E-02
VERSAPAK_HAC_FINH_12S_7X322Pd	0.1	0.9197	0.0011	0.9219	3.82E-02
VERSAPAK_HAC_FINH_12S_7X322Pe	0.5	0.8786	0.0011	0.8808	3.81E-02
VERSAPAK_HAC_FINH_12S_7X322Pf	1.0	0.8574	0.0013	0.8600	3.80E-02
VERSAPAK_HAC_FINH_12S_8x312P	0.0001	0.9246	0.0012	0.9270	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pb	0.001	0.9259	0.0012	0.9283	3.84E-02
VERSAPAK_HAC_FINH_12S_8X312Pc	0.01	0.9210	0.0012	0.9234	3.83E-02
VERSAPAK_HAC_FINH_12S_8X312Pd	0.1	0.9159	0.0012	0.9183	3.82E-02
VERSAPAK_HAC_FINH_12S_8X312Pe	0.5	0.8798	0.0011	0.8820	3.80E-02
VERSAPAK_HAC_FINH_12S_8X312Pf	1.0	0.8548	0.0012	0.8572	3.80E-02
VERSAPAK_HAC_FINH_12S_9x324P	0.0001	0.9214	0.0012	0.9238	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pb	0.001	0.9227	0.0013	0.9253	3.84E-02
VERSAPAK_HAC_FINH_12S_9X324Pc	0.01	0.9221	0.0012	0.9245	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pd	0.1	0.9158	0.0013	0.9184	3.83E-02
VERSAPAK_HAC_FINH_12S_9X324Pe	0.5	0.8771	0.0012	0.8795	3.81E-02
VERSAPAK_HAC_FINH_12S_9X324Pf	1.0	0.8557	0.0011	0.8579	3.80E-02
VERSAPAK_HAC_FINH_12S_10x300P	0.0001	0.9114	0.0011	0.9136	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pb	0.001	0.9145	0.0012	0.9169	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pc	0.01	0.9086	0.0011	0.9108	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pd	0.1	0.9032	0.0013	0.9058	3.83E-02
VERSAPAK_HAC_FINH_12S_10X300Pe	0.5	0.8712	0.0011	0.8734	3.80E-02
VERSAPAK_HAC_FINH_12S_10X300Pf	1.0	0.8559	0.0012	0.8583	3.80E-02
VERSAPAK_HAC_FINH_12S_12x300P	0.0001	0.9032	0.0011	0.9054	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pb	0.001	0.9035	0.0014	0.9063	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pc	0.01	0.8998	0.0011	0.9020	3.83E-02
VERSAPAK_HAC_FINH_12S_12X300Pd	0.1	0.8950	0.0012	0.8974	3.82E-02
VERSAPAK_HAC_FINH_12S_12X300Pe	0.5	0.8669	0.0012	0.8693	3.81E-02
VERSAPAK_HAC_FINH_12S_12X300Pf	1.0	0.8498	0.0012	0.8522	3.80E-02
MOD0 – Region/Mixture 9 – Exterior Package Region					
VERSAPAK_HAC_FINH_12S_4X272P	0.0001	0.9298	0.0012	0.9322	3.84E-02
VERSAPAK_HAC_FINH_12S_4X272Pb	0.001	0.9290	0.0011	0.9312	3.84E-02

VERSAPAK_HAC_FINH_12S_4X272Pc	0.01	0.9293	0.0012	0.9317	3.83E-02
VERSAPAK_HAC_FINH_12S_4X272Pd	0.1	0.9195	0.0013	0.9221	3.83E-02
VERSAPAK_HAC_FINH_12S_4X272Pe	0.5	0.8808	0.0012	0.8832	3.80E-02
VERSAPAK_HAC_FINH_12S_4X272Pf	1.0	0.8575	0.0012	0.8599	3.80E-02
VERSAPAK_HAC_FINH_12S_5X280P	0.0001	0.9364	0.0011	0.9386	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pb	0.001	0.9359	0.0012	0.9383	3.84E-02
VERSAPAK_HAC_FINH_12S_5X280Pc	0.01	0.9363	0.0014	0.9391	3.83E-02
VERSAPAK_HAC_FINH_12S_5X280Pd	0.1	0.9216	0.0012	0.9240	3.82E-02
VERSAPAK_HAC_FINH_12S_5X280Pe	0.5	0.8774	0.0012	0.8798	3.80E-02
VERSAPAK_HAC_FINH_12S_5X280Pf	1.0	0.8594	0.0012	0.8618	3.80E-02

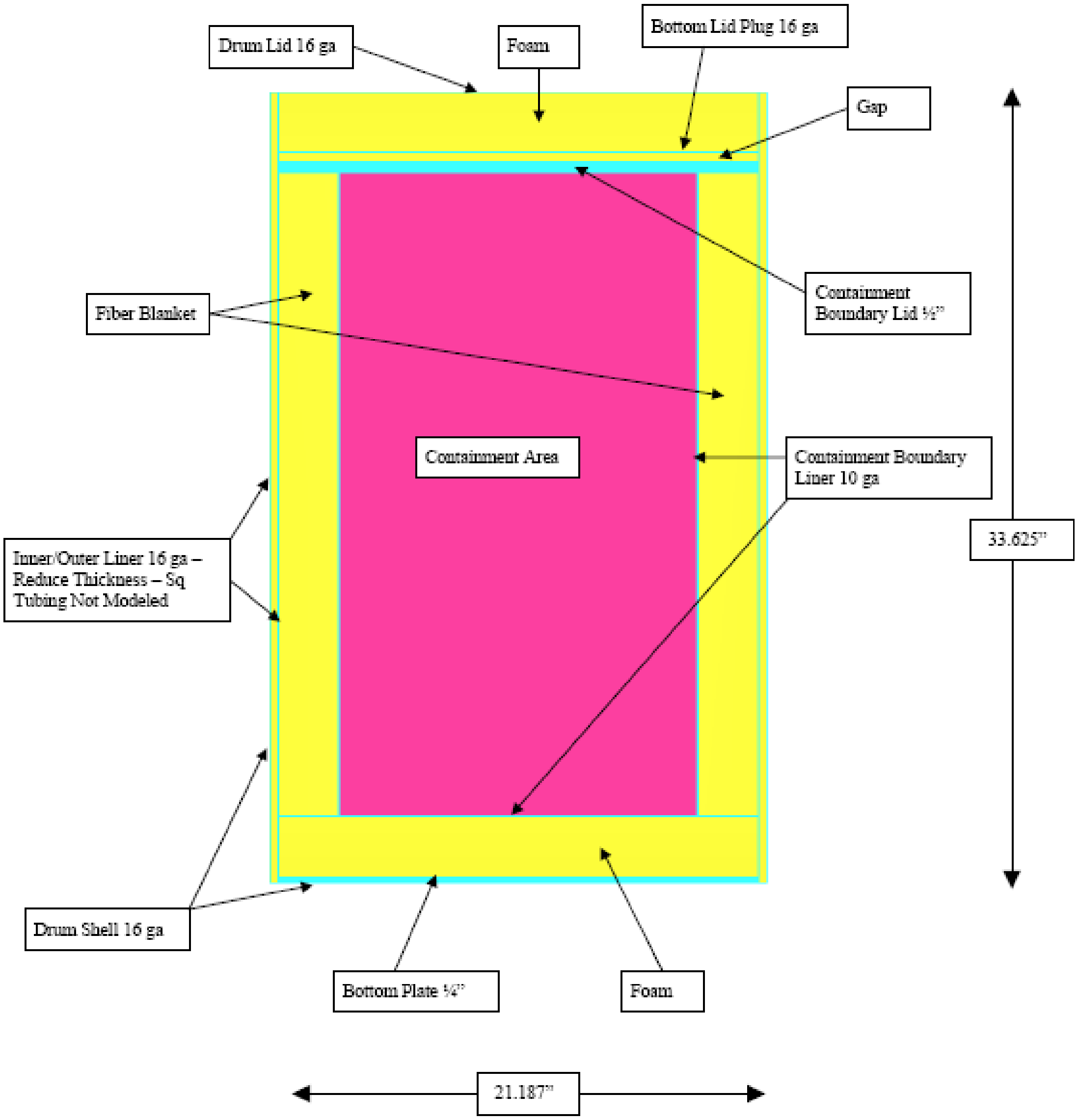

Figure 6-1 Illustration of the KENO Model of the Century Versa-Pac Shipping Container for the Normal Condition of Transport and Hypothetical Accident Condition.

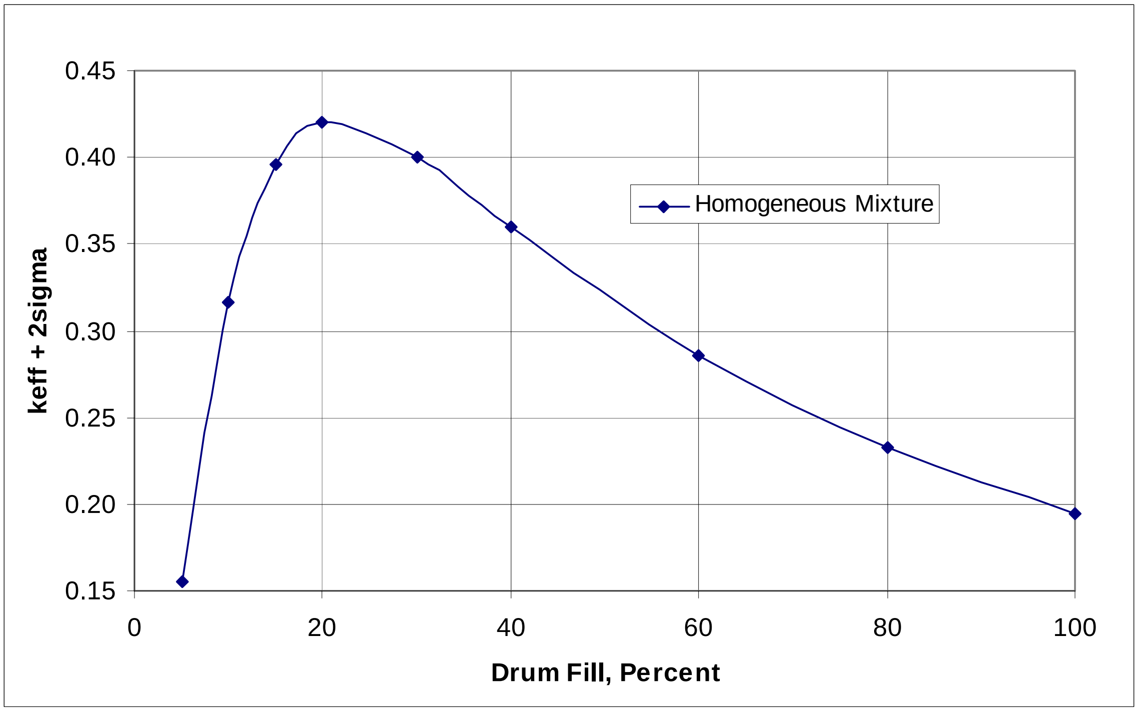

Figure 6-2 KENO VI results for single model calculation as a function of drum fill percentage for the Normal Condition of Transport and Hypothetical Condition.

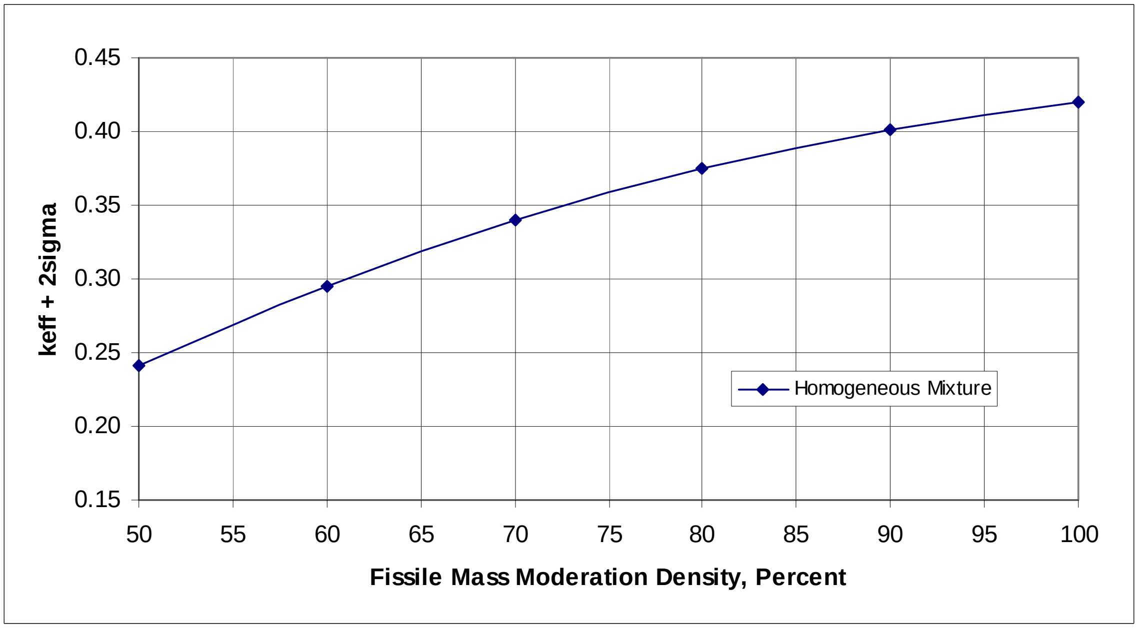

Figure 6-3 KENO VI results for single model calculation as a function of poly-moderator density (20% filled drum) for the Normal Condition of Transport and Hypothetical Condition.

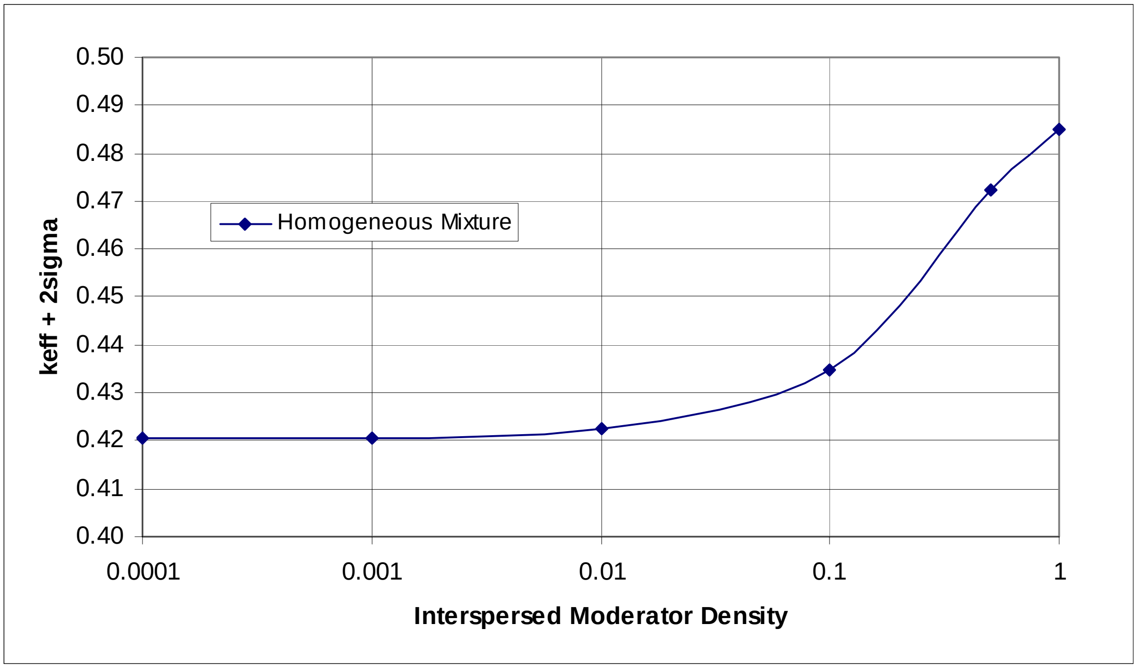

Figure 6-4 KENO VI results for single model calculation as a function of interspersed moderator (20% filled drum) for the Normal Condition of Transport and Hypothetical Condition.

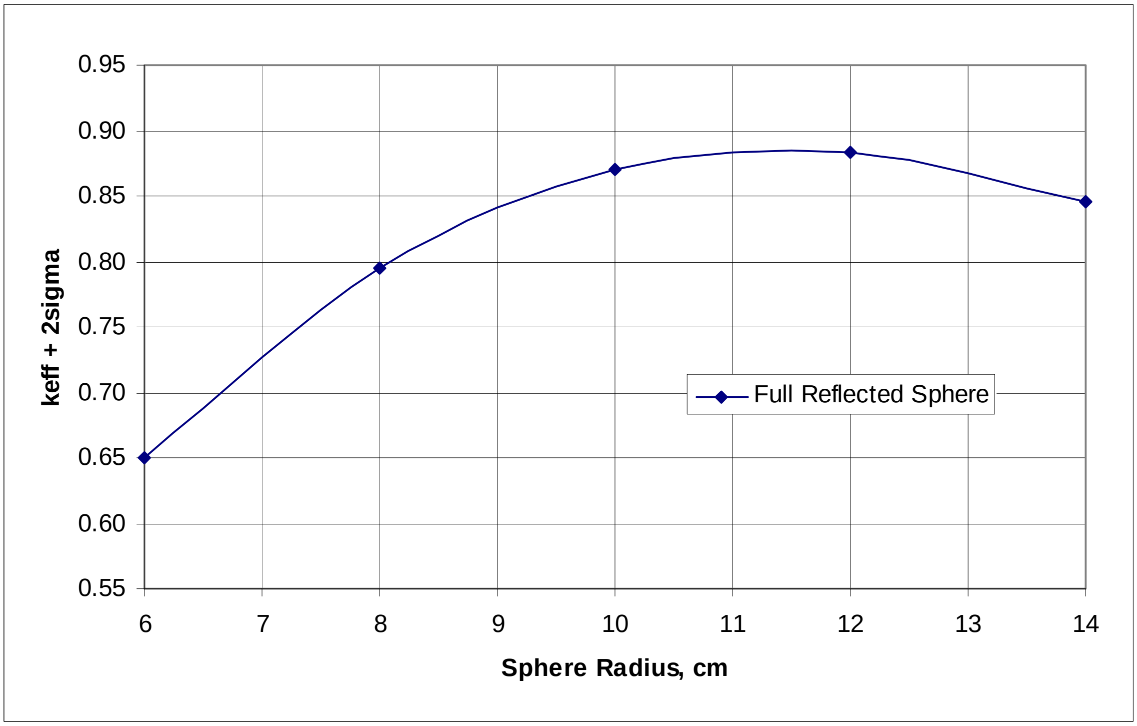

Figure 6-5 KENO VI results for fully reflected spheres representing the Normal Condition of Transport and Hypothetical Condition for a single package.

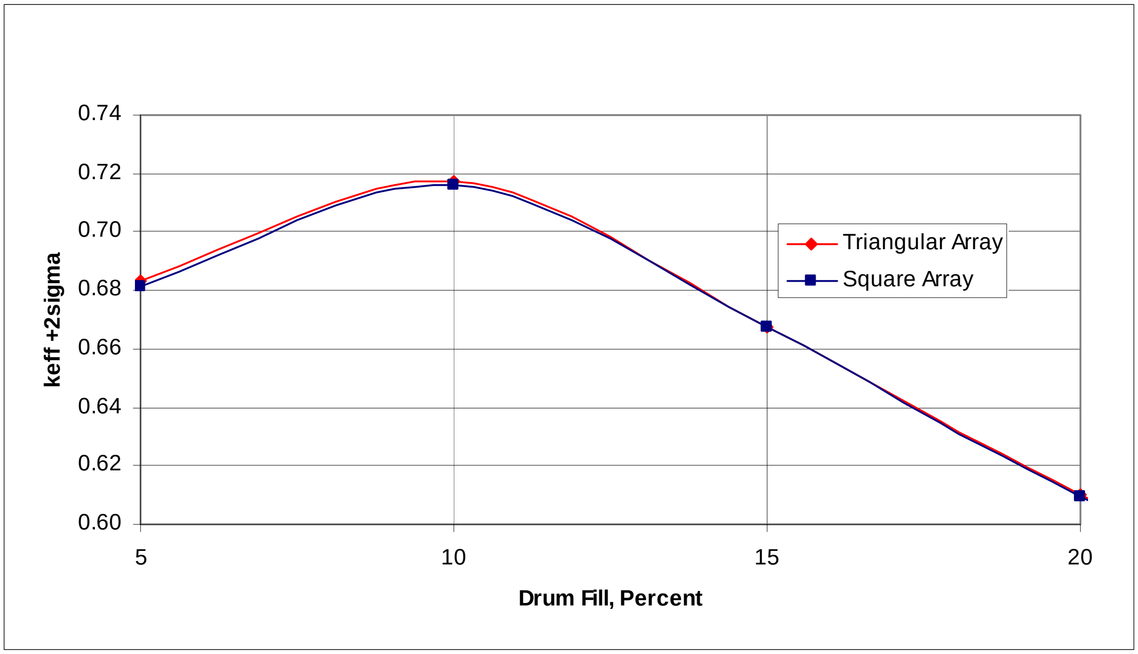

Figure 6-6 KENO VI results for infinite array model calculation as a function of drum fill percentage for the Normal Condition of Transport and Hypothetical Condition.

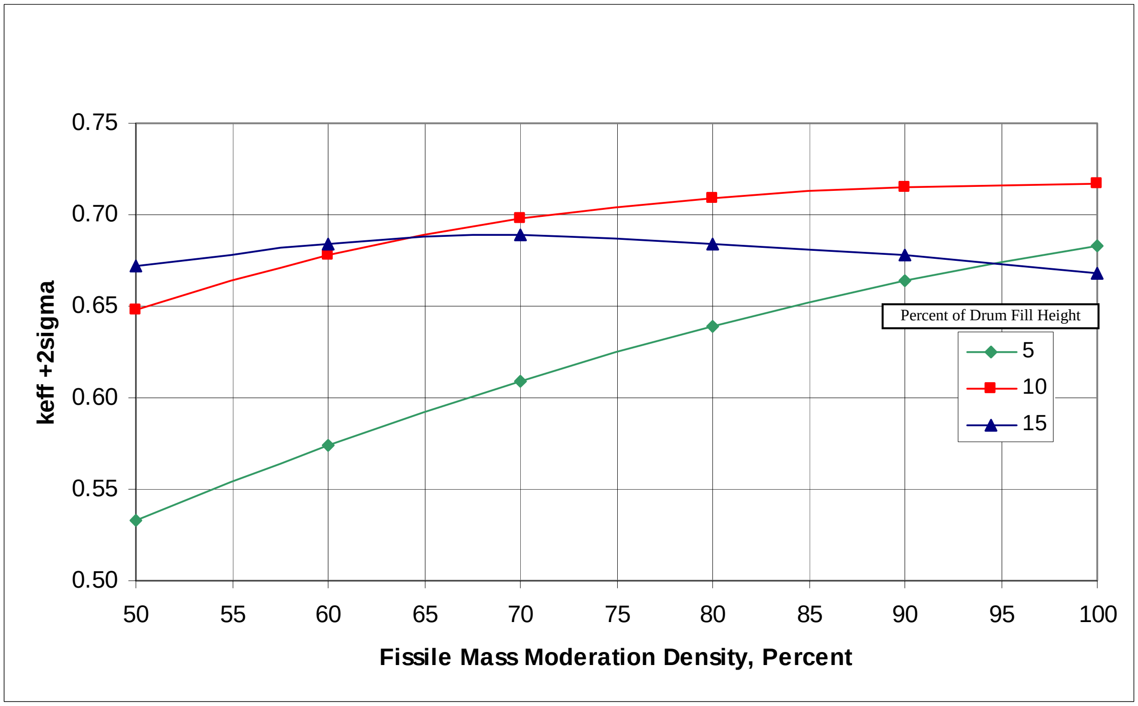

Figure 6-7 KENO VI results for infinite array model calculation as a function of the fissile mass poly-moderator density (as a function of drum fill height, 5%, 10%, and 20% filled drums) for the Normal Condition of Transport and Hypothetical Condition.

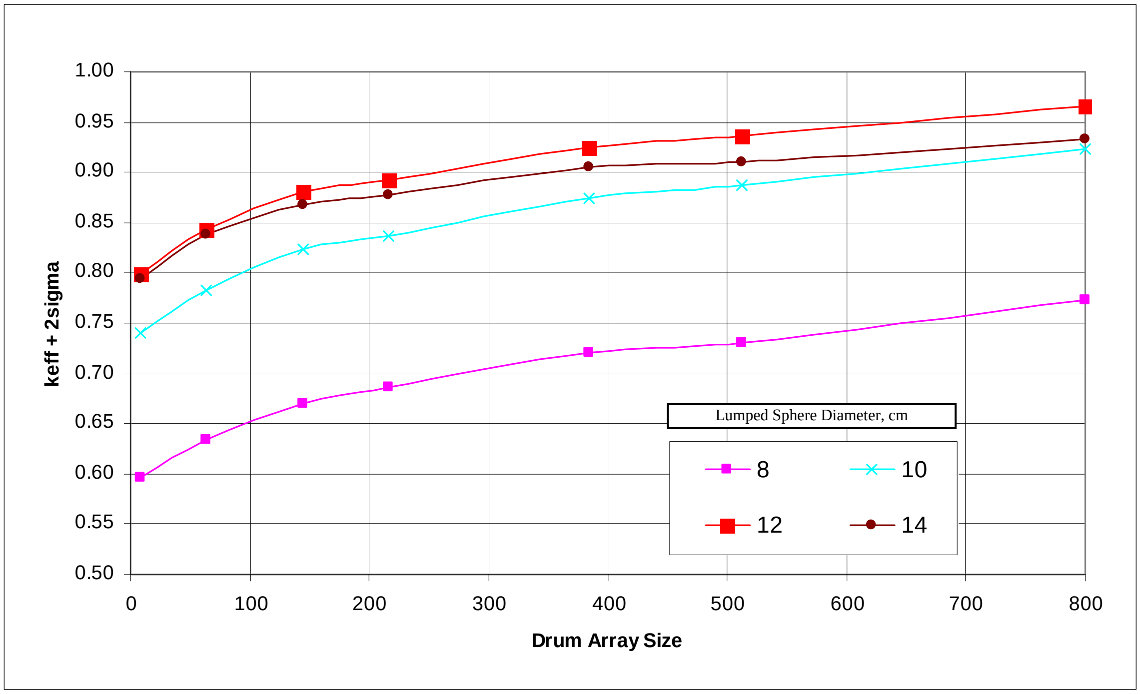

Figure 6-8 KENO VI results for triangular package array model calculation with lumped spheres as a function of package array size for the Normal Condition of Transport and Hypothetical Condition.

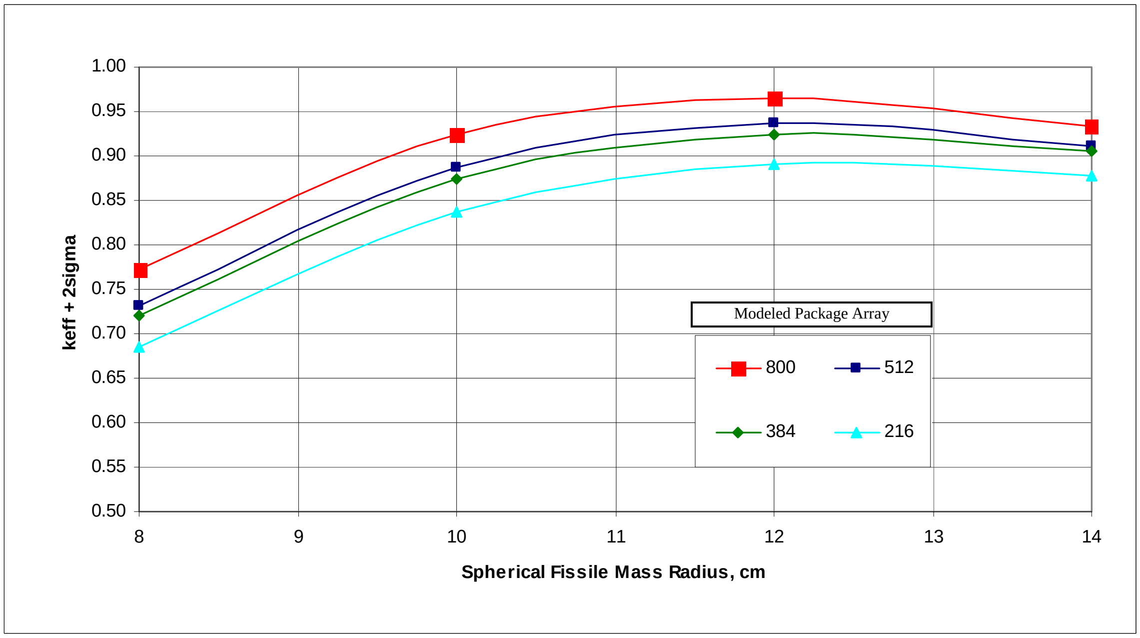

Figure 6-9 KENO VI results for triangular package array model calculation with lumped spheres as a function of sphere diameter for the Normal Condition of Transport and Hypothetical Condition.

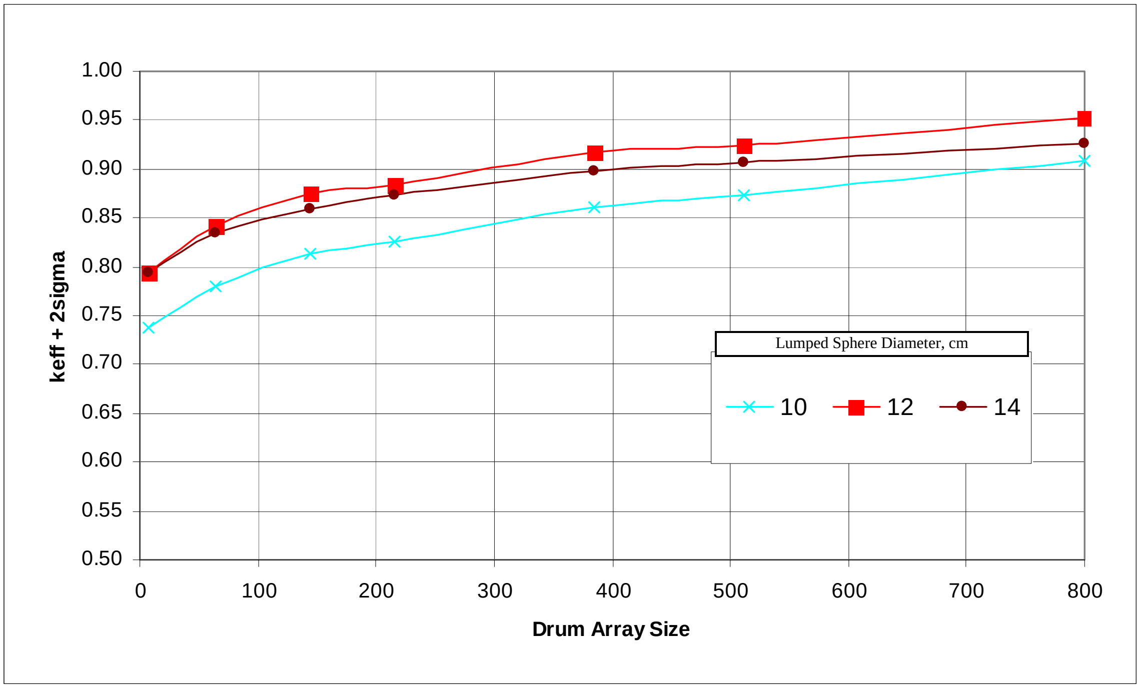

Figure 6-10 KENO VI results for square package array model calculation with lumped spheres as a function of package array size for the Normal Condition of Transport and Hypothetical Condition.

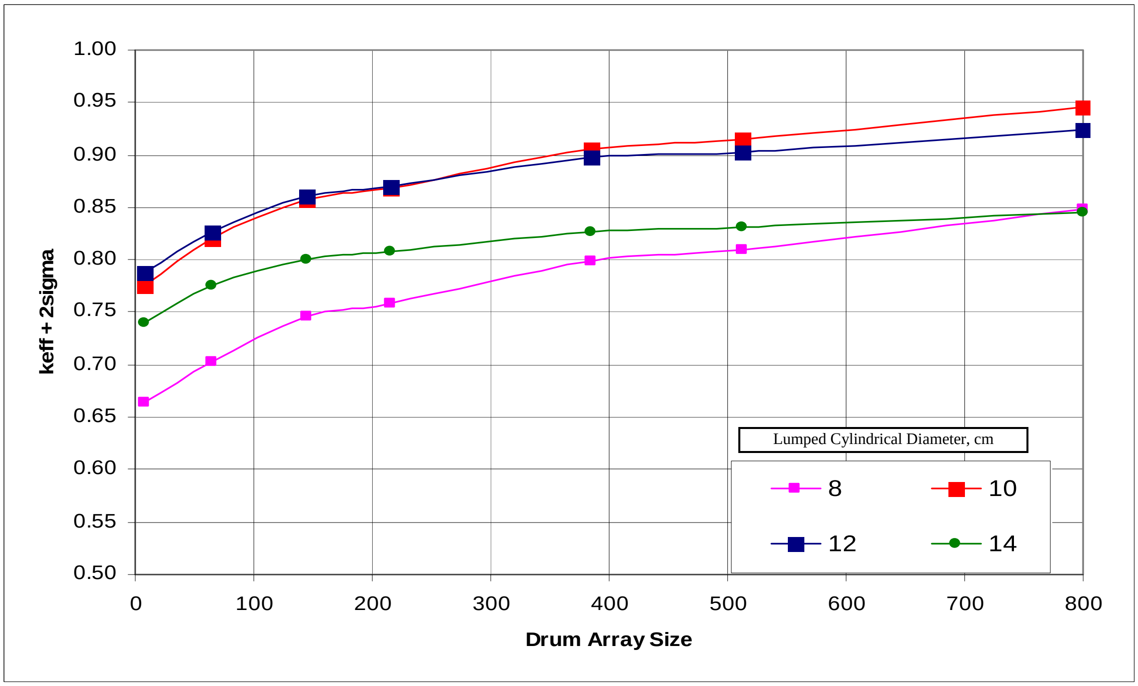

Figure 6-11 KENO VI results for triangular package array model calculation with lumped cylinders as a function of package array size for the Normal Condition of Transport and Hypothetical Condition.

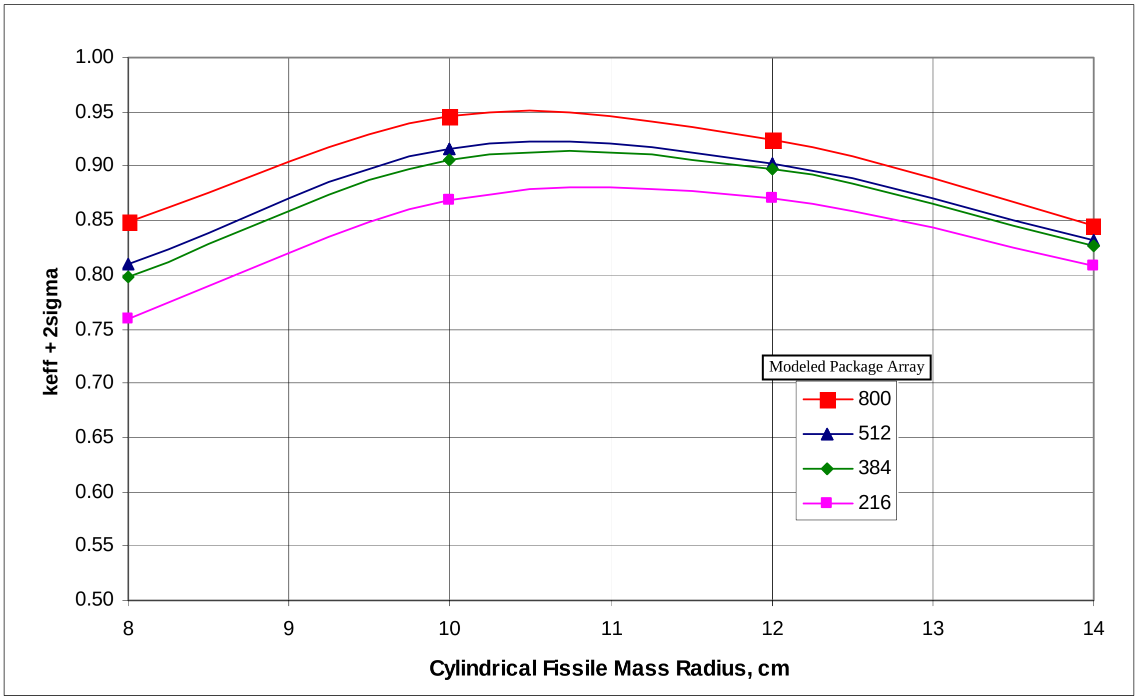

Figure 6-12 KENO VI results for triangular package array model calculation with lumped cylinders as a function of cylinder diameter for the Normal Condition of Transport and Hypothetical Condition.

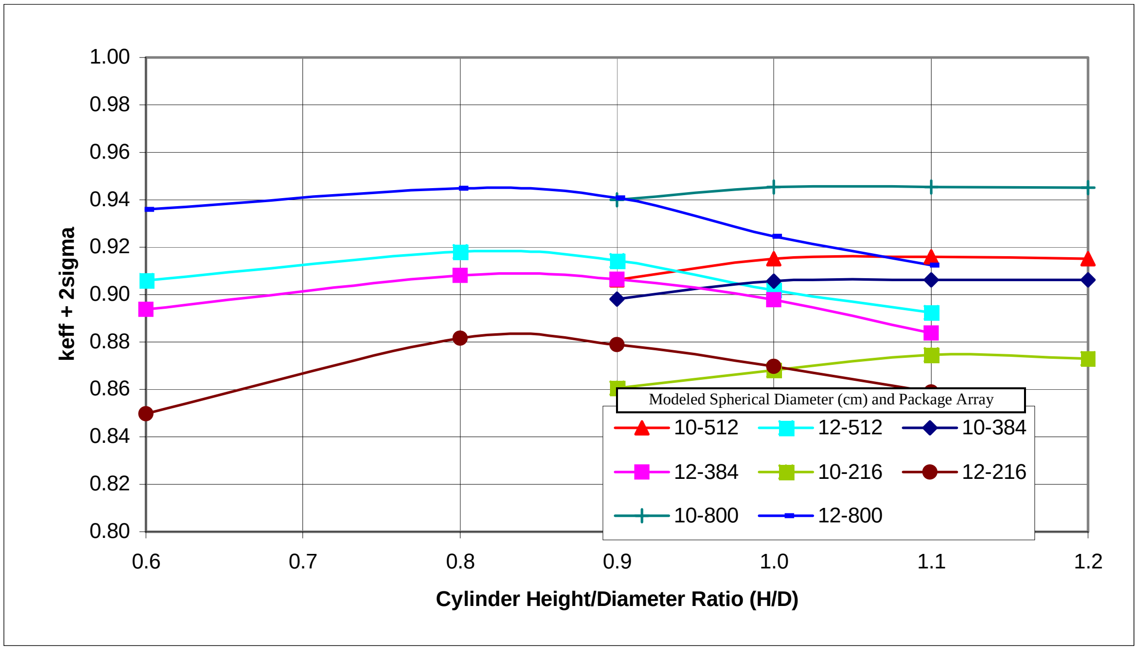

Figure 6-13 KENO VI results for triangular package array model calculation with lumped cylinders as a function of cylinder height-to-diameter ratio for the Normal Condition of Transport and Hypothetical Condition.

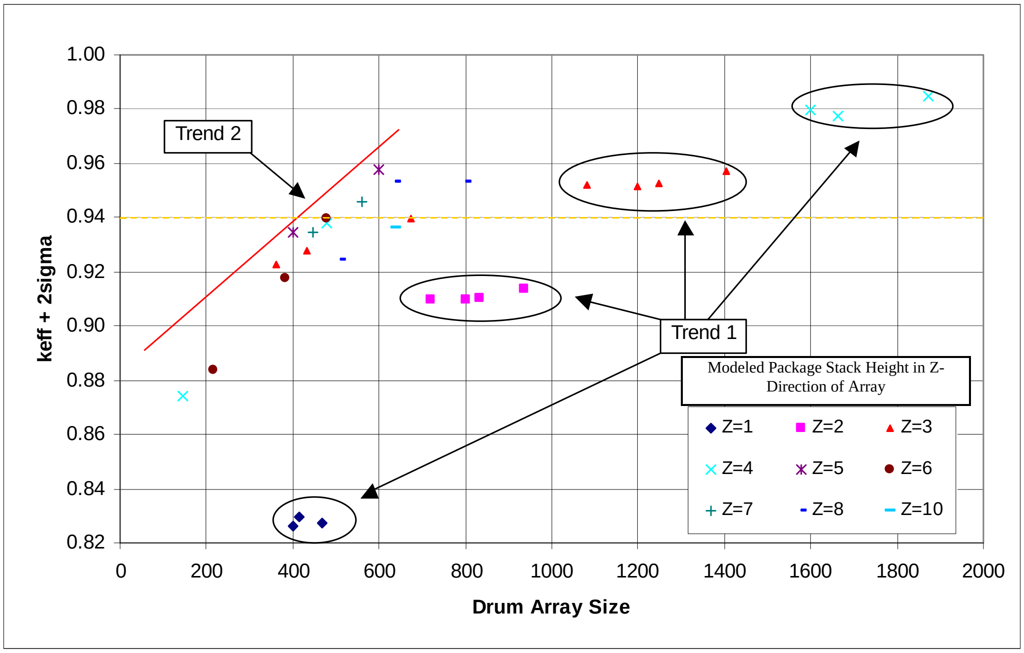

Figure 6-14 KENO VI results for triangular package array model calculation with poly-moderated (0.92 g/cc) lumped spheres as a function of package array size for the Normal Condition of Transport and Hypothetical Condition.

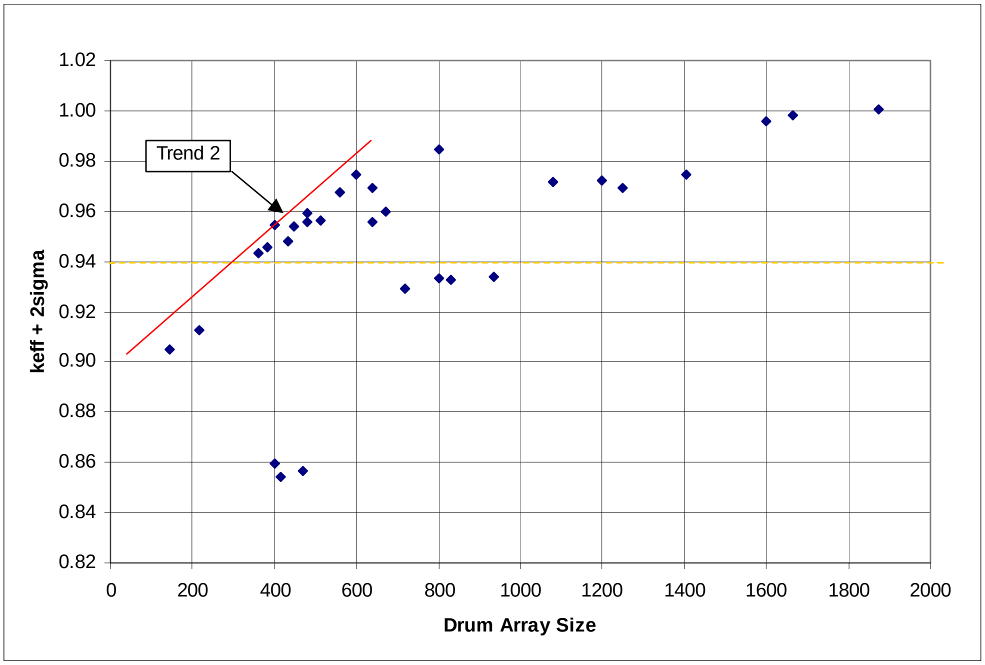

Figure 6-15 KENO VI results for triangular package array model calculation with poly-moderated (0.98 g/cc) lumped spheres as a function of package array size for the Normal Condition of Transport and Hypothetical Condition.

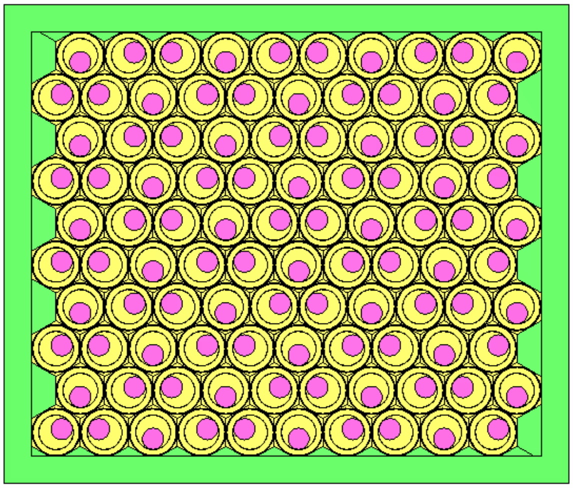

Figure 6-16 Illustration of KENO VI triangular package array model with orientation of lumped fissile mass for the Normal Condition of Transport and Hypothetical Condition.

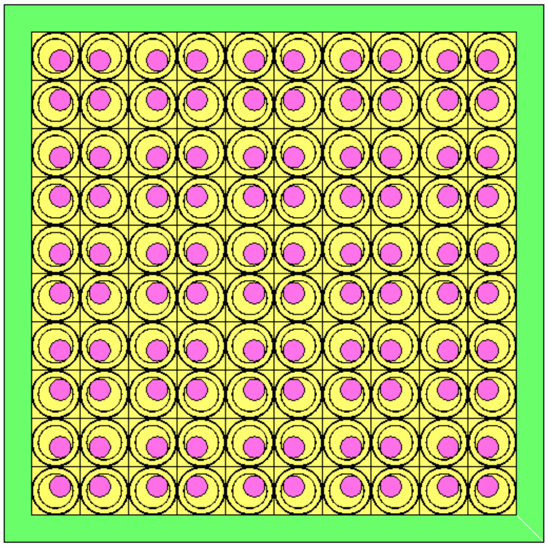

Figure 6-17 Illustration of KENO VI square package array model with orientation of lumped fissile mass for the Normal Condition of Transport and Hypothetical Condition.

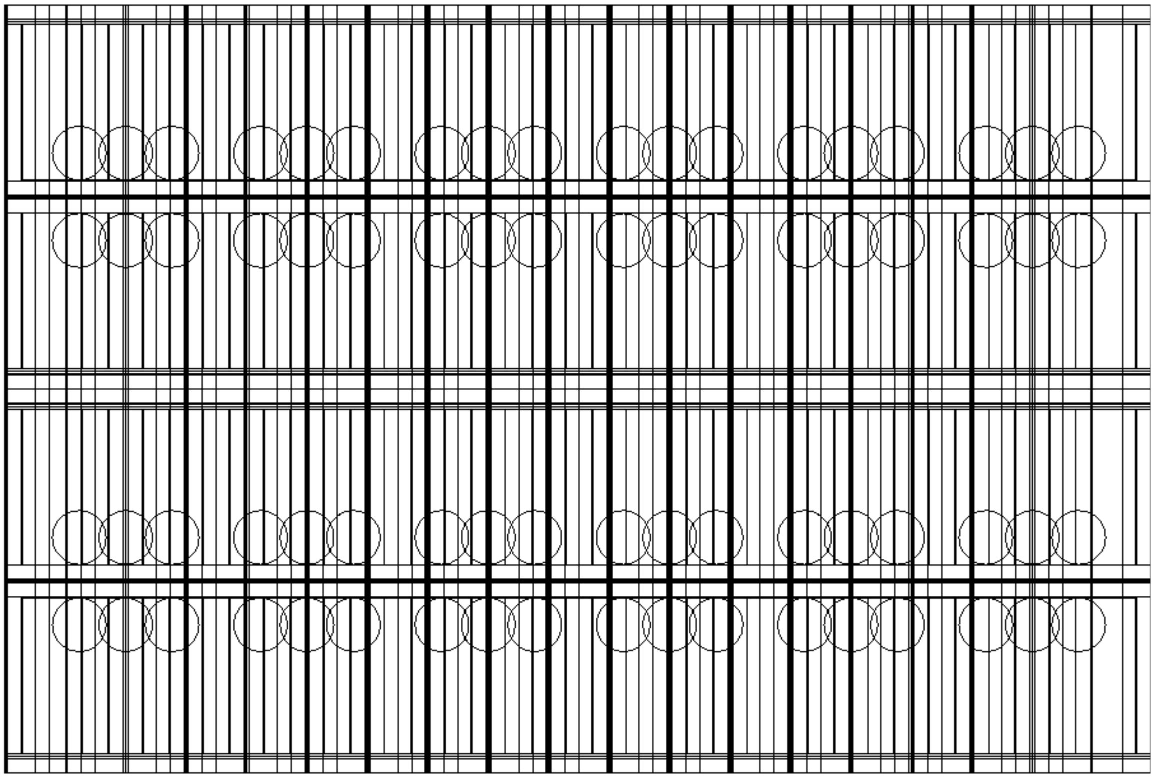

Figure 6-18 Illustration of KENO VI stacked X-Z view of the inverted bottom package and normally orientated top package in a triangular package array model with orientation of lumped fissile mass for the NCT and HAC (Initial MOD0 Configuration).

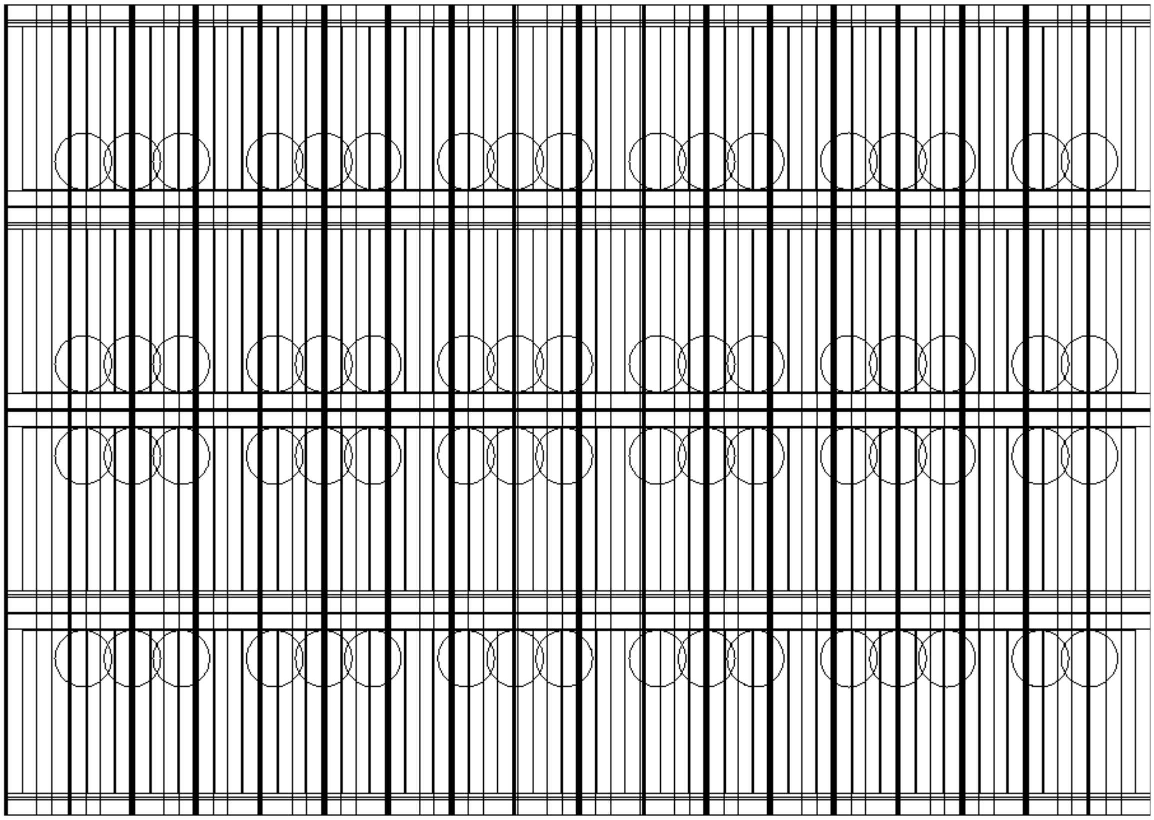

Figure 6-19 Illustration of KENO VI stacked X-Z view for the triangular package array model with orientation of lumped fissile mass for the NCT and HAC (MOD1 Configuration).

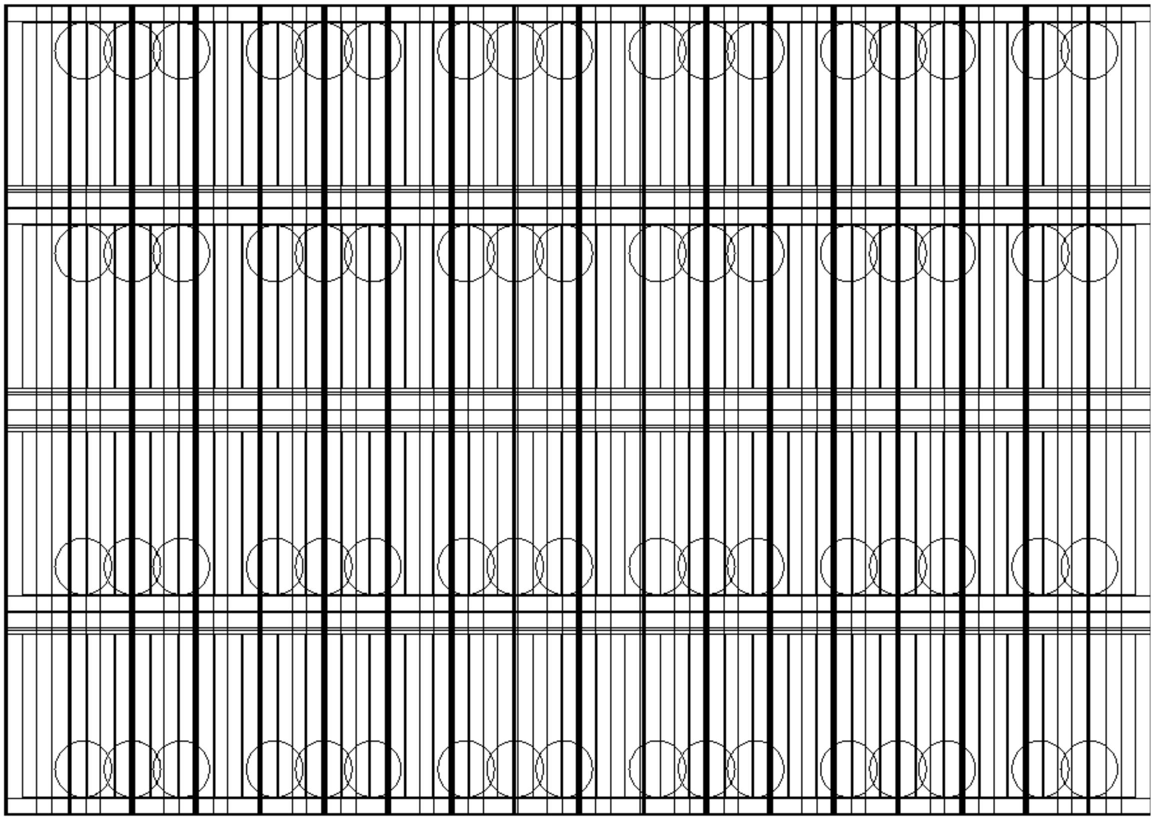

Figure 6-20 Illustration of KENO VI stacked X-Z view for the triangular package array model with orientation of lumped fissile mass for the NCT and HAC (MOD2 Configuration).

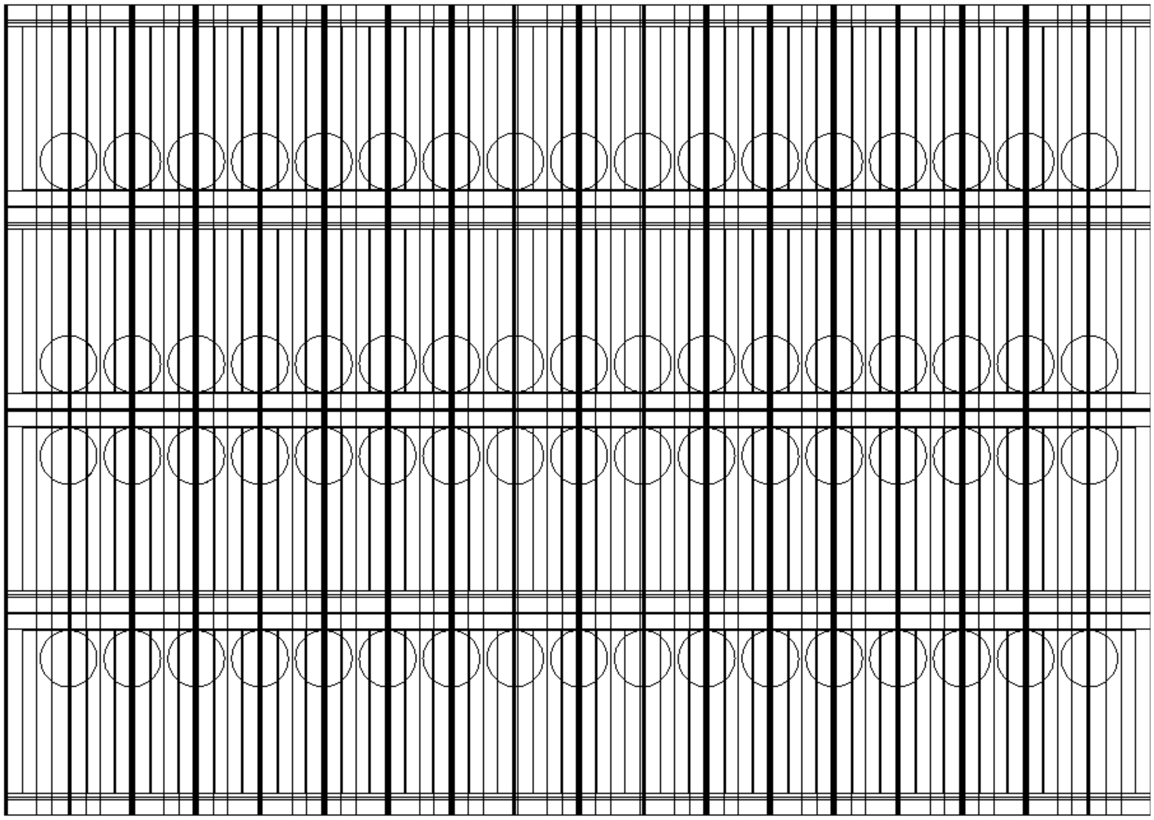

Figure 6-21 Illustration of KENO VI stacked X-Z view for the triangular package array model with orientation of lumped fissile mass for the NCT and HAC (MOD3 Configuration – note centered spheres as opposed to overlapping view as observed in Figure 6-19).

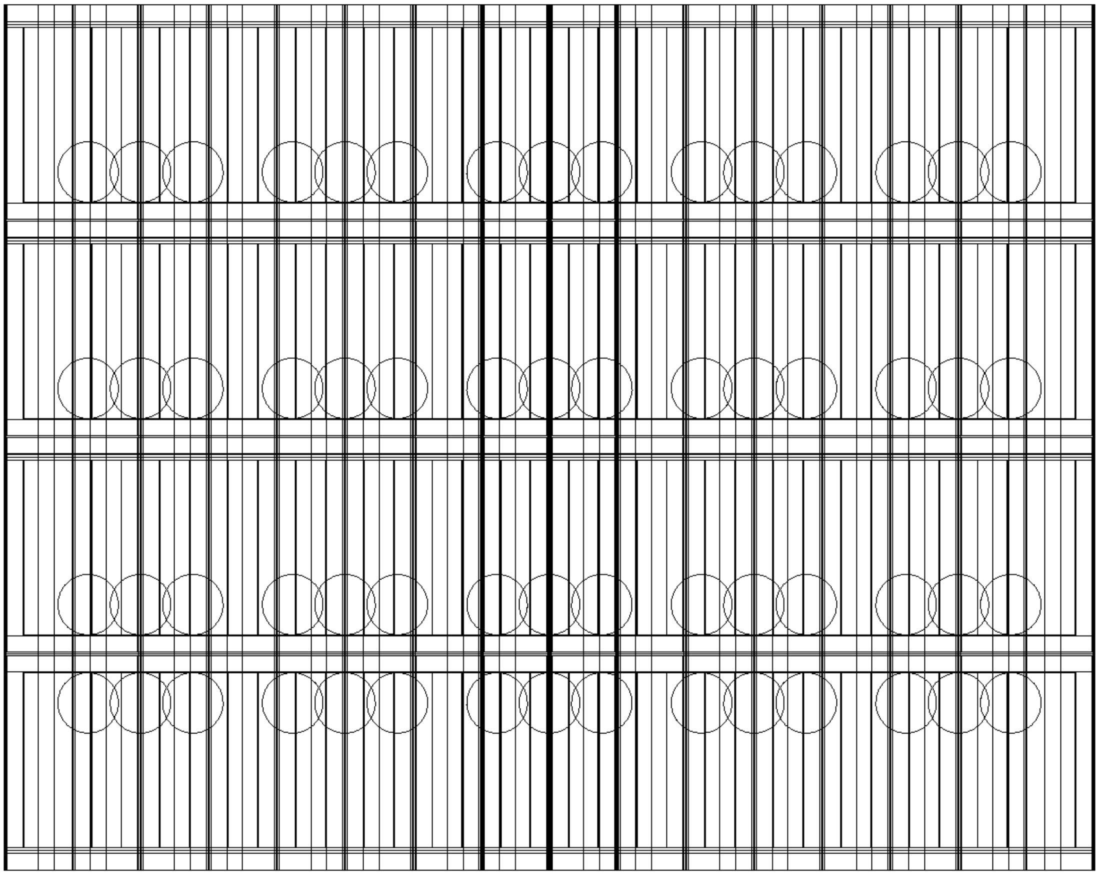

Figure 6-22 Illustration of KENO VI stacked X-Z view for the triangular package array model with orientation of lumped fissile mass for the NCT and HAC (MOD4 Configuration).

APPENDIX 6.9

Section 6.9.1 – Selected SCALE 4.4a Input Cases

Input Case: VERSA_HAC_INFH_10_A
HAC Case Infinite Homogeneous Hexagonal 10% Fill

```
=CSAS26     PARM='SIZE=00100000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00114760 294.0 92235 100.0 END
POLYETHYLENE    1 0.99885 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088  -27.6225  -34.5281
MEDIA  1  1  1
CYLINDER  2  19.2088  34.5281  -34.5281
MEDIA  5  1  2  -1
CYLINDER  3  19.5163  34.5281  -34.8357
MEDIA  3  1  3  -2  -1
CYLINDER  4  25.8663  34.5281  -34.8357
MEDIA  5  1  4  -3  -2  -1
CYLINDER  5  25.8663  35.7727  -34.8357
MEDIA  3  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.8560  -34.8357
MEDIA  5  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  36.9914  -34.8357
MEDIA  3  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  25.8663  43.3414  -41.1857
MEDIA  5  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.0017  43.3414  -41.7953
MEDIA  3  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.6374  43.3414  -41.7963
MEDIA  5  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.7727  43.3414  -41.7953
MEDIA  3  1  11  -10  -9  -8  -7  -6  -5  -4  -3  -
2  -1
CYLINDER  12  26.9081  43.4768  -41.9307
MEDIA  3  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
HEXPRISM  13  26.9081  43.4768  -41.9307
MEDIA  5  1  13 -12 -11 -10  -9  -8  -7  -6  -5  -4
-3  -2  -1
BOUNDARY  13

GLOBAL
UNIT  100
CUBOID  10  26.9081 -26.9081  93.2124  0.00
85.4075  0.00
ARRAY  1  10  PLACE 2 1 1  2*0.0 41.9307
BOUNDARY  10
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=3  NUY=3  NUZ=1
 FILL  10 10 10
      10 10 10
     10 10 10  END FILL
END ARRAY
READ BOUNDS
ALL=SPEC
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_INFH2_10_A
HAC Case Infinite Homogeneous Model 2 Hexagonal Inverted 10% Fill

```
=CSAS26     PARM='SIZE=00100000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00114760 294.0 92235 100.0 END
POLYETHYLENE    1 0.99885 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088  -27.6225  -34.5281
MEDIA  1  1  1
CYLINDER  2  19.2088  34.5281  -34.5281
MEDIA  5  1  2  -1
CYLINDER  3  19.5163  34.5281  -34.8357
MEDIA  3  1  3  -2  -1
CYLINDER  4  25.8663  34.5281  -34.8357
MEDIA  5  1  4  -3  -2  -1
CYLINDER  5  25.8663  35.7727  -34.8357
MEDIA  3  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.8560  -34.8357
MEDIA  5  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  36.9914  -34.8357
MEDIA  3  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  25.8663  43.3414  -41.1857
MEDIA  5  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.0017  43.3414  -41.7953
MEDIA  3  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.6374  43.3414  -41.7963
MEDIA  5  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.7727  43.3414  -41.7953
MEDIA  3  1  11  -10  -9  -8  -7  -6  -5  -4  -3  -
2  -1
CYLINDER  12  26.9081  43.4768  -41.9307
MEDIA  3  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
HEXPRISM  13  26.9081  43.4768  -41.9307
MEDIA  5  1  13 -12 -11 -10  -9  -8  -7  -6  -5  -4
-3  -2  -1
BOUNDARY  13

UNIT  20
CYLINDER  1  19.2088  34.5281   27.6225
MEDIA  1  1  1
CYLINDER  2  19.2088  34.5281  -34.5281
MEDIA  5  1  2  -1
CYLINDER  3  19.5163  34.8357  -34.5281
MEDIA  3  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -34.5281
MEDIA  5  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -35.7727
MEDIA  3  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.8560
```

```
MEDIA  5  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  34.8357  -36.9914
MEDIA  3  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  25.8663  41.1857  -43.3414
MEDIA  5  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.0017  41.7953  -43.3414
MEDIA  3  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.6374 41.7963  -43.3414
MEDIA  5  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.7727 41.7953  -43.3414
MEDIA  3  1  11  -10  -9  -8  -7  -6  -5  -4  -3  -
2  -1
CYLINDER  12  26.9081 41.9307  -43.4768
MEDIA  3  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
HEXPRISM  13  26.9081 41.9307  -43.4768
MEDIA  5  1  13 -12 -11 -10  -9  -8  -7  -6  -5  -4
-3  -2  -1
BOUNDARY  13

GLOBAL
UNIT  100
CUBOID  10  26.9081 -26.9081  93.2124  0.00
170.8150  0.00
ARRAY  1  10  PLACE 2 1 1  2*0.0 43.4768
BOUNDARY  10
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=3  NUY=3  NUZ=2
 FILL  20 20 20
      20 20 20
     20 20 20
       10 10 10
      10 10 10
     10 10 10  END FILL
END ARRAY
READ BOUNDS
ALL=SPEC
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINS_12S_A7 (MOD0 Array Configuration)
HAC Case Finite In-Homogeneous Square Lattice 12-cm Spheres 800 Packages

```
=CSAS26     PARM='SIZE=00100000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1 0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=5.097 Y=5.097  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
CUBOID  12  4P26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=5.097 Y=5.097  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
CUBOID  12  4P26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-5.097 Y=5.097  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
CUBOID  12  4P26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12
```

```
UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-5.097 Y=5.097  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
CUBOID  12  4P26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=5.097 Y=-5.097  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
CUBOID  12  4P26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=5.097 Y=-5.097  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
CUBOID  12  4P26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-5.097 Y=-5.097  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
CUBOID  12  4P26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-5.097 Y=-5.097  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
CUBOID  12  4P26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1
```

```
UNIT  200
CUBOID  10  107.6324  0.00  107.6324  0.00  170.815
0.00
ARRAY  1  10  PLACE 1 1 1 26.9081  26.9081  43.4768
BOUNDARY  10
GLOBAL
UNIT  300
CUBOID  10  538.16  0.00  538.16  0.00  683.260
0.00
ARRAY  2  10  PLACE 1 1 1  3*0.00
CUBOID  20  568.64  -30.48  568.64  -30.48  713.74
-30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
ARA=1 NUX=2 NUY=2 NUZ=2
      FILL 11 21 31 41 10 20 30 40  END FILL
ARA=2 NUX=5 NUY=5 NUZ=4
      FILL  F200  END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_A7 (MOD0 Array Configuration)
HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 800 Packages

```
=CSAS26     PARM='SIZE=00100000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1 0.99746 294.0  END
‘SUB FOR HIGH DENSITY POLY
‘POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
‘SUB FOR GRAPHITE
'GRAPHITE   1 0.99746 294.0  END
'INTERSPERSED MODERATOR
H2O         2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O         4 1.0   294.0  END
'INSULATION
H2O         5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
```

```
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12
```

```
UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
```

```
CUBOID  10  565.1  0.00  473.3  0.00  683.260  0.00
ARRAY  1  10  PLACE 6 2 1  26.9081  26.9081
43.4768
CUBOID  20  595.55  -30.48  503.75  -30.48  713.74
-30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=16 NUY=12 NUZ=8
      FILL 51 51 51 51 51 51 51 51 51 51 51 51 51
51 51 51
          51 51 51 51 51 11 21 31 11 21 31 11 21 31
11 51
         51 51 51 51 51 31 11 21 31 11 21 31 11 21
31 51
        51 51 51 51 11 21 31 11 21 31 11 21 31 11
51 51
       51 51 51 51 31 11 21 31 11 21 31 11 21 31 51
51
      51 51 51 11 21 31 11 21 31 11 21 31 11 51 51
51
     51 51 51 31 11 21 31 11 21 31 11 21 31 51 51
51
    51 51 11 21 31 11 21 31 11 21 31 11 51 51 51 51
   51 51 31 11 21 31 11 21 31 11 21 31 51 51 51 51
  51 11 21 31 11 21 31 11 21 31 11 51 51 51 51 51
 51 31 11 21 31 11 21 31 11 21 31 51 51 51 51 51
51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
           50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50
          50 50 50 50 50 10 20 30 10 20 30 10 20 30
10 50
         50 50 50 50 50 30 10 20 30 10 20 30 10 20
30 50
        50 50 50 50 10 20 30 10 20 30 10 20 30 10
50 50
       50 50 50 50 30 10 20 30 10 20 30 10 20 30 50
50
      50 50 50 10 20 30 10 20 30 10 20 30 10 50 50
50
     50 50 50 30 10 20 30 10 20 30 10 20 30 50 50
50
    50 50 10 20 30 10 20 30 10 20 30 10 50 50 50 50
   50 50 30 10 20 30 10 20 30 10 20 30 50 50 50 50
  50 10 20 30 10 20 30 10 20 30 10 50 50 50 50 50
 50 30 10 20 30 10 20 30 10 20 30 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
3Q384 END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_10X064 (MOD0 Array Configuration)
HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 8X8X10 Packages

```
=CSAS26     PARM='SIZE=00100000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1 0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
```

```
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
```

```
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  457.5  0.00  380.1  0.00  854.075  0.00
ARRAY  1  10  PLACE 5 2 1  26.9081  26.9081
43.4768
CUBOID  20  487.91  -30.48  410.53  -30.48  884.555
-30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=13  NUY=10  NUZ=10
    FILL 51 51 51 51 51 51 51 51 51 51 51 51 51
        51 51 51 51 11 21 31 11 21 31 11 21 51
       51 51 51 51 31 11 21 31 11 21 31 11 51
      51 51 51 11 21 31 11 21 31 11 21 51 51
     51 51 51 31 11 21 31 11 21 31 11 51 51
    51 51 11 21 31 11 21 31 11 21 51 51 51
   51 51 31 11 21 31 11 21 31 11 51 51 51
  51 11 21 31 11 21 31 11 21 51 51 51 51
 51 31 11 21 31 11 21 31 11 51 51 51 51
51 51 51 51 51 51 51 51 51 51 51 51 51
         50 50 50 50 50 50 50 50 50 50 50 50 50
        50 50 50 50 10 20 30 10 20 30 10 20 50
       50 50 50 50 30 10 20 30 10 20 30 10 50
      50 50 50 10 20 30 10 20 30 10 20 50 50
     50 50 50 30 10 20 30 10 20 30 10 50 50
    50 50 10 20 30 10 20 30 10 20 50 50 50
   50 50 30 10 20 30 10 20 30 10 50 50 50
  50 10 20 30 10 20 30 10 20 50 50 50 50
 50 30 10 20 30 10 20 30 10 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50
4Q260  END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_1X324 (MOD0 Array Configuration)
HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 18X18X1 Packages

```
=CSAS26     PARM='SIZE=00900000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
'PARAFFIN       1  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
```

```
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
```

```
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  995.5997  0.00  846.1215  0.00  85.4075
0.00
ARRAY  1  10  PLACE 10 2 1  26.9081  26.9081
43.4768
CUBOID  20  1026.0797  -30.48  876.6015 -30.48
115.8875  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=28  NUY=20  NUZ=1
FILL
                   51 51 51 51 51 51 51 51 51 51 51
51 51 51 51 51 51 51 51
51 51 51 51 51 51 51 51 51
                  51 51 51 51 51 51 51 51 51 11 21
31 11 21 31 11 21 31 11
21 31 11 21 31 11 21 31 51
                 51 51 51 51 51 51 51 51 51 31 11
21 31 11 21 31 11 21 31
11 21 31 11 21 31 11 21 51
                51 51 51 51 51 51 51 51 11 21 31 11
21 31 11 21 31 11 21
31 11 21 31 11 21 31 51 51
               51 51 51 51 51 51 51 51 31 11 21 31
11 21 31 11 21 31 11
21 31 11 21 31 11 21 51 51
              51 51 51 51 51 51 51 11 21 31 11 21
31 11 21 31 11 21 31
11 21 31 11 21 31 51 51 51
             51 51 51 51 51 51 51 31 11 21 31 11 21
31 11 21 31 11 21
31 11 21 31 11 21 51 51 51
            51 51 51 51 51 51 11 21 31 11 21 31 11
21 31 11 21 31 11
21 31 11 21 31 51 51 51 51
           51 51 51 51 51 51 31 11 21 31 11 21 31
11 21 31 11 21 31
11 21 31 11 21 51 51 51 51
          51 51 51 51 51 11 21 31 11 21 31 11 21 31
11 21 31 11 21
31 11 21 31 51 51 51 51 51
         51 51 51 51 51 31 11 21 31 11 21 31 11 21
31 11 21 31 11
21 31 11 21 51 51 51 51 51
        51 51 51 51 11 21 31 11 21 31 11 21 31 11
21 31 11 21 31
11 21 31 51 51 51 51 51 51
       51 51 51 51 31 11 21 31 11 21 31 11 21 31 11
21 31 11 21
31 11 21 51 51 51 51 51 51
      51 51 51 11 21 31 11 21 31 11 21 31 11 21 31
11 21 31 11
21 31 51 51 51 51 51 51 51
     51 51 51 31 11 21 31 11 21 31 11 21 31 11 21
31 11 21 31
11 21 51 51 51 51 51 51 51
    51 51 11 21 31 11 21 31 11 21 31 11 21 31 11 21
31 11 21
31 51 51 51 51 51 51 51 51
   51 51 31 11 21 31 11 21 31 11 21 31 11 21 31 11
21 31 11
21 51 51 51 51 51 51 51 51
  51 11 21 31 11 21 31 11 21 31 11 21 31 11 21 31
11 21 31
51 51 51 51 51 51 51 51 51
 51 31 11 21 31 11 21 31 11 21 31 11 21 31 11 21 31
11 21
51 51 51 51 51 51 51 51 51
51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
51 51
51 51 51 51 51 51 51 51 51  END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_2X338 (MOD0 Array Configuration)
HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 13X13X2 Packages

```
=CSAS26     PARM='SIZE=00900000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
'PARAFFIN       1  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
```

```
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
```

```
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
```

```
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  726.5187  0.00  613.5706  0.00
170.8150  0.00
ARRAY  1  10  PLACE 8 2 1  26.9081  26.9081
43.4768
CUBOID  20  756.9987  -30.48  643.5706 -30.48
201.2950  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=21  NUY=15  NUZ=2
FILL
               51 51 51 51 51 51 51 51 51 51 51 51
51 51 51 51 51 51 51 51 51
              51 51 51 51 51 51 51 11 21 31 11 21
31 11 21 31 11 21 31 11 51
             51 51 51 51 51 51 51 31 11 21 31 11 21
31 11 21 31 11 21 31 51
            51 51 51 51 51 51 11 21 31 11 21 31 11
21 31 11 21 31 11 51 51
           51 51 51 51 51 51 31 11 21 31 11 21 31
11 21 31 11 21 31 51 51
          51 51 51 51 51 11 21 31 11 21 31 11 21 31
11 21 31 11 51 51 51
         51 51 51 51 51 31 11 21 31 11 21 31 11 21
31 11 21 31 51 51 51
        51 51 51 51 11 21 31 11 21 31 11 21 31 11
21 31 11 51 51 51 51
       51 51 51 51 31 11 21 31 11 21 31 11 21 31 11
21 31 51 51 51 51
      51 51 51 11 21 31 11 21 31 11 21 31 11 21 31
11 51 51 11 51 51
     51 51 51 31 11 21 31 11 21 31 11 21 31 11 21
31 51 21 31 11 51
    51 51 11 21 31 11 21 31 11 21 31 11 21 31 11 51
51 51 51 51 51
   51 51 31 11 21 31 11 21 31 11 21 31 11 21 31 51
51 51 51 51 51
  51 11 21 31 11 21 31 11 21 31 11 21 31 11 51 51
51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
51 51 51 51
               50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50
              50 50 50 50 50 50 50 10 20 30 10 20
30 10 20 30 10 20 30 10 50
             50 50 50 50 50 50 50 30 10 20 30 10 20
30 10 20 30 10 20 30 50
            50 50 50 50 50 50 10 20 30 10 20 30 10
20 30 10 20 30 10 50 50
           50 50 50 50 50 50 30 10 20 30 10 20 30
10 20 30 10 20 30 50 50
          50 50 50 50 50 10 20 30 10 20 30 10 20 30
10 20 30 10 50 50 50
         50 50 50 50 50 30 10 20 30 10 20 30 10 20
30 10 20 30 50 50 50
        50 50 50 50 10 20 30 10 20 30 10 20 30 10
20 30 10 50 50 50 50
       50 50 50 50 30 10 20 30 10 20 30 10 20 30 10
20 30 50 50 50 50
      50 50 50 10 20 30 10 20 30 10 20 30 10 20 30
10 50 50 50 50 50
     50 50 50 30 10 20 30 10 20 30 10 20 30 10 20
30 50 50 50 50 50
    50 50 10 20 30 10 20 30 10 20 30 10 20 30 10 50
50 50 50 50 50
   50 50 30 10 20 30 10 20 30 10 20 30 10 20 30 50
50 50 50 50 50
  50 10 20 30 10 20 30 10 20 30 10 20 30 10 50 50
50 50 50 50 50
 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50
```

```
END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_3X300 (MOD0 Array Configuration)
HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 10X10X3 Packages

```
=CSAS26     PARM='SIZE=00900000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
'PARAFFIN       1  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
```

```
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  565.0701  0.00  473.2720  0.00
256.2225  0.00
ARRAY  1  10  PLACE 6 2 1  26.9081  26.9081
43.4768
CUBOID  20  595.5501  -30.48  503.7520 -30.48
286.7025  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=16  NUY=12  NUZ=3
FILL
            51 51 51 51 51 51 51 51 51 51 51 51 51
51 51 51
           51 51 51 51 51 11 21 31 11 21 31 11 21
31 11 51
          51 51 51 51 51 31 11 21 31 11 21 31 11 21
31 51
         51 51 51 51 11 21 31 11 21 31 11 21 31 11
51 51
        51 51 51 51 31 11 21 31 11 21 31 11 21 31
51 51
```

```
       51 51 51 11 21 31 11 21 31 11 21 31 11 51 51
51
      51 51 51 31 11 21 31 11 21 31 11 21 31 51 51
51
     51 51 11 21 31 11 21 31 11 21 31 11 51 51 51
51
    51 51 31 11 21 31 11 21 31 11 21 31 51 51 51 51
   51 11 21 31 11 21 31 11 21 31 11 51 51 51 51 51
  51 31 11 21 31 11 21 31 11 21 31 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
            50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50
           50 50 50 50 50 10 20 30 10 20 30 10 20
30 10 50
          50 50 50 50 50 30 10 20 30 10 20 30 10 20
30 50
         50 50 50 50 10 20 30 10 20 30 10 20 30 10
50 50
        50 50 50 50 30 10 20 30 10 20 30 10 20 30
50 50
       50 50 50 10 20 30 10 20 30 10 20 30 10 50 50
50
      50 50 50 30 10 20 30 10 20 30 10 20 30 50 50
50
     50 50 10 20 30 10 20 30 10 20 30 10 50 50 50
50
    50 50 30 10 20 30 10 20 30 10 20 30 50 50 50 50
   50 10 20 30 10 20 30 10 20 30 10 50 50 50 50 50
  50 30 10 20 30 10 20 30 10 20 30 50 50 50 50 50
 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
1Q192
END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_4X272 (MOD1 Array Configuration)
HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 8/7X9X4 Packages

```
=CSAS26     PARM='SIZE=00900000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
'PARAFFIN       1  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O         2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
```

```
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
```

```
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  511.2639  0.00  426.6658  0.00
341.6300  0.00
ARRAY  1  10  PLACE 6 2 1  26.9081  26.9081
43.4768
CUBOID  20  541.7339  -30.48  457.1458 -30.48
372.1100  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=15  NUY=11  NUZ=4
FILL
           51 51 51 51 51 51 51 51 51 51 51 51 51
51 51
          51 51 51 51 51 11 21 31 11 21 31 11 21 51
51
         51 51 51 51 51 31 11 21 31 11 21 31 51 51
51
        51 51 51 51 11 21 31 11 21 31 11 21 51 51
51
       51 51 51 51 31 11 21 31 11 21 31 51 51 51 51
      51 51 51 11 21 31 11 21 31 11 21 51 51 51 51
     51 51 51 31 11 21 31 11 21 31 51 51 51 51 51
    51 51 11 21 31 11 21 31 11 21 51 51 51 51 51
   51 51 31 11 21 31 11 21 31 51 51 51 51 51 51
  51 11 21 31 11 21 31 11 21 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
1Q165
           50 50 50 50 50 50 50 50 50 50 50 50 50
50 50
          50 50 50 50 50 10 20 30 10 20 30 10 20 50
50
         50 50 50 50 50 30 10 20 30 10 20 30 50 50
50
        50 50 50 50 10 20 30 10 20 30 10 20 50 50
50
       50 50 50 50 30 10 20 30 10 20 30 50 50 50 50
      50 50 50 10 20 30 10 20 30 10 20 50 50 50 50
     50 50 50 30 10 20 30 10 20 30 50 50 50 50 50
    50 50 10 20 30 10 20 30 10 20 50 50 50 50 50
   50 50 30 10 20 30 10 20 30 50 50 50 50 50 50
  50 10 20 30 10 20 30 10 20 50 50 50 50 50 50
 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
1Q165
END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_5X280 (MOD1 Array Configuration)
HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 7X8X5 Packages

```
=CSAS26     PARM='SIZE=00900000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
'PARAFFIN       1  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
```

```
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
```

```
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  457.4377  0.00  380.0596  0.00
427.0375  0.00
ARRAY  1  10  PLACE 5 2 1  26.9081  26.9081
43.4768
CUBOID  20  487.9177  -30.48  410.5396 -30.48
457.5175  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=13  NUY=10  NUZ=5
FILL
          51 51 51 51 51 51 51 51 51 51 51 51 51
         51 51 51 51 11 21 31 11 21 31 11 51 51
        51 51 51 51 31 11 21 31 11 21 31 51 51
       51 51 51 11 21 31 11 21 31 11 51 51 51
      51 51 51 31 11 21 31 11 21 31 51 51 51
     51 51 11 21 31 11 21 31 11 51 51 51 51
    51 51 31 11 21 31 11 21 31 51 51 51 51
   51 11 21 31 11 21 31 11 51 51 51 51 51
  51 31 11 21 31 11 21 31 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51
2Q130
          50 50 50 50 50 50 50 50 50 50 50 50 50
         50 50 50 50 10 20 30 10 20 30 10 50 50
        50 50 50 50 30 10 20 30 10 20 30 50 50
       50 50 50 10 20 30 10 20 30 10 50 50 50
      50 50 50 30 10 20 30 10 20 30 50 50 50
     50 50 10 20 30 10 20 30 10 50 50 50 50
    50 50 30 10 20 30 10 20 30 50 50 50 50
   50 10 20 30 10 20 30 10 50 50 50 50 50
  50 30 10 20 30 10 20 30 50 50 50 50 50
 50 50 50 50 50 50 50 50 50 50 50 50 50
1Q130
END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_6X288 (MOD1 Array Configuration)
HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 6X8X6 Packages

```
=CSAS26     PARM='SIZE=00900000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
PARAFFIN        1  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
```

```
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
```

```
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  457.4377  0.00  380.0596  0.00
512.4450  0.00
ARRAY  1  10  PLACE 5 2 1  26.9081  26.9081
43.4768
CUBOID  20  487.9177  -30.48  410.5396 -30.48
542.9250  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=13  NUY=10  NUZ=6
FILL
          51 51 51 51 51 51 51 51 51 51 51 51 51
         51 51 51 51 11 21 31 11 21 31 51 51 51
        51 51 51 51 31 11 21 31 11 21 51 51 51
       51 51 51 11 21 31 11 21 31 51 51 51 51
      51 51 51 31 11 21 31 11 21 51 51 51 51
     51 51 11 21 31 11 21 31 51 51 51 51 51
    51 51 31 11 21 31 11 21 51 51 51 51 51
   51 11 21 31 11 21 31 51 51 51 51 51 51
  51 31 11 21 31 11 21 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51
2Q130
          50 50 50 50 50 50 50 50 50 50 50 50 50
         50 50 50 50 10 20 30 10 20 30 50 50 50
        50 50 50 50 30 10 20 30 10 20 50 50 50
       50 50 50 10 20 30 10 20 30 50 50 50 50
      50 50 50 30 10 20 30 10 20 50 50 50 50
     50 50 10 20 30 10 20 30 50 50 50 50 50
    50 50 30 10 20 30 10 20 50 50 50 50 50
   50 10 20 30 10 20 30 50 50 50 50 50 50
  50 30 10 20 30 10 20 50 50 50 50 50 50
 50 50 50 50 50 50 50 50 50 50 50 50 50
2Q130
END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_7X322 (MOD1 Array Configuration)
HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 7/6X7X7 Packages

```
=CSAS26     PARM='SIZE=00900000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
PARAFFIN        1  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
```

```
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
```

```
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  403.6215  0.00  333.4534  0.00
597.8525  0.00
ARRAY  1  10  PLACE 5 2 1  26.9081  26.9081
43.4768
CUBOID  20  434.1015  -30.48  363.9334 -30.48
628.3325  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=12  NUY=9  NUZ=7
FILL
         51 51 51 51 51 51 51 51 51 51 51 51
        51 51 51 51 11 21 31 11 21 31 11 51
       51 51 51 51 31 11 21 31 11 21 51 51
      51 51 51 11 21 31 11 21 31 11 51 51
     51 51 51 31 11 21 31 11 21 51 51 51
    51 51 11 21 31 11 21 31 11 51 51 51
   51 51 31 11 21 31 11 21 51 51 51 51
  51 11 21 31 11 21 31 11 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51
3Q108
         50 50 50 50 50 50 50 50 50 50 50 50
        50 50 50 50 10 20 30 10 20 30 10 50
       50 50 50 50 30 10 20 30 10 20 50 50
      50 50 50 10 20 30 10 20 30 10 50 50
     50 50 50 30 10 20 30 10 20 50 50 50
    50 50 10 20 30 10 20 30 10 50 50 50
   50 50 30 10 20 30 10 20 50 50 50 50
  50 10 20 30 10 20 30 10 50 50 50 50
 50 50 50 50 50 50 50 50 50 50 50 50
2Q108
END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_8X312 (MOD1 Array Configuration)

HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 6/5X7X8 Packages

```
=CSAS26     PARM='SIZE=00900000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
'PARAFFIN       1  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
```

```
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
```

```
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  403.6215  0.00  333.4534  0.00
683.2600  0.00
ARRAY  1  10  PLACE 5 2 1  26.9081  26.9081
43.4768
CUBOID  20  434.1015  -30.48  363.9334 -30.48
713.7400  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=12  NUY=9  NUZ=8
FILL
         51 51 51 51 51 51 51 51 51 51 51 51
        51 51 51 51 11 21 31 11 21 31 51 51
       51 51 51 51 31 11 21 31 11 51 51 51
      51 51 51 11 21 31 11 21 31 51 51 51
     51 51 51 31 11 21 31 11 51 51 51 51
    51 51 11 21 31 11 21 31 51 51 51 51
   51 51 31 11 21 31 11 51 51 51 51 51
  51 11 21 31 11 21 31 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51
3Q108
         50 50 50 50 50 50 50 50 50 50 50 50
        50 50 50 50 10 20 30 10 20 30 50 50
       50 50 50 50 30 10 20 30 10 50 50 50
      50 50 50 10 20 30 10 20 30 50 50 50
     50 50 50 30 10 20 30 10 50 50 50 50
    50 50 10 20 30 10 20 30 50 50 50 50
   50 50 30 10 20 30 10 50 50 50 50 50
  50 10 20 30 10 20 30 50 50 50 50 50
 50 50 50 50 50 50 50 50 50 50 50 50
3Q108
END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_9X324 (MOD1 Array Configuration)
HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 6X7X9 Packages

```
=CSAS26     PARM='SIZE=00900000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
'PARAFFIN        1  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
```

```
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
```

```
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  349.8053  0.00  286.8472  0.00
768.6675  0.00
ARRAY  1  10  PLACE 4 2 1  26.9081  26.9081
43.4768
CUBOID  20  380.2853  -30.48  317.8472 -30.48
799.1475  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=10  NUY=8  NUZ=9
FILL
        51 51 51 51 51 51 51 51 51 51
       51 51 51 11 21 31 11 21 31 51
      51 51 51 31 11 21 31 11 21 51
     51 51 11 21 31 11 21 31 51 51
    51 51 31 11 21 31 11 21 51 51
   51 11 21 31 11 21 31 51 51 51
  51 31 11 21 31 11 21 51 51 51
 51 51 51 51 51 51 51 51 51 51
4Q80
        50 50 50 50 50 50 50 50 50 50
       50 50 50 10 20 30 10 20 30 50
      50 50 50 30 10 20 30 10 20 50
     50 50 10 20 30 10 20 30 50 50
    50 50 30 10 20 30 10 20 50 50
   50 10 20 30 10 20 30 50 50 50
  50 30 10 20 30 10 20 50 50 50
 50 50 50 50 50 50 50 50 50 50
3Q80
END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_10X300 (MOD1 Array Configuration)

HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 5X5X10 Packages

```
=CSAS26     PARM='SIZE=00900000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
PARAFFIN        1  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
```

```
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
```

```
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  349.8053  0.00  286.8472  0.00
854.0750  0.00
ARRAY  1  10  PLACE 4 2 1  26.9081  26.9081
43.4768
CUBOID  20  380.2853  -30.48  317.8472 -30.48
884.5550  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=10  NUY=8  NUZ=10
FILL
        51 51 51 51 51 51 51 51 51 51
       51 51 51 11 21 31 11 21 51 51
      51 51 51 31 11 21 31 11 51 51
     51 51 11 21 31 11 21 51 51 51
    51 51 31 11 21 31 11 51 51 51
   51 11 21 31 11 21 51 51 51 51
  51 31 11 21 31 11 51 51 51 51
 51 51 51 51 51 51 51 51 51 51
4Q80
        50 50 50 50 50 50 50 50 50 50
       50 50 50 10 20 30 10 20 50 50
      50 50 50 30 10 20 30 10 50 50
     50 50 10 20 30 10 20 50 50 50
    50 50 30 10 20 30 10 50 50 50
   50 10 20 30 10 20 50 50 50 50
  50 30 10 20 30 10 50 50 50 50
 50 50 50 50 50 50 50 50 50 50
4Q80
END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Input Case: VERSA_HAC_FINH_12S_12X300 (MOD1 Array Configuration)

HAC Case Finite In-Homogeneous Hexagonal Lattice 12-cm Spheres 5X4X12 Packages

```
=CSAS26     PARM='SIZE=00900000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U         1 0.00253829 294.0 92235 100.0 END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
'PARAFFIN       1  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'INSULATION
H2O          5 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
```

```
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
```

```
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  40
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  41
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=-3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  5  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  5  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  5  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  5  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  5  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
UNIT  1000
CUBOID  10  295.9891  0.00  240.2410  0.00
1024.8900  0.00
ARRAY  1  10  PLACE 4 2 1  26.9081  26.9081
43.4768
CUBOID  20  326.4691  -30.48  270.7210 -30.48
1055.3700  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=9  NUY=7  NUZ=12
FILL
       51 51 51 51 51 51 51 51 51
      51 51 51 11 21 31 11 21 51
     51 51 51 31 11 21 31 11 51
    51 51 11 21 31 11 21 51 51
   51 51 31 11 21 31 11 51 51
  51 11 21 31 11 21 51 51 51
 51 51 51 51 51 51 51 51 51
5Q63
       50 50 50 50 50 50 50 50 50
      50 50 50 10 20 30 10 20 50
     50 50 50 30 10 20 30 10 50
    50 50 10 20 30 10 20 50 50
   50 50 30 10 20 30 10 50 50
  50 10 20 30 10 20 50 50 50
 50 50 50 50 50 50 50 50 50
5Q63
END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

MULTIREGION Input Case: VERSA_HAC_FINH_12S_4X272_MR
(MOD1 Array Configuration)
HAC Case Finite In-Homogeneous Hexagonal Lattice
12-cm Spheres 8/7X9X4 Packages

```
=CSAS26     PARM='SIZE=1000000'
CENTURY INDUSTRIES VERSA-PAK
44GR     INFHOM
'URANIUM METAL
U          1 0.00253829 294.0 92235 100.0 END
'PARAFFIN  1  0.99746  294.0  END
POLYETHYLENE    1  DEN=0.98  0.99746 294.0  END
'GRAPHITE   1 0.100 294.0  END
'INTERSPERSED MODERATOR
H2O          2 1.0  294.0  END
'PACKAGE STEEL
CARBONSTEEL  3 1.0  294.0  END
'REFLECTOR
H2O          4 1.0   294.0  END
'PAYLOAD CAVITY
H2O          5 0.0001 294.0 END
'RADIAL CAVITY
H2O          6 0.0001 294.0 END
'TOP BOTTOM CAVITY
H2O          7 0.0001 294.0 END
'RADIAL INNER OUTER CAVITY
H2O          8 0.0001 294.0 END
'PACKAGE EXTERIOR
```

```
H2O         9 0.0001 294.0 END
END COMP
READ PARM  NUB=YES GEN=600 NPG=1000 NSK=5
END PARM
READ GEOMETRY

UNIT  10
CYLINDER  1  19.2088 34.5281 -34.5281
'PAYLOAD
MEDIA  5  1  1
HOLE   100  ORIGIN  X=6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
'PAYLOAD RADIAL INSULATION
MEDIA  6  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
'TOP INSULATION
MEDIA  7  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
'TOP/BOTTOM INSULATION
MEDIA  7  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
'INNER/OUTER RADIAL LINER INSULATION
MEDIA  8  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
'EXTERIOR MODERATION
MEDIA  9  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  11
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE  100  ORIGIN X=6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  6  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  7  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  7  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  8  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  9  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  20
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  6  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  7  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  7  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  8  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  9  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  21
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=-6.24  Y=3.60  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  6  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  7  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  7  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  8  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  9  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  30
CYLINDER  1  19.2088 34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=-22.528
CYLINDER  2  19.5163  34.5281  -34.8357
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.5281  -34.8357
MEDIA  6  1  3  -2  -1
CYLINDER  4  25.8663  35.7727  -34.8357
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  36.8560  -34.8357
MEDIA  7  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  36.9914  -34.8357
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  43.3414  -41.1857
MEDIA  7  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  43.3414  -41.7953
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374  43.3414  -41.7963
MEDIA  8  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727  43.3414  -41.7953
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081  43.4768  -41.9307
```

```
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081  43.4768  -41.9307
MEDIA  9  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT  31
CYLINDER  1  19.2088  34.5281 -34.5281
MEDIA  5  1  1
HOLE   100  ORIGIN  X=0.00  Y=-7.208  Z=22.528
CYLINDER  2  19.5163  34.8357  -34.5281
MEDIA  3  1  2  -1
CYLINDER  3  25.8663  34.8357  -34.5281
MEDIA  6  1  3  -2  -1
CYLINDER  4  25.8663  34.8357  -35.7727
MEDIA  3  1  4  -3  -2  -1
CYLINDER  5  25.8663  34.8357  -36.8560
MEDIA  7  1  5  -4  -3  -2  -1
CYLINDER  6  25.8663  34.8357  -36.9914
MEDIA  3  1  6  -5  -4  -3  -2  -1
CYLINDER  7  25.8663  41.1857  -43.3414
MEDIA  7  1  7  -6  -5  -4  -3  -2  -1
CYLINDER  8  26.0017  41.7953  -43.3414
MEDIA  3  1  8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  9  26.6374 41.7963  -43.3414
MEDIA  8  1  9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  10  26.7727 41.7953  -43.3414
MEDIA  3  1  10  -9  -8  -7  -6  -5  -4  -3  -2  -1
CYLINDER  11  26.9081 41.9307  -43.4768
MEDIA  3  1  11 -10  -9  -8  -7  -6  -5  -4  -3  -2
-1
HEXPRISM  12  26.9081 41.9307  -43.4768
MEDIA  9  1  12 -11 -10  -9  -8  -7  -6  -5  -4  -3
-2  -1
BOUNDARY  12

UNIT 50
HEXPRISM  10  26.9081  43.4768 -41.9307
MEDIA  4  1  10
BOUNDARY  10

UNIT 51
HEXPRISM  10  26.9081  41.9307 -43.4768
MEDIA  4  1  10
BOUNDARY  10

UNIT  100
SPHERE  1  12.00
MEDIA  1  1  1
BOUNDARY  1

GLOBAL
```

```
UNIT  1000
CUBOID  10  511.2639  0.00  426.6658  0.00
341.6300  0.00
ARRAY  1  10  PLACE 6 2 1  26.9081  26.9081
43.4768
CUBOID  20  541.7339  -30.48  457.1458 -30.48
372.1100  -30.48
MEDIA  4  10  20  -10
BOUNDARY  20
END GEOMETRY
READ ARRAY
GBL=1 ARA=1 TYP=TRIANGULAR NUX=15  NUY=11  NUZ=4
FILL
           51 51 51 51 51 51 51 51 51 51 51 51 51
51 51
          51 51 51 51 51 11 21 31 11 21 31 11 21 51
51
         51 51 51 51 51 31 11 21 31 11 21 31 51 51
51
        51 51 51 51 11 21 31 11 21 31 11 21 51 51
51
       51 51 51 51 31 11 21 31 11 21 31 51 51 51 51
      51 51 51 11 21 31 11 21 31 11 21 51 51 51 51
     51 51 51 31 11 21 31 11 21 31 51 51 51 51 51
    51 51 11 21 31 11 21 31 11 21 51 51 51 51 51
   51 51 31 11 21 31 11 21 31 51 51 51 51 51 51
  51 11 21 31 11 21 31 11 21 51 51 51 51 51 51
 51 51 51 51 51 51 51 51 51 51 51 51 51 51 51
1Q165
           50 50 50 50 50 50 50 50 50 50 50 50 50
50 50
          50 50 50 50 50 10 20 30 10 20 30 10 20 50
50
         50 50 50 50 50 30 10 20 30 10 20 30 50 50
50
        50 50 50 50 10 20 30 10 20 30 10 20 50 50
50
       50 50 50 50 30 10 20 30 10 20 30 50 50 50 50
      50 50 50 10 20 30 10 20 30 10 20 50 50 50 50
     50 50 50 30 10 20 30 10 20 30 50 50 50 50 50
    50 50 10 20 30 10 20 30 10 20 50 50 50 50 50
   50 50 30 10 20 30 10 20 30 50 50 50 50 50 50
  50 10 20 30 10 20 30 10 20 50 50 50 50 50 50
 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
1Q165
END FILL
END ARRAY
READ BOUNDS
ALL=VACUUM
END BOUNDS
END DATA
END
```

Section 6.9.2 – Reference [6-1]

Richard Montgomery –
Validation of Scale PC for HEU Systems

49 Pages

Validation of SCALE4.4a-PC for High Enriched Uranium Systems

Richard D. Montgomery

Montgomery Engineering & Technical Services

June 2009

MTS-424 Rev. 1

Table of Contents

Index of Tables and Figures

1.0 Introduction

The SCALE4.4a KENO code [**Reference 1**] has been validated for enriched uranium systems using several different methods [**References 2** through **5**]. The objective of this evaluation is to establish that the CSAS25, CSAS26, and CSAS2X sequences will conservatively predict the multiplication factor (k_{eff}) of High Enriched Uranium (HEU) systems. In order to demonstrate the applicability of the SCALE4.4a KENO code for HEU systems, several critical experiments [**References 6** through **53**] using a variety of material forms were modeled with the SCALE4.4a KENO code and run on a desktop PC. The critical experiments were segregated into various groups based on the uranium system, and the results were evaluated using various statistical methods. Validations are performed using both KENO Va and KENO VI.

2.0 Methodology

2.1 Experiment Selection

Table 1 provides a summary of the critical experiments that were modeled. The critical experiments selected were chosen for analysis because they consist of HEU systems and are documented in sufficient detail to develop an accurate analytical model. Each critical experiment report provides comprehensive data on the materials of construction, dimensions, fissionable material, and experimental uncertainties.

The HEU experiments were selected and categorized into four distinct groups. These groupings consisted of:

Group 1: All experiments (161) used in this validation,
Group 2: Experiments (81) with ALCF ≤ 10^2 eV, data sets 1-82, and
Group 3: Experiments (56) with ALCF > 10^2 eV and ≤ 10^5 eV, data sets 83-138, and
Group 4: Experiments (24) with ALCF > 10^5 eV, data sets 139-162.

The experimental and calculated results were then compared based on a review of the k_{eff} distribution, enrichment (wt%^{235}U), average lethargy causing fission (ALCF), the hydrogen-to-fissile atom ratio (H/X), and the fissile material density (g ^{235}U/l).

2.2 SCALE4.4a Models

Each critical experiment was modeled exactly as described in **References 6** and **53**. All criticality calculations were run to convergence, which typically required 600 generations and 1000 neutrons per generation for a total of 600,000 histories. Default values were used for all other parameters. All calculations were performed using the SCALE4.4a KENO Va Code with the 44-Group Standard Cross Section Library [**Reference 1**]. **Appendix A** contains the input decks for each critical experiment modeled. All dimensional and material information is identical to that reported in **References 6** and **53**. C5TOC6 is then executed to generate the initial KENO VI cases. Each case is then reviewed and further edited by the analyst (incorporate evaluator specific traits) and then executed for the validation.

2.3 Methodology for Statistical Evaluation of Results

The results of the SCALE4.4a KENO calculations were compared with the experimental results of the critical experiments through the use of various statistical analyses. The multiplication factor for each critical experiment is equal to unity; therefore, an accurate prediction of the multiplication factor using

SCALE4.4a KENO must be equivalent to unity also. The KENO program uses a Monte Carlo probability-based method, and as a result of this method, the calculated multiplication factors of an infinite number of critical experiments should provide a normal distribution about a mean multiplication factor of unity. However, it is known that biases exist in the SCALE4.4a program that lead to over-estimation of the multiplication factor for specific groups of fissile systems. Therefore, the objective of the statistical evaluation is to determine whether or not the results for each Group are normally distributed about unity (KENO predicts accurately for the Group) with an acceptable deviation (KENO predicts precisely for the Group). If KENO does not provide an accurate prediction, further evaluations are provided to determine whether or not a bias exists. The methods used to calculate the SCALE4.4a KENO Va bias and bias uncertainty is outlined in **References 54** and **55**.

2.3.1 Accuracy measures: Comparison of the Means

The calculated multiplication factors and the experimental multiplication factors represent two populations having the means μ_1 and μ_2 and the variances σ_1 and σ_2. The objective of this comparison is to determine whether or not the means of the experimental and calculated data are statistically equivalent, and if they are not, whether or not there is an identifiable bias. A two-tailed t-test for the difference between two means [**Reference 55**] is used to test the hypothesis that the means of the two data sets are equal, or $\mu_1 = \mu_2$. The alternative hypothesis is $\mu_1 \neq \mu_2$, or the mean of the two populations are not equal, and that a bias exists in the calculated data. The t-value is calculated using Equation 1:

$$t = \frac{\mu_1 - \mu_2 - \delta}{\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}}, \qquad \text{(Equation 1)}$$

where:

μ_1 is the mean of the standard data set,
μ_2 is the mean of the data set to be tested,
δ is the null hypothesis constant (0 here for the hypothesis of $\mu_1 = \mu_2$),
σ_1 is the standard deviation of the standard data set,
σ_2 is the standard deviation of the data set to be tested,
n_1 is the number of observation in the standard data set, and
n_2 is the number of observations in the data set to be tested.

2.3.2 Accuracy Measures: Determination Of Method Bias

The bias is defined as:

$$Bias = \bar{k}_{calc} - \bar{k}_{exp}, \qquad \text{(Equation 2)}$$

where k_{exp} and k_{calc} are the mean of the experimental and calculated (KENO) k_{eff} values, respectively.

2.3.3 Precision Measures: Determination Of Calculational Variance and Standard Deviation

The variance, S^2, of the calculated KENO k_{eff} is defined as:

$$S^2 = \frac{\sum(\overline{k_{calc}} - k_i)^2}{n-1}, \qquad \text{(Equation 3)}$$

where k_i is the calculated k_{eff} for the i^{th} critical experiment and n is the total number of experiments.

The standard deviation, σ_{calc}, of the KENO-calculated k_{eff} is the positive square root of the variance, S^2. Note that this is *not* the KENO-calculated standard deviation, $\sigma_{KENO\text{-}calc}$, presented in **Table 3**, which is an average value of the calculated k_{eff} uncertainties.

2.3.4 Precision Measures: Determination Of Experimental Variance and Standard Deviation

The variance of the experimental k_{eff} is generally ignored, since the uncertainty associated with the measured k_{eff} (the known standard) is typically very small. Values reported for various experiments range from 0.0004 to 0.0019. Since the experimental uncertainties are usually reported as standard deviations, the experimental variance, S_o, is simply the average standard deviation of the group of experiments, $\overline{\sigma_{\exp}}$, squared:

$$S_0^2 = (\overline{\sigma_{\exp}})^2. \qquad \text{(Equation 4)}$$

2.3.5 Precision Measures: Determination Of Bias Uncertainty

According to **Reference 55**, the variance associated with the bias is given by the following equation:

$$V_B = \frac{S^2}{n} \quad + \quad S_0^2, \qquad \text{(Equation 5)}$$

where S^2 is the calculated k_{eff} variance (Equation 3), and S_o^2 is the experimental k_{eff} variance (Equation 4).

For conservatism, an additional term is added to Equation 5 to incorporate the effect of the individual uncertainties of the KENO-calculated k_{eff} value for each critical experiment model. The variance of the KENO-calculated uncertainty, S_u^2, is defined as:

$$S_u^2 = \frac{\sum(\sigma_{calc,i})^2}{n}, \qquad \text{(Equation 6)}$$

where, $\sigma_{calc,i}$ is the uncertainty associated with the KENO results for experiment i, and n is the number of experiments. This equation is the square-weighted average of the individual KENO uncertainties. The standard deviation of the KENO-calculated uncertainties is the square root of the variance, S_u^2.

Incorporating Equation 6 into Equation 5, the final equation for the variance associated with the KENO-calculated k_{eff} bias is:

$$V = \frac{\left(S^2 \quad + \quad S_u^2\right)}{n} \quad + \quad S_0^2 . \qquad \text{(Equation 7)}$$

The standard deviation of the bias value is then simply the square root of the variance:

$$U = \kappa\sqrt{V}\ , \qquad \text{(Equation 8)}$$

where, κ is the 95/95 one-sided tolerance factor that is applied to the bias uncertainty for the number of critical experiments **[Reference 54]**.

2.4 Methodology for Determination Applicable Limits

With the determination of the KENO bias and bias uncertainty associated with each Group of experiments, it is possible to calculate the Upper Subcritical Limits and the maximum allowable or biased KENO k_{eff} to maintain subcriticality for each system type.

2.4.1 Practical application: Calculation of an Upper Subcritical k_{eff} Limit

Starting at a multiplication factor of 1 (critical), the biases and uncertainties are subtracted, and the resulting number is the Upper Subcritical Limit for the system. At a 95% confidence level:

$$\textit{Upper Subcritical Limit} = 1 + \textit{bias} - U, \qquad \text{(Equation 9)}$$

where the *bias* and *U* are substituted from **Equations 2** and **8**, respectively. Values determined using this method are provided in **Table 3.** For systems with a positive bias, the second term of **Equation 9**, *bias*, is omitted.

In practice, the calculated system is considered to be subcritical if the following condition is met:

$$\textit{KENO}_{\textit{-calc}}\textit{-k}_{\textit{eff}} + \kappa(\sigma_{\text{KENO-calc}}) < \textit{Upper Subcritical Limit}, \qquad \text{(Equation 10)}$$

where the system is subcritical at a 95% confidence level. A bounding κ factor of 1.645 is historically applied to the corresponding $\sigma_{\text{KENO-calc}}$ uncertainty for the calculation. This κ factor is different from that used in **Equation 8** for determination of the bias uncertainty.

2.4.2 Practical application: Calculation of the biased KENO Multiplication Factor

Alternatively starting with the calculated $\text{KENO}_{\text{-calc}}\text{-k}_{\text{eff}}$, a biased k_{eff} can be calculated:

$$\textit{Biased KENO-k}_{\textit{eff}} = \text{KENO}_{\text{-calc}}\text{-k}_{\text{eff}} + \kappa(\sigma_{\text{KENO-calc}}) - \textit{bias} + U. \qquad \text{(Equation 11)}$$

And the system is considered to be subcritical if the following condition is met:

$$\textit{Biased KENO-k}_{\textit{eff}} < 1. \qquad \text{(Equation 12)}$$

In the case where the bias is positive (KENO consistently over-estimates k_{eff}), the bias term is omitted for conservatism.

3.0 Calculation Results

Table 2 presents the multiplication factor (k_{eff}), standard deviation (σ), and average lethargy causing fission (ALCF) calculated for each critical experiment modeled using the SCALE4.4a code with the 44 group cross-section library. **Table 3** provides the results of the statistical evaluations from different groupings of critical experiment data sets. The Upper Limit Subcritical k_{eff} for each group was calculated using the mean KENO-calculated uncertainty for the Group. In practice, it is preferable to use the actual

KENO-calculated standard deviation for the calculation being performed. However, it is conservative to use the mean KENO-calculated uncertainty to establish the bias for the group and then use the actual KENO-calculated standard deviation for the calculation to ensure a margin below the established limit.

4.0 Discussion

In order to validate the SCALE4.4a code for use with high enriched uranium systems, it is necessary to determine if KENO predicts the multiplication factor in an accurate and precise manner throughout the range of fission energies of interest. To evaluate the accuracy of the code, the mean of each Group of experiments was compared to the mean of the experimental results. A t-test was performed for each Group to determine whether or not the average result of a KENO calculation (the mean calculated k_{eff} for each Group) is statistically the same as the experimental result (unity). Passing the t-test affirms that the KENO code predicts multiplication factors accurately for the Group being tested, without bias. Failure of the t-test indicates that the mean KENO k_{eff} is statistically different from the experimental mean, and that a bias exists in the data. Groups that failed the t-test were further evaluated for bias and uncertainty, and these parameters applied to provide an upper limit subcritical multiplication factor for the Group.

Each Group of KENO-calculated k_{eff}s are also graphed against key system parameters (Enrichment {wtg%^{235}U}, Energy of the Average Lethargy Causing Fission {ALCF}, Hydrogen-to-Fissile Atom Ratio {H/^{235}U}, and fissile material density {g ^{235}U/cc}) to identify trends within the data that may indicate inaccurate cross-sections or instabilities in the code. The normality of residuals is also tested using the Anderson-Darling method. The null hypothesis of a normality test is that there is no significant departure from normality. When the probability level, ρ is greater than 0.05, it fails to reject the null hypothesis and thus the assumption holds. Histogram, skewness and kurtosis plots are also provided for each group.

4.1 Comparison of the Means

The t-statistic for each Group evaluated against the experimental data is provided in **Table 3**. A two-tailed test at the 95% confidence limit was performed. All Groupings of the data were found to have statistically different means, and therefore, the mean KENO-calculated k_{eff} is biased.

4.2 Comparison of Uncertainty

In order to benchmark the performance of the code, the uncertainty associated with the KENO-calculated k_{eff}, must take into account the uncertainty associated with the critical experiment, since it is inherently a part of the result. The experimental uncertainty impacting the modeling of the experiment stems from material and geometric tolerances, rather than measurement of the experimental k_{eff}. Unfortunately, this type of uncertainty is not well evaluated or documented. Therefore, an average uncertainty of 0.0011 was assigned to those experiments that did not report an uncertainty value.

The bias uncertainty associated with Groups 1 though 4 are 0.0022, 0.0024, 0.0027, and 0.0037, respectively, at a 95% confidence level. For Groups 3 and 4, the uncertainty is higher than the bias. This fact leads to the conclusion that there is no detectable bias (either positive or negative) in the data, since application of the uncertainty obscures it. The uncertainty is lower than the bias for Groups 1 and 2 suggesting that there is a detectable bias in this data. However, as indicated in **Table 3** the bias is positive for all data groups.

4.3 Comparison of System Behavior as a Function of the System Attributes

For hydrogen moderated ^{235}U systems, the fission energy is proportional to the degree of moderation. Variations in the bias over the data range for the fissile density (g^{235}U/cc), energy of the average lethargy causing fission (ALCF) and the hydrogen-to-fissile atomic ratio (H/^{235}U) should be similar. However, differences will be evident due to statistical variations in the experimental and calculated results.

4.3.1 Oxide and Solution Systems

Dry (non-hydrogenous moderated) UO_2 systems at any enrichment are fast (neutronic) systems. The results of the critical experiments documented elsewhere, as well as the results of the critical experiments modeled here; show that the typical average lethargy causing fission in a fast system ranges from 10^4 to 10^6 eV. Fast critical UO_2 systems enriched to less than 15wt% are not feasible due to the large quantity of material required. However, a few LEU fast critical systems (metal) have been performed ranging in enrichment from 10 – 15wt%. The neutronic attributes of these fast metal experiments are very similar to the fast metal experiments with enrichments ranging from 93 - 97wt%. Several of these types of experiments are evaluated in this validation. The only major difference between the experiments at these different enrichments is the fact that more material is required for the lower enriched systems to achieve criticality. Various analytical methods have shown that an infinite UO_2 mass system has sufficient ^{235}U density to achieve criticality for enrichments near 7.0 wt %. However, without moderation, the system is fast. A few low-enriched (<5wt%) metal critical experiments have been performed; however, these systems also required moderation (water) to achieve critical configurations and therefore were driven by intermediate and thermal energy neutrons.

As moderator is introduced to the system, the neutronics of the system changes. A fast system becomes an under-moderated intermediate system. The typical average lethargy causing fission in an intermediate system ranges from 10^0 to 10^4 eV. Very few low enriched intermediate critical experiments have been performed. These systems are difficult to construct and maintain due to the under-moderated configurations. However, a few intermediate experiments have been completed using mixtures of low-enriched metals and fissile solutions. Several of these types of experiments are evaluated in this validation.

With additional moderation the intermediate system becomes a thermal system. The typical average lethargy causing fission in a thermal system ranges from 10^{-2} to 10^0 eV. The large majority of critical experiments are thermal. These systems are easily constructed at all enrichments. For a low enriched UO_2 system approximately 5.0wt% water is required to change the neutronics of the system from fast to thermal. Little difference is observed for enrichments less than 5.0wt% and those ranging from 5 to 10wt%. However, for enrichments ranging from 90 to 97wt%, a large amount of water, approximately 90wt%, is necessary to change the neutronics of a fast system to an intermediate, and finally a thermal, system.

Given that the mechanics of hydrogen moderated critical systems are the same regardless of enrichment, analytical computer codes predicting the k_{eff} of enriched systems should perform equally well at all enrichments. Since the SCALE4.4a KENO Code has been validated as performing accurately over a large range of enrichments with a variety of moderators and moderation levels, it is reasonable that it should also perform accurately in the remaining ranges. The results of these calculations demonstrate that the SCALE4.4a KENO Code is accurate in the high enrichment range. These results also demonstrate that the level of accuracy is the same as the accuracy of the KENO Code at other enrichment ranges [**Reference 56**].

4.3.2 Metal Systems

Metal systems are typically fast due to experimental configurations involving single and arrays of units at high densities with little or no moderation. Several experiments display similar attributes when the fissile media is further diluted with non-fissile metals. A few metal (fast) experiments exist at 10wt% however the majority of these experiments are highly enriched. Several of these types of experiments are evaluated in this validation.

4.4 Comparison of the k_{eff} Distributions

The KENO-calculated, unbiased k_{eff} was plotted for Groups 1 through 4 using a histogram to demonstrate the relative distributions about the mean value, as shown in **Figures 1** through **4**, respectively. If the CSAS25 sequence performs accurately without systemic errors, then the k_{eff} results will be normally distributed about a mean k_{eff}. This is expected since KENO is a Monte Carlo probability-based program. Also, a k_{eff} of unity is expected since the experiments were reported as being critical. As shown in the histograms, the distribution appears to be normal, with a slight positive bias indicating that the CSAS25 sequence contains a systemic conservative bias.

The normality of residuals, using the Anderson-Darling method, indicated that the probability level ρ is greater than 0.05 for **Groups 2** through **4**. Therefore, the test fails to reject the null hypothesis and thus the assumption, normal data, holds. The null hypothesis of a normality test is that there is no significant departure from normality. Since the probability level ρ is greater than 0.05, it fails to reject the null hypothesis and thus the assumption holds. Histogram, skewness and kurtosis plots are also provided for each group in **Figures 1** through **3** for **Groups 2** through **4**, respectively.

4.5 Bias Trends with Enrichment

Figure 5 shows the KENO-calculated, unbiased k_{eff} plotted as a function of the system enrichment. The enrichments of the selected benchmarks ranged from 62.40 to 97.68 wt% ^{235}U. Based on this plot, there appears to be no distinct or observable bias in the k_{eff} as a function of enrichment. Based on this, the proposed enrichment range for the validation can be extended from 97.68 wt% to 100.00 wt%.

4.6 Bias Trends with Average Lethargy Causing Fission (ALCF)

Figure 6 shows the KENO-calculated unbiased k_{eff} plotted as a function of the energy of the average lethargy causing fission (ALCF). The ALCF plots use a logarithmic scale to distinguish between the different neutron energy ranges. Based on this plot, there appears to be no distinct or observable bias in the k_{eff} as a function of the ALCF. Considering all experiments presented in this validation, the ALCF covers a range of energies from 0.0291eV to 914,000eV, spanning the thermal, intermediate, and fast fission groups.

4.7 Bias Trends with Hydrogen-to-Fissile Atom Ratio (H/X)

Figure 7 shows the KENO-calculated unbiased k_{eff} plotted as a function of the hydrogen-to-fissile atom ratio (H/X, where X is ^{235}U). Considering all experiments, the H/X covers a range from 0 to 1,836. This spans the under-moderated (less than 200), optimum (200 to 300), and over-moderated (greater than 300) regions. The H/X plots use a logarithmic scale to distinguish the different ranges of H/X values for the experiments. Overall, there appears to be no distinct or observable bias in the k_{eff} as a function of the hydrogen-to-fissile atom ratio.

4.8 Fissile Density (g ^{235}U/cc)

Figure 8 shows the KENO-calculated unbiased k_{eff} plotted as a function of the fissile material density for all experiments. Considering all experiments, the fissile density covers a range from 0.014 to 18.36 g ^{235}U/cc. The plot of the fissile density is similar to the plot of the ALCF. Overall, there appears to be no distinct or observable bias in the k_{eff} as a function of the fissile density.

4.9 KENO VI and KENO Va Comparison

Figure 9 shows the KENO VI-calculated unbiased k_{eff} plotted as a function of the KENO Va-calculated unbiased k_{eff}. The KENO VI results appear to be slightly higher for k_{eff} results less than 1.00 and slightly lower for k_{eff} results greater than 1.00. However, these observed k_{eff} differences are less than 0.0025. The results of both code versions statistically give essentially the same result. The KENO VI results are further provided in Table 2. The statistical results (bias and bias uncertainty) are further provided in Table 3.

5.0 Conclusions

The SCALE4.4a KENO Code provides precise results (slight positive bias for Groups 1 through 4) using the 44-Group Standard Cross Section Library for high enrichments with a variety of material forms, geometry, neutron energy, water-to-fuel ratio, density and ALCF. The precision of the code varies somewhat depending upon the fissile system being analyzed, as demonstrated by the results of the statistical evaluations. For the Group 1 (all experiments) at a 95% confidence level, the bias uncertainty of the KENO results is ±0.0022. The overall bias (Group 1) associated with the KENO results is +0.0031.

Additionally, the results of the parametric studies indicate that there appears to be no distinct or observable trends with the energy of the average lethargy causing fission, the moderator-to-fissile atom ratio, fissile density or enrichment. The recommended application of the KENO-calculated standard deviation, uncertainty, and Upper Subcritical Limits will prevent a critical system from being mistakenly evaluated as subcritical. The Group 1 data is normally distributed about a mean k_{eff} value of 1.0030 such that a one-sided 95% confidence level can be used to establish the Upper Limit k_{eff}. Based on this validation, the Upper Limit k_{eff} for Group 1 (All Data) is 0.9969 (includes the bias and bias uncertainty at a 95% confidence level). This value does not include an arbitrary administrative margin.

Many of the critical experiments available for code validation do not document experimental uncertainties that may impact the modeling of the system; therefore, it is difficult to assess whether poor results are due to faulty code performance or simply poor modeling of the experiment due to lack of proper information.

The overall (Group 1) Upper Subcritical Limit is 0.9969. However, an Upper Subcritical Limit of 0.9966 should be used for Groups 2 and 3 for ALCF values to 10^5eV. An Upper Subcritical Limit of 0.9958 must be used (Group 4) for ALCF values greater than 10^5eV. For all cases, including both KENO VI and KENO Va, an Upper Subcritical Limit of 0.9958 is bounding for ALCF values ranging from less than 10^{-2}eV to greater than 10^5eV.

Based on these results, an administrative upper subcritical limit of 0.95 is overly restrictive. An administrative upper subcritical limit of 0.97 is justified based on this validation. This provides an arbitrary administrative margin of 3%. With a 3% margin the Upper Subcritical Limit is 0.9658. However, with a 5% margin the Upper Subcritical Limit is 0.9458. Values provided in Table 3 implement the Upper Subcritical Limit with a 5% margin. As applied to analyses, since the bias is positive in all cases and neglected, limiting the $k_{eff} + 2\sigma$ to less than or equal to 0.9458 (5% administrative margin) meets the intended requirements of this validation.

6.0 Area of Applicability

An essential portion of a code validation effort is to define the area of applicability for the code. The area of applicability defines the types of materials, options, and range of parameter values that were used or were bounded by the validation. This study has demonstrated that Scale 4.4a/KENO V.a with the ENDF/B-V 44 group cross-sectional data is accurate for use in evaluating the multiplication factor for high enriched uranium (60.0-100.0 wt%), moderated, reflected and unreflected systems or configurations. The H/^{235}U values used in the benchmark experiments varied from 0 to 1,836. The fissile density (g ^{235}U/cc) ranges from 0.014 to 18.36. The average lethargy causing fission (ALCF) ranges from 0.0291eV to 914,000eV. This defines the range of applicability for the enrichment, H/^{235}U, ACLF, and fissile density of this validation.

The MULTIREGION and INFHOM cross-sectional modeling options were used in the benchmark modeling. This validation specifically covers uranium systems (homogeneous and heterogeneous) moderated by hydrogen (water- or poly-bound hydrogen) with carbon, nitrogen, fluorine and oxygen also present as a portion of the uranium compound. This validation further covers various moderator and reflector materials such as water, carbon, concrete, paraffin, plexiglas, aluminum, natural uranium and polyethylene. The basic geometry package consisting of cuboid, cylinder, sphere and hemisphere were used in modeling the benchmark critical experiments. Several other materials including boron, chlorine, gadolinium, stainless steel, and carbon steel were also used in modeling the benchmark experiments.

If the parameters of a fissile system or configuration being evaluated are outside of the boundaries or limits of this evaluation, then an additional margin of subcriticality determined from an alternate code or specific experimental benchmark will be used to ensure that the system remains subcritical.

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45) HEU-SOL-THERM-025, *Uranium Nitrate Solutions with Gadolinium,* (NEA/NSC/DOC/(95)03/II), (September 2002).

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47) HEU-SOL-THERM-028, *Uranium (89%* ^{235}*U) Nitrate Solutions with Central Boron Carbide Absorber Rod,* (NEA/NSC/DOC/(95)03/II), (September 2002).

48) HEU-SOL-THERM-030, *Uranium (89% ^{235}U) Nitrate Solutions with Cluster of Several Boron Carbide Absorber Rods,* (NEA/NSC/DOC/(95)03/II), (September 2002).

49) HEU-SOL-THERM-032, *A 48-Inch-Diameter Unreflected Sphere of ^{235}U Nitrate Solution,* (NEA/NSC/DOC/(95)03/II), (September 2002).

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51) HEU-SOL-THERM-035, *Boron Carbide Absorber Rods in Uranium (89% ^{235}U) Nitrate Solutions,* (NEA/NSC/DOC/(95)03/II), (September 2002).

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53) HEU-SOL-THERM-037, *Hexagonally Pitched Lattices of Boron Carbide Absorber Rods in Uranium Nitrate Solution,* (NEA/NSC/DOC/(95)03/II), (September 2002).

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Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heust-032-001	1	1836.68	0.01411	Uranyl Nitrate	Spherical	Water/NO3	Aluminum/Steel	93.21
Heust-002-009	2	458.76	0.05558	Uranyl Nitrate	Cylinder	Water/NO3	Concrete/Aluminum	93.17
Heust-012-001	3	1272.25	0.02047	Uranyl Fluoride	Spherical	Water/HF	Water/Aluminum	93.18
Heust-037-005	4	463.05	0.05469	Uranyl Nitrate	Cylinder	Water/NO3	Water	89.08
Heust-028-001	5	374.56	0.06770	Uranyl Nitrate	Cylinder	Water/NO3	Water	89.08
Heust-014-002	6	418.13	0.06064	Uranyl Nitrate	Cylinder	Water/NO3	Water/Steel	89.04
Heust-035-005	7	378.60	0.06670	Uranyl Nitrate	Cylinder	Water/NO3	Water/Steel	89.08
Heust-035-001	8	766.63	0.03341	Uranyl Nitrate	Cylinder	Water/NO3	Water/Steel	89.08
Heust-007-009	9	336.62	0.07520	Uranyl Nitrate	Cylinder	Water/NO3	Concrete/Aluminum/Stainless Steel	93.17
Heust-037-002	10	684.46	0.03732	Uranyl Nitrate	Cylinder	Water/NO3	Water	89.08
Heust-011-001	11	523.41	0.04940	Uranyl Fluoride	Spherical	Water/HF	Water/Aluminum	93.20
Heumt-006-012	12	0.00	0.72167	U-Al Metal	Cuboid	Aluminum	Water	93.17
Heust-025-006	13	586.11	0.04336	Uranyl Nitrate	Cylinder	Water/NO3	Water	89.04
Heust-008-007	14	453.75	0.05620	Uranyl Nitrate	Cylinder	Water/NO3	Plexiglass/Aluminum/Stainless Steel	93.17
Heust-002-010	15	458.76	0.05558	Uranyl Nitrate	Cylinder	Water/NO3	Concrete/Aluminum	93.17

Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heust-003-001	16	453.75	0.05620	Uranyl Nitrate	Cylinder	Water/NO3	Plexiglass/Stainless Steel	93.17
Heumt-006-005	17	0.00	0.72167	U-Al Metal	Cuboid	Aluminum	Water	93.17
Heust-028-008	18	374.56	0.06770	Uranyl Nitrate	Cylinder	Water/NO3	Water	89.08
Heumt-006-016	19	0.00	0.72167	U-Al Metal	Cuboid	Aluminum	Water	93.17
Heust-007-010	20	325.16	0.07779	Uranyl Nitrate	Cylinder	Water/NO3	Concrete/Aluminum/Stainless Steel	93.17
Heust-037-009	21	339.68	0.07393	Uranyl Nitrate	Cylinder	Water/NO3	Water	89.08
Heust-010-003	22	245.70	0.10190	Uranyl Fluoride	Spherical	Water/HF	Water/Aluminum	93.13
Heust-036-002	23	302.47	0.08263	Uranyl Nitrate	Cuboid	Water/NO3	Steel	89.14
Heumt-006-018	24	0.00	0.72167	U-Al Metal	Cuboid	Aluminum	Water	93.17
Heust-015-003	25	278.39	0.08948	Uranyl Nitrate	Cylinder	Water/NO3	Water/Steel	89.04
Heumt-006-010	26	0.00	0.72167	U-Al Metal	Cuboid	Aluminum	Water	93.17
Heust-027-001	27	203.61	0.12115	Uranyl Nitrate	Cylinder	Water/NO3	None	89.08
Heust-027-005	28	203.61	0.12115	Uranyl Nitrate	Cylinder	Water/NO3	None	89.08
Heust-002-012	29	183.79	0.13452	Uranyl Nitrate	Cylinder	Water/NO3	Concrete/Aluminum	93.17
Heust-002-011	30	183.79	0.13452	Uranyl Nitrate	Cylinder	Water/NO3	Concrete/Aluminum	93.17

Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heuct-010-021	31	0.00	1.49407	Uranium Dioxide	Cylinder	Beryllium/Borated Uranyl Nitrate/Water	Water	62.40
Heuct-010-010	32	0.00	1.49410	Uranium Dioxide	Cylinder	Beryllium/Water	Water	62.40
Heuct-014-002	33	0.00	1.03792	Uranium Dioxide	Cylinder	Aluminum/Silicon Oxides	Water	79.38
Heuct-010-017	34	0.00	1.49407	Uranium Dioxide	Cylinder	Beryllium/Boric Acid/Water	Water	62.40
Heuct-010-015	35	0.00	1.49407	Uranium Dioxide	Cylinder	Beryllium/Water	Water	62.40
Heuct-010-008	36	0.00	1.49407	Uranium Dioxide	Cylinder	Beryllium/Water	Water	62.40
Heuct-014-001	37	0.00	1.03792	Uranium Dioxide	Cylinder	Aluminum/Silicon Oxides	Water	79.38
Heust-020-003	38	847.40	0.03010	Uranyl Fluoride	Cylinder	D2O/Water/HF	D2O/Water/Steel/Aluminum	93.65
Heuct-010-005	39	0.00	1.49407	Uranium Dioxide	Cylinder	Beryllium/Water	Water	62.40
Heuct-010-006	40	0.00	1.49407	Uranium Dioxide	Cylinder	Beryllium/Water	Water	62.40
Heust-030-004	41	91.14	0.25745	Uranyl Nitrate	Cylinder	Water/NO3	Water	89.08
Heust-025-017	42	62.68	0.35010	Uranyl Nitrate	Cylinder	Water/NO3	Water	89.04
Heust-025-016	43	61.85	0.35616	Uranyl Nitrate	Cylinder	Water/NO3	Water	89.04
Heuct-010-004	44	0.00	1.49407	Uranium Dioxide	Cylinder	Beryllium/Water	Water	62.40

Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heust-008-014	45	68.75	0.33164	Uranyl Nitrate	Cylinder	Water/NO3	Plexiglass/Aluminum/ Stainless Steel	93.17
Heust-021-006	46	58.78	0.38429	Uranyl Nitrate	Cylinder	Water/NO3	Paraffin	92.60
heust-005-015	47	80.26	0.28947	Uranyl Nitrate	Cylinder	Water/NO3	None	87.40
Heust-003-011	48	70.94	0.32175	Uranyl Nitrate	Cylinder	Water/NO3	Plexiglass/Aluminum	93.17
Heust-005-008	49	80.26	0.28947	Uranyl Nitrate	Cylinder	Water/NO3	Water	87.40
Heust-008-008	50	80.26	0.28947	Uranyl Nitrate	Cylinder	Water/NO3	Water	87.40
Heust-002-003	51	73.50	0.31191	Uranyl Nitrate	Cylinder	Water/NO3	Concrete/Stainless Steel	93.17
Heust-003-018	52	70.94	0.32175	Uranyl Nitrate	Cylinder	Water/NO3	Plexiglass/Aluminum	93.17
Heust-007-008	53	66.78	0.33925	Uranyl Nitrate	Cylinder	Water/NO3	Concrete/Aluminum/Stainless Steel	93.17
Heust-007-006	54	67.50	0.33576	Uranyl Nitrate	Cylinder	Water/NO3	Concrete/Aluminum/Stainless Steel	93.17
Heust-021-018	55	58.78	0.38429	Uranyl Nitrate	Cylinder	Water/NO3	top (paraffin), bottom (paraffin)	92.60
Heust-033-003	56	68.10	0.33317	Uranyl Nitrate	Annular	Water/NO3	Concrete	93.22
Heust-021-023	57	58.78	0.38429	Uranyl Nitrate	Cylinder	Water/NO3	top (plexiglass), bottom (plexiglass)	92.60

Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heust-033-008	58	68.10	0.33317	Uranyl Nitrate	Annular	Water/NO3	Concrete	93.22
Heuct-013-002	59	0.00	1.03792	Uranium Dioxide	Cylinder	Aluminum/Silicon Oxides	Water	79.38
Heust-006-022	60	84.54	0.27481	Uranyl Nitrate	Cylinder	Water/NO3	Borated Water	93.06
Heust-009-002	61	47.23	0.50603	Uranyl Fluoride	Spherical	Water/HF	Water/Aluminum	93.19
Heuct-010-003	62	0.00	1.49407	Uranium Dioxide	Cylinder	Berrylium/Water	Water	62.40
Heucm-001-002	63	0.00	1.74728	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heust-006-014	64	84.98	0.27452	Uranyl Nitrate	Cylinder	Water/NO3	Nickel	93.06
Heust-006-021	65	84.24	0.27360	Uranyl Nitrate	Cylinder	Water/NO3	Nickel/Borated Water	93.06
Heuct-013-001	66	0.00	1.03792	Uranium Dioxide	Cylinder	Aluminum/Silicon Oxides	Water	79.38
Heuct-011-002	67	0.00	1.03792	Uranium Dioxide	Cylinder	Aluminum/Silicon Oxides	Water	79.38
Heuct-012-001	68	0.00	1.03792	Uranium Dioxide	Cylinder	Aluminum/Silicon Oxides	Water	79.48
Heuct-011-001	69	0.00	1.03792	Uranium Dioxide	Cylinder	Aluminum/Silicon Oxides	Water	79.38
Heust-004-004	70	134.90	0.18499	Uranyl Fluoride	Spherical	D2O/Water/HF	D2O/Water/Steel	93.65

Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heust-020-001	71	227.70	0.10940	Uranyl Fluoride	Cylinder	D2O/Water/HF	D2O/Water/Steel/Aluminum	93.65
Heust-004-003	72	80.96	0.30200	Uranyl Fluoride	Spherical	D2O/Water/HF	D2O/Water/Steel	93.65
Heumt-003-005	73	0.00	17.69982	U-Metal	Cuboid	None	Water	94.52
Heust-004-002	74	53.54	0.44298	Uranyl Fluoride	Spherical	D2O/Water/HF	D2O/Water/Steel	93.65
Heust-004-001	75	34.10	0.67902	Uranyl Fluoride	Spherical	D2O/Water/HF	D2O/Water/Steel	93.65
Heucm-001-018	76	34.10	0.67902	Uranyl Fluoride	Spherical	D2O/Water/HF	D2O/Water/Steel	93.65
Heucm-001-017	77	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heucm-001-015	78	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heucm-001-016	79	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heumf-007-043	80	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heucm-001-019	81	0.00	17.18152	U-Metal	Cuboid	None	Polyethylene	93.15
Heuci-004-001	82	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heucm-001-013	83	0.45	0.09763	Uranium Dioxide	Cuboid	Graphite/Water	None	92.28

Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heucm-001-011	84	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heucm-001-012	85	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heumf-007-042	86	0.00	17.18338	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-041	87	0.00	17.21505	U-Metal	Cuboid	None	Polyethylene	93.15
Heucm-001-009	88	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heumf-007-018	89	0.00	17.23368	U-Metal	Cuboid	None	Polyethylene	93.15
Heucm-001-010	90	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heumf-007-017	91	0.00	17.23554	U-Metal	Cuboid	None	Polyethylene	93.15
Heucm-001-027	92	1.56	5.41384	Uranium Dioxide	Cylinder	Alcohol	Alcohol/Plexiglass/Polyethylene	93.15
Heucm-001-026	93	1.56	5.41384	Uranium Dioxide	Cylinder	Alcohol	Alcohol/Plexiglass/Polyethylene	93.15
Heucm-001-025	94	1.56	5.41384	Uranium Dioxide	Cylinder	Alcohol	Alcohol/Plexiglass/Polyethylene	93.15
Heucm-001-023	95	1.56	5.41384	Uranium Dioxide	Cylinder	Alcohol	Alcohol/Plexiglass/Polyethylene	93.15

Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heucm-001-024	96	1.56	5.41384	Uranium Dioxide	Cylinder	Alcohol	Alcohol/Plexiglass/Polyethylene	93.15
Heucm-001-029	97	1.56	5.41384	Uranium Dioxide	Cylinder	Alcohol	Alcohol/Plexiglass/Polyethylene	93.15
Heucm-001-028	98	1.56	5.41384	Uranium Dioxide	Cylinder	Alcohol	Alcohol/Plexiglass/Polyethylene	93.15
Heucm-001-022	99	1.56	5.41384	Uranium Dioxide	Cylinder	Alcohol	Alcohol/Plexiglass/Polyethylene	93.15
Heucm-001-021	100	1.56	5.41384	Uranium Dioxide	Cylinder	Alcohol	Alcohol/Plexiglass/Polyethylene	93.15
Heucm-001-020	101	1.56	5.41384	Uranium Dioxide	Cylinder	Alcohol	Alcohol/Plexiglass/Polyethylene	93.15
Heucm-001-008	102	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heumm-002-001	103	0.00	16.52425	U-Metal	Sphere	None	Polyethylene	90.00
Heumm-003-001	104	0.00	16.52425	U-Metal	Sphere	None	Polyethylene	90.00
Heucm-001-005	105	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heumf-007-031	106	0.00	17.37061	U-Metal	Cuboid	None	Plexiglass	93.15
Heumf-007-039	107	0.00	17.24859	U-Metal	Cuboid	None	Polyethylene	93.15

Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heumf-007-040	108	0.00	17.28957	U-Metal	Cuboid	None	Polyethylene	93.15
Heucm-001-007	109	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heumf-007-038	110	0.00	17.17034	U-Metal	Cuboid	None	Polyethylene	93.15
Heucm-001-006	111	0.00	4.49781	Uranium Dioxide	Cylinder	Oxygen	Water/Plexiglass/Polyethylene	93.15
Heumf-007-037	112	0.00	17.18897	U-Metal	Cuboid	None	Polyethylene	93.15
Heumm-001-001	113	0.00	17.83457	U-Metal	Cylinder/Slab	None	Titanium/Polyethylene	95.98
Heumf-007-013	114	0.00	17.20853	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-016	115	0.00	17.28212	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-015	116	0.00	17.28957	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-014	117	0.00	17.17872	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-036	118	0.00	17.34639	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-023-020	119	0.00	17.48432	U-Metal	Cylinder	None	Polyethylene	93.20
Heumf-007-011	120	0.00	17.20853	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-031	121	0.00	17.83087	U-Metal	Cylinder	Carbon/Iron/Tungsten	Polyethylene	95.96
Heumf-007-035	122	0.00	17.11072	U-Metal	Cuboid	None	Polyethylene	93.15

Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heumf-026-004	123	0.00	17.48432	U-Metal	Cylinder	None	Paraffin	93.20
Heumf-034-003	124	0.00	17.83087	U-Metal	Cylinder	Carbon/Iron/Tungsten	Titanium/Polyethylene /Aluminum	95.96
Heumf-034-001	125	0.00	17.60018	U-Metal	Cuboid	None	Water	94.01
Heumf-034-002	126	0.00	17.83087	U-Metal	Cylinder	Carbon/Iron/Tungsten	Titanium/Polyethylene /Aluminum	95.96
Heumf-026-006	127	0.00	17.48432	U-Metal	Cylinder	None	Paraffin	93.20
Heumf-007-030	128	0.00	17.37806	U-Metal	Cuboid	None	Plexiglass	93.15
Heumt-003-001	129	0.00	17.60018	U-Metal	Cuboid	None	Water	94.01
Heumf-007-026	130	0.00	17.27374	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-010	131	0.00	17.24113	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-025	132	0.00	17.28212	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-026-003	133	0.00	17.48432	U-Metal	Cylinder	None	Paraffin	93.20
Heumf-004-002	134	0.00	18.35603	U-Metal	Sphere	None	Water	97.68
Heumf-004-001	135	0.00	18.35603	U-Metal	Sphere	None	Water, Plexiglass	97.68
Heumf-007-024	136	0.00	0.44400	U-Metal	Cylinder	Iron/Nickel/Chromium	Carbon Steel	93.18
Heumf-007-023	137	0.00	17.27933	U-Metal	Cuboid	None	Polyethylene	93.15

Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heumf-007-006	138	0.00	17.31752	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-022	139	0.00	17.30541	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-009	140	0.00	17.27001	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-008	141	0.00	17.27839	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-005	142	0.00	17.26442	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-007-003	143	0.00	17.26256	U-Metal	Cuboid	None	Polyethylene	93.15
Heumf-020	144	0.00	17.29423	U-Metal	Cuboid	None	Plexiglass	93.15
Heumf-007-002	145	0.00	16.58525	U-Metal	Sphere	Carbon/Iron/Tungsten	Polyethylene	89.65
Heumf-003-004	146	0.00	17.53125	U-Metal	Sphere	None	Tungsten Carbide	93.50
Heumf-041	147	0.00	17.37150	U-Metal	Cuboid	None	Beryillum	93.90
Heumf-003-003	148	0.00	17.53125	U-Metal	Sphere	None	Tungsten Carbide	93.50
Heumf-003-002	149	0.00	17.53125	U-Metal	Sphere	None	Tungsten Carbide	93.50
Heumf-007-034	150	0.00	17.13215	U-Metal	Cuboid	None	Teflon	93.15
Heumf-003-001	151	0.00	17.53125	U-Metal	Sphere	None	Tungsten Carbide	93.50
Heumf-007-033	152	0.00	17.17779	U-Metal	Cuboid	None	Teflon	93.15
Heumf-007-032	153	0.00	17.17779	U-Metal	Cuboid	None	Teflon	93.15

Table 1 Summary of Critical Experiments Modeled

Case ID	Case Number	H/^{235}U Atom Ratio	g^{235}U/cc	Material	Geometry	Moderator	Reflector	Enrichment
Heumf-019	154	0.00	16.54912	U-Metal	Sphere	Carbon/Iron/Tungsten	Graphite	89.60
Heumf-027	155	0.00	16.29293	U-Metal	Sphere	Carbon/Iron/Tungsten	Lead/Iron	89.47
Heumf-023-016	156	0.00	17.48430	U-Metal	Cylinder	None	Polyethylene	93.20
Heumf-018	157	0.00	16.33423	U-Metal	Sphere	Carbon/Iron/Tungsten	None	89.65
Heumf-026-001	158	0.00	17.48432	U-Metal	Cylinder	None	None	93.20
Heumf-001-001	159	0.00	17.65883	U-Metal	Sphere	None	None	93.90
Heumf-007-019	160	0.00	17.31845	U-Metal	Cuboid	None	None	93.15
Heumf-007-001	161	0.00	17.21598	U-Metal	Cuboid	None	None	93.15

Table 2 Experimental and Calculation Results

Case ID	Case Number	Kexp	Sigexp	K5calc	Sig5calc	K6calc	Sig6calc	ALCF, eV
Heust-032-001	1	1.0000	0.0004	0.9994	0.0008	0.9979	0.0009	2.91E-02
Heust-002-009	2	1.0000	0.0004	1.0081	0.0017	1.0077	0.0018	3.05E-02
Heust-012-001	3	1.0000	0.0004	1.0047	0.0009	1.0018	0.0010	3.08E-02
Heust-037-005	4	1.0000	0.0004	1.0092	0.0012	1.0046	0.0011	3.16E-02
Heust-028-001	5	1.0000	0.0004	1.0019	0.0017	1.0014	0.0021	3.28E-02
Heust-014-002	6	1.0000	0.0004	1.0149	0.0014	1.0157	0.0014	3.31E-02
Heust-035-005	7	1.0000	0.0004	1.0066	0.0013	1.0096	0.0012	3.45E-02
Heust-035-001	8	1.0000	0.0004	1.0045	0.0013	1.0014	0.0011	3.52E-02
Heust-007-009	9	1.0000	0.0004	1.0085	0.0013	1.0080	0.0013	3.61E-02
Heust-037-002	10	1.0000	0.0004	1.0061	0.0011	1.0044	0.0013	3.71E-02
Heust-011-001	11	1.0000	0.0004	1.0075	0.0012	1.0049	0.0013	3.79E-02
Heumt-006-012	12	1.0000	0.0004	1.0054	0.0016	1.0049	0.0014	4.00E-02
Heust-025-006	13	1.0000	0.0004	1.0107	0.0009	1.0120	0.0009	4.07E-02
Heust-008-007	14	1.0000	0.0004	1.0003	0.0014	0.9986	0.0014	4.13E-02

Table 2 Experimental and Calculation Results

Case ID	Case Number	Kexp	Sigexp	K5calc	Sig5calc	K6calc	Sig6calc	ALCF, eV
Heust-002-010	15	1.0000	0.0004	1.0079	0.0013	1.0089	0.0014	4.19E-02
Heust-003-001	16	1.0000	0.0004	1.0070	0.0014	1.0008	0.0014	4.19E-02
Heumt-006-005	17	1.0000	0.0004	1.0023	0.0015	1.0048	0.0016	4.34E-02
Heust-028-008	18	1.0000	0.0004	1.0010	0.0014	0.9992	0.0015	4.56E-02
Heumt-006-016	19	1.0000	0.0004	1.0030	0.0014	1.0008	0.0017	4.73E-02
Heust-007-010	20	1.0000	0.0004	1.0142	0.0013	1.0162	0.0011	5.06E-02
Heust-037-009	21	1.0000	0.0004	1.0057	0.0013	1.0057	0.0015	5.20E-02
Heust-010-003	22	1.0000	0.0004	1.0023	0.0016	1.0012	0.0015	5.33E-02
Heust-036-002	23	1.0000	0.0004	1.0006	0.0015	0.9966	0.0015	5.56E-02
Heumt-006-018	24	1.0000	0.0004	1.0036	0.0018	1.0031	0.0016	6.04E-02
Heust-015-003	25	1.0000	0.0004	1.0124	0.0013	1.0128	0.0013	6.04E-02
Heumt-006-010	26	1.0000	0.0004	1.0040	0.0015	1.0040	0.0016	6.28E-02
Heust-027-001	27	1.0000	0.0004	0.9983	0.0019	0.9999	0.0016	7.18E-02
Heust-027-005	28	1.0000	0.0004	0.9946	0.0014	0.9989	0.0014	7.33E-02
Heust-002-012	29	1.0000	0.0004	1.0113	0.0014	1.0082	0.0013	7.52E-02

Table 2 Experimental and Calculation Results

Case ID	Case Number	Kexp	Sigexp	K5calc	Sig5calc	K6calc	Sig6calc	ALCF, eV
Heust-002-011	30	1.0000	0.0004	1.0041	0.0015	1.0034	0.0015	7.69E-02
Heuct-010-021	31	1.0000	0.0004	1.0059	0.0012	1.0040	0.0013	9.09E-02
Heuct-010-010	32	1.0000	0.0004	1.0009	0.0011	1.0019	0.0011	9.57E-02
Heuct-014-002	33	1.0000	0.0004	1.0028	0.0013	1.0000	0.0013	9.61E-02
Heuct-010-017	34	1.0000	0.0004	1.0056	0.0013	1.0042	0.0012	9.69E-02
Heuct-010-015	35	1.0000	0.0004	1.0027	0.0011	1.0031	0.0012	9.96E-02
Heuct-010-008	36	1.0000	0.0004	1.0025	0.0012	1.0029	0.0012	1.09E-01
Heuct-014-001	37	1.0000	0.0004	1.0001	0.0013	1.0036	0.0012	1.16E-01
Heust-020-003	38	1.0000	0.0004	1.0098	0.0016	1.0083	0.0017	1.32E-01
Heuct-010-005	39	1.0000	0.0004	0.9968	0.0011	0.9963	0.0012	1.37E-01
Heuct-010-006	40	1.0000	0.0004	0.9947	0.0013	0.9965	0.0012	1.38E-01
Heust-030-004	41	1.0000	0.0004	1.0028	0.0015	1.0016	0.0015	1.56E-01
Heust-025-017	42	1.0000	0.0004	1.0057	0.0010	1.0062	0.0010	1.67E-01
Heust-025-016	43	1.0000	0.0004	1.0148	0.0010	1.0134	0.0010	1.79E-01
Heuct-010-004	44	1.0000	0.0004	0.9964	0.0013	0.9958	0.0014	1.90E-01

Table 2 Experimental and Calculation Results

Case ID	Case Number	Kexp	Sigexp	K5calc	Sig5calc	K6calc	Sig6calc	ALCF, eV
Heust-008-014	45	1.0000	0.0004	1.0000	0.0017	1.0005	0.0014	2.06E-01
Heust-021-006	46	1.0000	0.0004	1.0132	0.0015	1.0138	0.0014	2.15E-01
Heust-005-015	47	1.0000	0.0004	0.9984	0.0014	0.9985	0.0014	2.23E-01
Heust-003-011	48	1.0000	0.0004	1.0024	0.0017	1.0012	0.0014	2.28E-01
Heust-005-008	49	1.0000	0.0004	1.0039	0.0012	1.0031	0.0013	2.33E-01
Heust-008-008	50	1.0000	0.0004	1.0004	0.0016	0.9998	0.0015	2.40E-01
Heust-002-003	51	1.0000	0.0004	1.0020	0.0017	1.0029	0.0017	2.48E-01
Heust-003-018	52	1.0000	0.0004	0.9990	0.0016	1.0003	0.0014	2.54E-01
Heust-007-008	53	1.0000	0.0004	1.0046	0.0015	1.0040	0.0015	2.66E-01
Heust-007-006	54	1.0000	0.0004	1.0065	0.0014	1.0059	0.0016	2.70E-01
Heust-021-018	55	1.0000	0.0004	1.0030	0.0015	1.0061	0.0016	2.79E-01
Heust-033-003	56	1.0000	0.0004	1.0033	0.0013	1.0020	0.0013	2.90E-01
Heust-021-023	57	1.0000	0.0004	0.9989	0.0014	1.0014	0.0014	2.98E-01
Heust-033-008	58	1.0000	0.0004	1.0029	0.0013	1.0041	0.0014	3.07E-01
Heuct-013-002	59	1.0000	0.0004	0.9993	0.0012	1.0004	0.0011	3.12E-01

Table 2 Experimental and Calculation Results

Case ID	Case Number	Kexp	Sigexp	K5calc	Sig5calc	K6calc	Sig6calc	ALCF, eV
Heust-006-022	60	1.0000	0.0004	1.0037	0.0012	1.0024	0.0011	3.14E-01
Heust-009-002	61	1.0000	0.0004	1.0046	0.0014	1.0045	0.0014	3.18E-01
Heuct-010-003	62	1.0000	0.0004	0.9947	0.0015	0.9912	0.0014	3.24E-01
Heucm-001-002	63	1.0000	0.0004	1.0102	0.0014	1.0111	0.0013	3.56E-01
Heust-006-014	64	1.0000	0.0004	1.0048	0.0010	1.0029	0.0012	3.58E-01
Heust-006-021	65	1.0000	0.0004	1.0040	0.0008	1.0043	0.0009	4.44E-01
Heuct-013-001	66	1.0000	0.0004	0.9995	0.0014	0.9994	0.0012	4.49E-01
Heuct-011-002	67	1.0000	0.0004	0.9976	0.0012	0.9954	0.0011	5.39E-01
Heuct-012-001	68	1.0000	0.0004	0.9957	0.0015	0.9963	0.0014	5.94E-01
Heuct-011-001	69	1.0000	0.0004	0.9972	0.0012	0.9972	0.0012	7.04E-01
Heust-004-004	70	1.0000	0.0004	1.0027	0.0017	1.0044	0.0016	1.09E+00
Heust-020-001	71	1.0000	0.0004	1.0065	0.0020	1.0037	0.0019	1.35E+00
Heust-004-003	72	1.0000	0.0004	1.0017	0.0015	1.0015	0.0016	2.68E+00
Heumt-003-005	73	1.0000	0.0004	0.9943	0.0017	0.9917	0.0015	2.73E+00
Heust-004-002	74	1.0000	0.0004	1.0000	0.0017	1.0015	0.0017	5.59E+00

Table 2 Experimental and Calculation Results

Case ID	Case Number	Kexp	Sigexp	K5calc	Sig5calc	K6calc	Sig6calc	ALCF, eV
Heust-004-001	75	1.0000	0.0004	1.0049	0.0016	1.0013	0.0016	1.30E+01
Heucm-001-018	76	1.0000	0.0004	1.0072	0.0016	1.0079	0.0014	2.35E+01
Heucm-001-017	77	1.0000	0.0004	1.0022	0.0010	1.0019	0.0010	2.50E+01
Heucm-001-015	78	1.0000	0.0004	1.0129	0.0011	1.0129	0.0012	2.88E+01
Heucm-001-016	79	1.0000	0.0004	1.0024	0.0011	1.0051	0.0010	2.92E+01
Heumf-007-043	80	1.0000	0.0004	1.0081	0.0017	1.0073	0.0017	3.32E+01
Heucm-001-019	81	1.0000	0.0004	1.0061	0.0014	1.0075	0.0017	5.81E+01
Heuci-004-001	82	1.0000	0.0004	1.0138	0.0004	1.0141	0.0004	1.45E+02
Heucm-001-013	83	1.0000	0.0004	1.0061	0.0011	1.0081	0.0010	2.32E+02
Heucm-001-011	84	1.0000	0.0004	1.0074	0.0013	1.0085	0.0012	2.58E+02
Heucm-001-012	85	1.0000	0.0004	1.0050	0.0012	1.0011	0.0011	2.59E+02
Heumf-007-042	86	1.0000	0.0004	1.0066	0.0011	1.0037	0.0013	2.91E+02
Heumf-007-041	87	1.0000	0.0004	1.0044	0.0015	1.0035	0.0014	3.05E+02
Heucm-001-009	88	1.0000	0.0004	1.0061	0.0012	1.0042	0.0012	3.46E+02
Heumf-007-018	89	1.0000	0.0004	0.9972	0.0014	0.9959	0.0013	3.47E+02

Table 2 Experimental and Calculation Results

Case ID	Case Number	Kexp	Sigexp	K5calc	Sig5calc	K6calc	Sig6calc	ALCF, eV
Heucm-001-010	90	1.0000	0.0004	0.9996	0.0012	1.0004	0.0012	3.50E+02
Heumf-007-017	91	1.0000	0.0004	0.9943	0.0014	0.9959	0.0013	3.72E+02
Heucm-001-027	92	1.0000	0.0004	1.0066	0.0012	1.0063	0.0012	3.83E+02
Heucm-001-026	93	1.0000	0.0004	1.0049	0.0012	1.0052	0.0012	4.01E+02
Heucm-001-025	94	1.0000	0.0004	1.0021	0.0014	1.0025	0.0012	4.42E+02
Heucm-001-023	95	1.0000	0.0004	1.0131	0.0011	1.0107	0.0013	4.54E+02
Heucm-001-024	96	1.0000	0.0004	1.0056	0.0011	1.0080	0.0013	4.54E+02
Heucm-001-029	97	1.0000	0.0004	1.0096	0.0013	1.0064	0.0012	4.64E+02
Heucm-001-028	98	1.0000	0.0004	1.0089	0.0012	1.0112	0.0012	4.82E+02
Heucm-001-022	99	1.0000	0.0004	1.0059	0.0011	1.0046	0.0011	5.28E+02
Heucm-001-021	100	1.0000	0.0004	1.0067	0.0011	1.0077	0.0010	5.35E+02
Heucm-001-020	101	1.0000	0.0004	1.0122	0.0011	1.0100	0.0012	5.39E+02
Heucm-001-008	102	1.0000	0.0004	1.0017	0.0012	1.0017	0.0013	5.54E+02
Heumm-002-001	103	1.0000	0.0004	1.0096	0.0011	1.0108	0.0012	1.18E+03
Heumm-003-001	104	1.0000	0.0004	1.0107	0.0012	1.0084	0.0012	1.18E+03

Table 2 Experimental and Calculation Results

Case ID	Case Number	Kexp	Sigexp	K5calc	Sig5calc	K6calc	Sig6calc	ALCF, eV
Heucm-001-005	105	1.0000	0.0004	1.0084	0.0011	1.0082	0.0011	1.54E+03
Heumf-007-031	106	1.0000	0.0004	1.0002	0.0015	1.0011	0.0014	1.61E+03
Heumf-007-039	107	1.0000	0.0004	1.0041	0.0011	1.0019	0.0013	1.70E+03
Heumf-007-040	108	1.0000	0.0004	1.0066	0.0012	1.0071	0.0014	1.70E+03
Heucm-001-007	109	1.0000	0.0004	1.0092	0.0012	1.0073	0.0011	1.72E+03
Heumf-007-038	110	1.0000	0.0004	1.0016	0.0011	1.0008	0.0012	1.74E+03
Heucm-001-006	111	1.0000	0.0004	1.0035	0.0010	1.0024	0.0010	1.82E+03
Heumf-007-037	112	1.0000	0.0004	1.0032	0.0012	1.0032	0.0011	1.90E+03
Heumm-001-001	113	1.0000	0.0004	1.0053	0.0012	1.0050	0.0012	2.26E+03
Heumf-007-013	114	1.0000	0.0004	0.9972	0.0014	0.9997	0.0012	2.54E+03
Heumf-007-016	115	1.0000	0.0004	0.9947	0.0014	0.9954	0.0014	2.82E+03
Heumf-007-015	116	1.0000	0.0004	0.9949	0.0013	0.9925	0.0012	2.83E+03
Heumf-007-014	117	1.0000	0.0004	0.9974	0.0013	0.9953	0.0013	3.70E+03
Heumf-007-036	118	1.0000	0.0004	1.0049	0.0011	1.0046	0.0013	3.90E+03
Heumf-023-020	119	1.0000	0.0004	1.0036	0.0013	1.0020	0.0012	5.14E+03

Table 2 Experimental and Calculation Results

Case ID	Case Number	Kexp	Sigexp	K5calc	Sig5calc	K6calc	Sig6calc	ALCF, eV
Heumf-007-011	120	1.0000	0.0004	0.9931	0.0012	0.9955	0.0015	5.53E+03
Heumf-031	121	1.0000	0.0004	1.0018	0.0012	1.0045	0.0012	6.81E+03
Heumf-007-035	122	1.0000	0.0004	0.9971	0.0012	0.9964	0.0012	7.53E+03
Heumf-026-004	123	1.0000	0.0004	1.0013	0.0012	1.0033	0.0011	1.08E+04
Heumf-034-003	124	1.0000	0.0004	1.0006	0.0011	1.0003	0.0013	1.51E+04
Heumf-034-001	125	1.0000	0.0004	0.9963	0.0012	0.9966	0.0012	1.58E+04
Heumf-034-002	126	1.0000	0.0004	0.9937	0.0012	0.9940	0.0013	1.62E+04
Heumf-026-006	127	1.0000	0.0004	0.9999	0.0011	1.0029	0.0011	1.65E+04
Heumf-007-030	128	1.0000	0.0004	0.9942	0.0013	0.9946	0.0013	1.75E+04
Heumt-003-001	129	1.0000	0.0004	1.0009	0.0013	1.0013	0.0012	1.83E+04
Heumf-007-026	130	1.0000	0.0004	0.9943	0.0014	0.9934	0.0013	2.50E+04
Heumf-007-010	131	1.0000	0.0004	0.9970	0.0012	0.9934	0.0013	2.64E+04
Heumf-007-025	132	1.0000	0.0004	0.9940	0.0012	0.9970	0.0013	2.66E+04
Heumf-026-003	133	1.0000	0.0004	1.0036	0.0012	1.0037	0.0011	3.06E+04
Heumf-004-002	134	1.0000	0.0004	0.9972	0.0013	1.0002	0.0011	3.10E+04

Table 2 Experimental and Calculation Results

Case ID	Case Number	Kexp	Sigexp	K5calc	Sig5calc	K6calc	Sig6calc	ALCF, eV
Heumf-004-001	135	1.0000	0.0004	0.9988	0.0011	0.9954	0.0011	3.12E+04
Heumf-007-024	136	1.0000	0.0004	0.9975	0.0011	0.9959	0.0012	5.84E+04
Heumf-007-023	137	1.0000	0.0004	0.9975	0.0014	0.9969	0.0013	6.25E+04
Heumf-007-006	138	1.0000	0.0004	1.0011	0.0015	1.0035	0.0012	1.61E+05
Heumf-007-022	139	1.0000	0.0004	0.9979	0.0012	0.9961	0.0013	1.80E+05
Heumf-007-009	140	1.0000	0.0004	0.9965	0.0013	1.0004	0.0013	1.82E+05
Heumf-007-008	141	1.0000	0.0004	0.9960	0.0012	0.9946	0.0012	2.06E+05
Heumf-007-005	142	1.0000	0.0004	0.9965	0.0013	0.9949	0.0012	2.54E+05
Heumf-007-003	143	1.0000	0.0004	0.9964	0.0014	0.9994	0.0012	3.76E+05
Heumf-020	144	1.0000	0.0004	1.0016	0.0013	1.0001	0.0013	4.82E+05
Heumf-007-002	145	1.0000	0.0004	0.9962	0.0012	0.9969	0.0010	4.98E+05
Heumf-003-004	146	1.0000	0.0004	1.0135	0.0011	1.0143	0.0012	5.60E+05
Heumf-041	147	1.0000	0.0004	1.0066	0.0012	1.0065	0.0011	5.65E+05
Heumf-003-003	148	1.0000	0.0004	1.0088	0.0010	1.0083	0.0011	5.75E+05
Heumf-003-002	149	1.0000	0.0004	1.0045	0.0011	1.0048	0.0011	6.23E+05

Table 2 Experimental and Calculation Results

Case ID	Case Number	Kexp	Sigexp	K5calc	Sig5calc	K6calc	Sig6calc	ALCF, eV
Heumf-007-034	150	1.0000	0.0004	1.0105	0.0013	1.0099	0.0012	6.59E+05
Heumf-003-001	151	1.0000	0.0004	1.0063	0.0011	1.0048	0.0011	6.82E+05
Heumf-007-033	152	1.0000	0.0004	1.0064	0.0013	1.0082	0.0013	7.23E+05
Heumf-007-032	153	1.0000	0.0004	1.0005	0.0012	0.9991	0.0011	7.97E+05
Heumf-019	154	1.0000	0.0004	1.0061	0.0010	1.0047	0.0012	8.16E+05
Heumf-027	155	1.0000	0.0004	1.0131	0.0012	1.0131	0.0012	8.55E+05
Heumf-023-016	156	1.0000	0.0004	1.0019	0.0012	0.9999	0.0013	8.85E+05
Heumf-018	157	1.0000	0.0004	0.9987	0.0012	1.0019	0.0011	8.89E+05
Heumf-026-001	158	1.0000	0.0004	1.0021	0.0013	1.0031	0.0011	8.99E+05
Heumf-001-001	159	1.0000	0.0004	1.0014	0.0011	0.9999	0.0011	9.05E+05
Heumf-007-019	160	1.0000	0.0004	0.9962	0.0012	0.9971	0.0013	9.08E+05
Heumf-007-001	161	1.0000	0.0004	0.9960	0.0011	0.9937	0.0012	9.14E+05

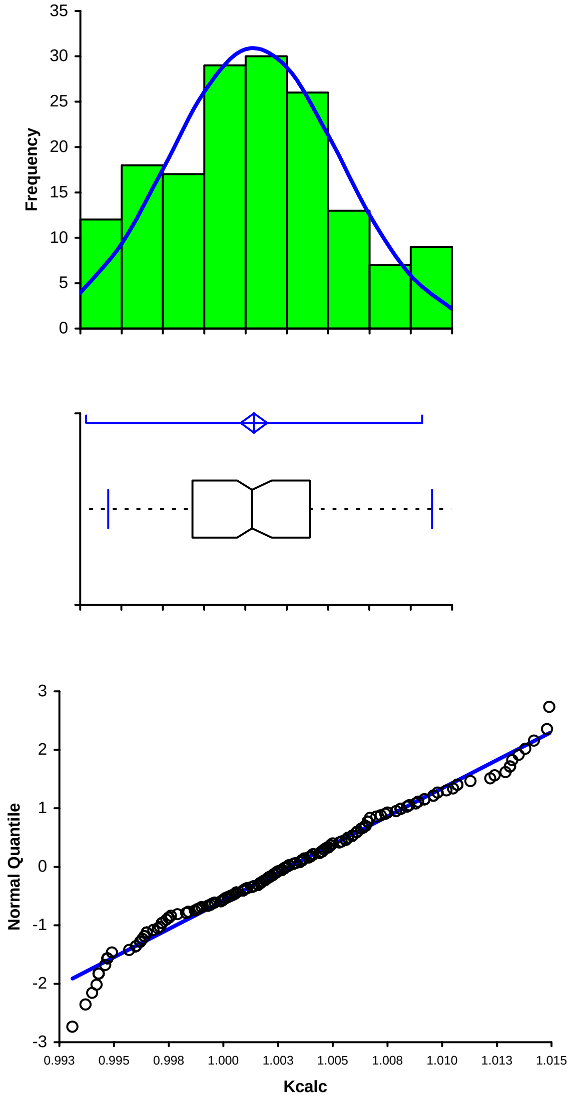
Table 3 Summary of Analysis Results

	K5Group 1 All Data	**K5Group 2 ALCF ≤ 10^2 eV**	**K5Group 3 10^2 eV < ALCF ≤ 10^5 eV**	**K5Group 4 ALCF > 10^5 eV**	**K6Group 1 All Data**	**K6Group 2 ALCF ≤ 10^2 eV**	**K6Group 3 10^2 eV < ALCF ≤ 10^5 eV**	**K6Group 4 ALCF > 10^5 eV**
Number of Experiments	161	81	56	24	161	81	56	24
Mean Experimental k_{eff}	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Mean Calculated k_{eff}	1.0030	1.0037	1.0024	1.0023	1.0028	1.0033	1.0022	1.0023
Experimental k_{eff} variance	1.6000E-07	1.6000E-07	1.6000E-07	1.6000E-07	1.6000E-07	1.6000E-07	1.6000E-07	1.6000E-07
Calculated k_{eff} variance	2.6907E-05	2.3170E-05	3.0155E-05	3.1154E-05	2.6907E-05	2.3170E-05	3.0155E-05	3.1154E-05
σKENO-calc mean	0.0013	0.0014	0.0012	0.0012	0.0013	0.0014	0.0012	0.0012
t-value	-2543	-1876	-1365	-879				
t-critical 1 tail (95%)	1.8610	1.9620	2.0380	2.3090				
t-critical 2 tail (95%)	1.9674	1.9750	1.9750	1.9818				
t-test 2 tail pass/fail	Fail	Fail	Fail	Fail				
Method Bias	+0.0030	+0.0037	+0.0024	+0.0023	+0.0030	+0.0037	+0.0024	+0.0023
Uncertainty (*U*) {1 tail (95%)}	0.0022	0.0024	0.0027	0.0037	0.0022	0.0024	0.0027	0.0037
Total Uncertainty *κ(σKENO-calc) + (U)*	0.0031	0.0033	0.0034	0.0042	0.0030	0.0033	0.0034	0.0042
Upper Limit k_{eff}	0.9469	0.9467	0.9466	0.9458	0.9470	0.9467	0.9466	0.9458

Notes; Positive biases were neglected in the determination of the k_{eff} limits and the mean KENO-calculated standard deviation (σ) was used to determine the Upper Limit.

analysed with: Analyse-it + General 1.65

Test	**Continuous summary descriptives** **Group 1** Kcalc		
Performed by	RDMontgomery	**Date**	7 July 2004



n	161
Mean	1.00302
95% CI	1.00222 to 1.00383
Variance	0.000027
SD	0.005187
SE	0.000409
CV	1%

Median	1.00290
96.0% CI	1.00200 to 1.00410
Range	0.0218
IQR	0.0071

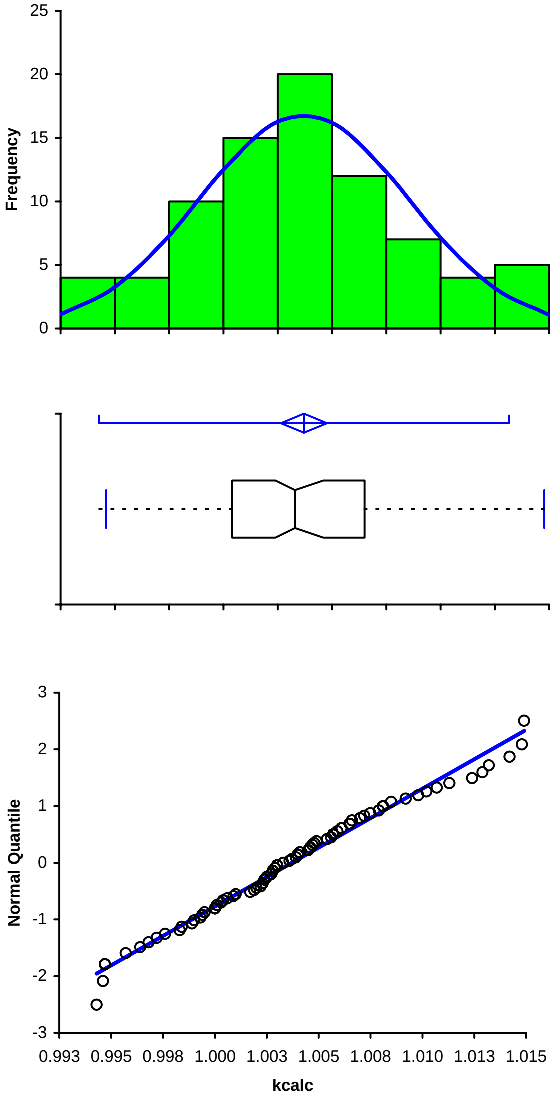
Percentile	
2.5th	0.99421
25th	0.99930
50th	1.00290
75th	1.00640
97.5th	1.01379

	Coefficient	p
Anderson-Darling	0.4951	0.2146
Skewness	0.1862	0.3228
Kurtosis	-0.5371	0.0741

Figure 1, Group 1 Histogram, Skewness and Kurtosis.

analysed with: Analyse-it + General 1.65

Test	**Continuous summary descriptives** **Group 2** kcalc		
Performed by	RDMontgomery	**Date**	10 September 2003



n	81
Mean	1.00371
95% CI	1.00264 to 1.00477
Variance	0.000023
SD	0.004814
SE	0.000535
CV	0%
Median	1.00330
95.5% CI	1.00240 to 1.00460
Range	0.0206
IQR	0.0061

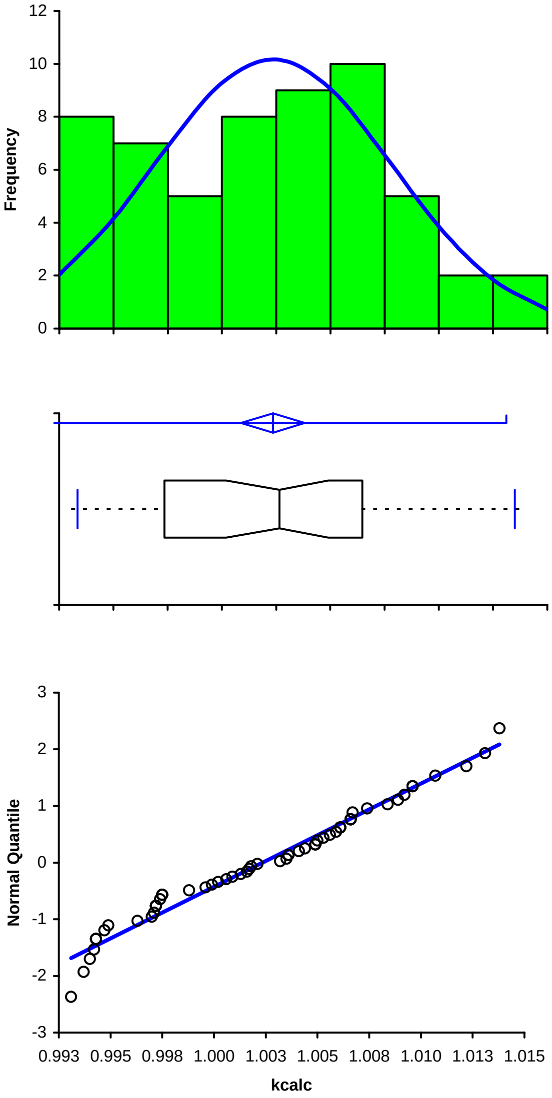
Percentile	
2.5th	0.99461
25th	1.00040
50th	1.00330
75th	1.00650
97.5th	1.01477

	Coefficient	p
Anderson-Darling	0.3513	0.4696
Skewness	0.2746	0.2927
Kurtosis	-0.0750	0.9661

Figure 2, Group 2 Histogram, Skewness and Kurtosis.

analysed with: Analyse-it + General 1.65

Test	**Continuous summary descriptives** **Group 3** kcalc		
Performed by	RDMontgomery	**Date**	10 September 2003



n	56
Mean	1.00235
95% CI	1.00088 to 1.00382
Variance	0.000030
SD	0.005491
SE	0.000734
CV	1%
Median	1.00265
95.6% CI	1.00020 to 1.00490
Range	0.0207
IQR	0.0091

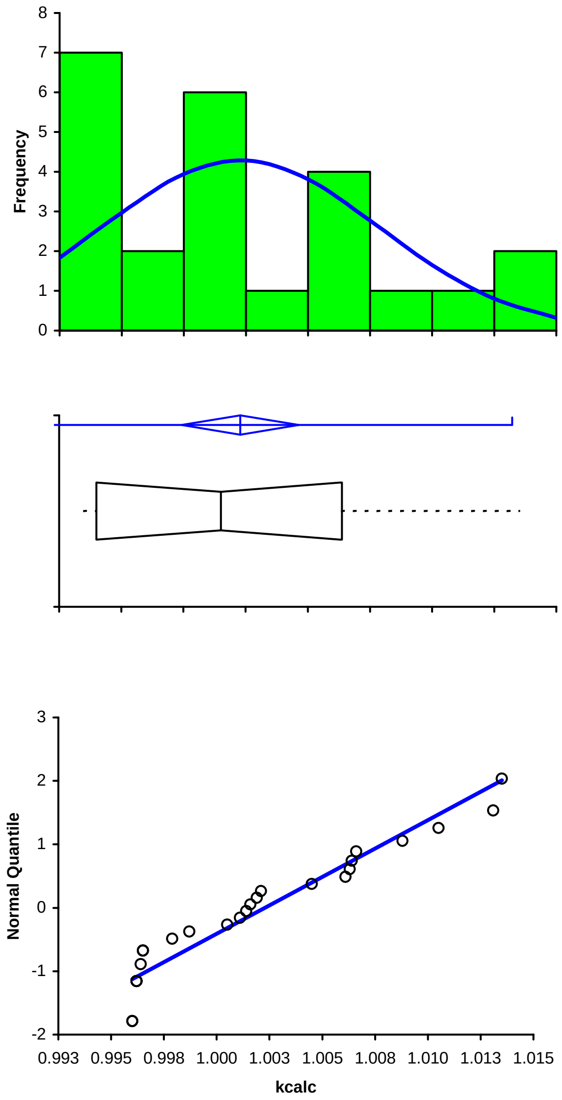
Percentile	
2.5th	0.99336
25th	0.99735
50th	1.00265
75th	1.00648
97.5th	1.01350

	Coefficient	p
Anderson-Darling	0.5075	0.2000
Skewness	0.0838	0.7834
Kurtosis	-0.8797	0.0391

Figure 3, Group 3 Histogram, Skewness and Kurtosis.

analysed with: Analyse-it + General 1.65

Test	**Continuous summary descriptives** **Group 4** kcalc		
Performed by	RDMontgomery	**Date**	10 September 2003



n	24
Mean	1.00228
95% CI	0.99993 to 1.00464
Variance	0.000031
SD	0.005582
SE	0.001139
CV	1%
Median	1.00150
97.7% CI	0.99650 to 1.00630
Range	0.0175
IQR	0.0099

Percentile	
2.5th	-
25th	0.99650
50th	1.00150
75th	1.00638
97.5th	-

	Coefficient	p
Anderson-Darling	0.7342	0.0557
Skewness	0.5767	0.2084
Kurtosis	-0.7094	0.4126

Figure 4, Group 4 Histogram, Skewness and Kurtosis.

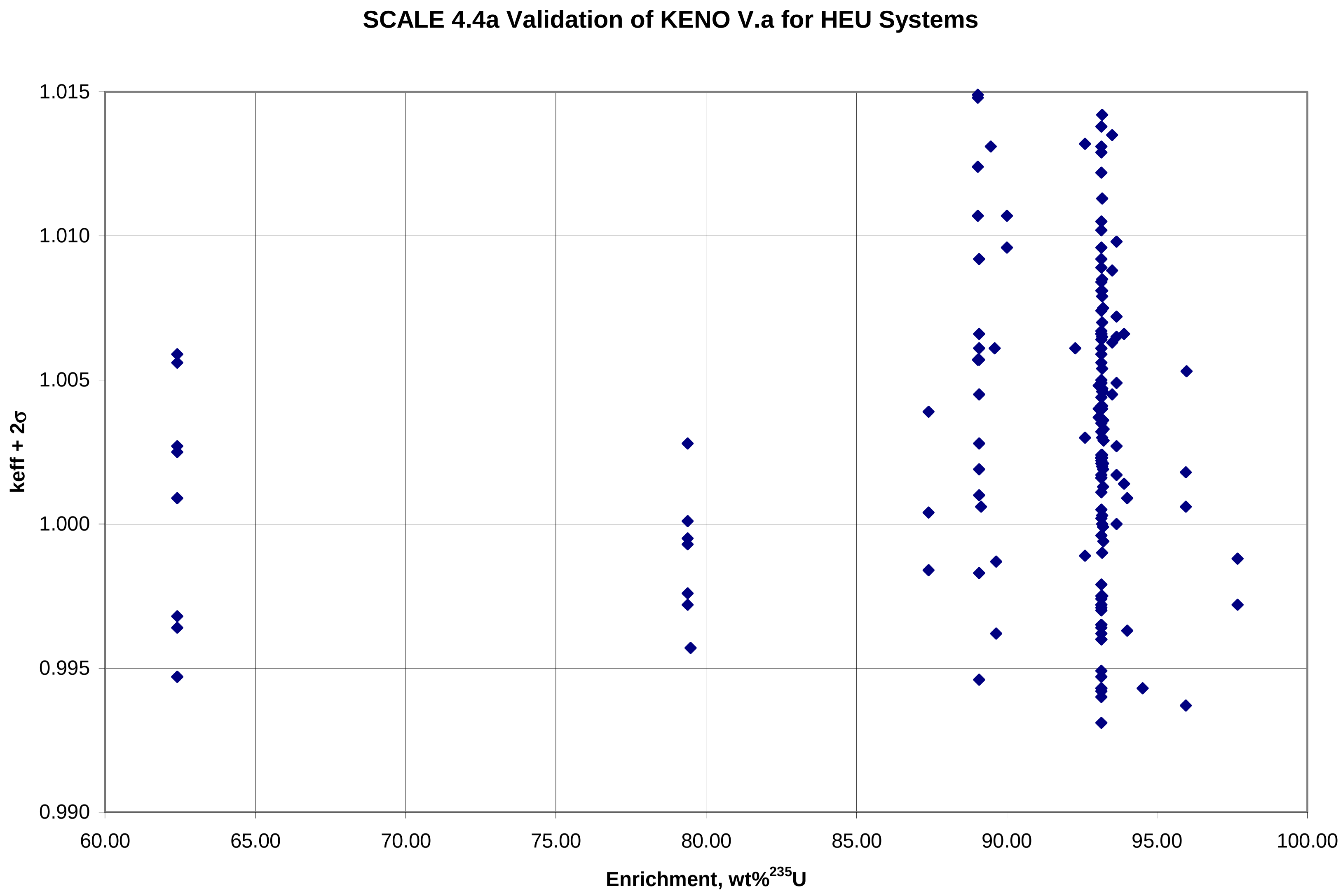


Figure 5, Plot of k_{eff} with the Enrichment (wt%^{235}U).

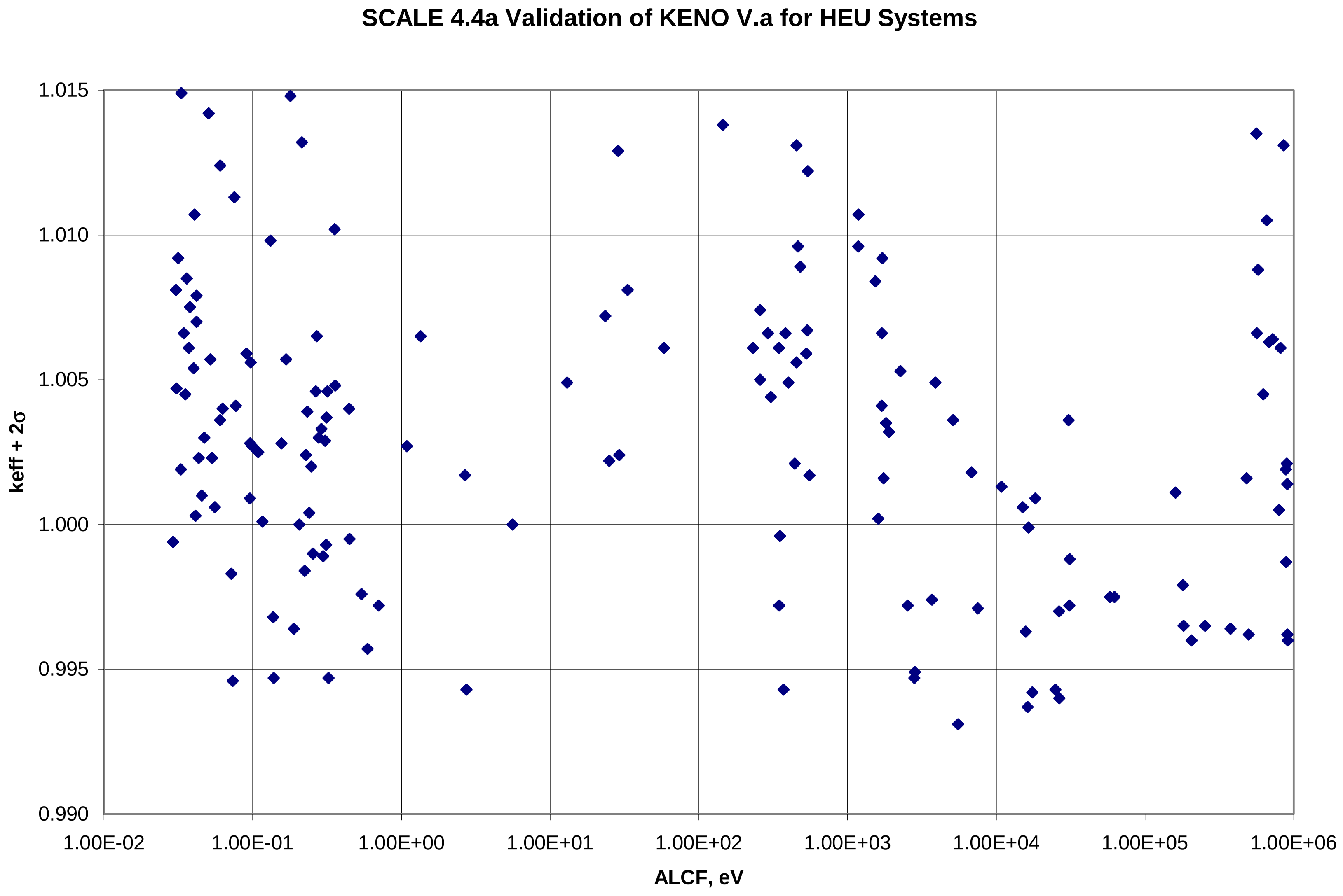


Figure 6, Plot of k_{eff} with the Energy of the Average Lethargy Causing Fission (ALCF).

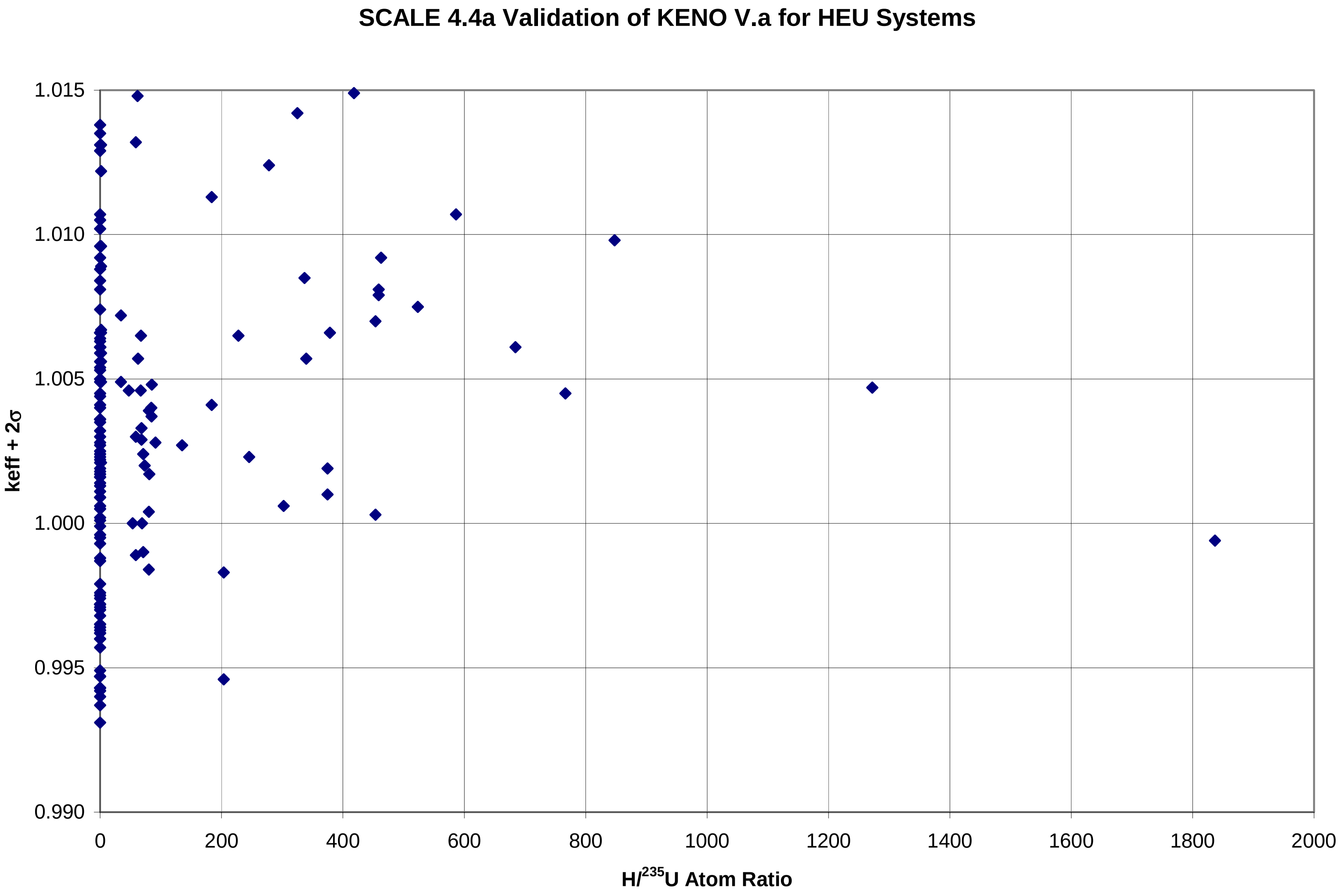


Figure 7, Plot of the k_{eff} with the Moderator-to-Fissile atom ratio (H/^{235}U).

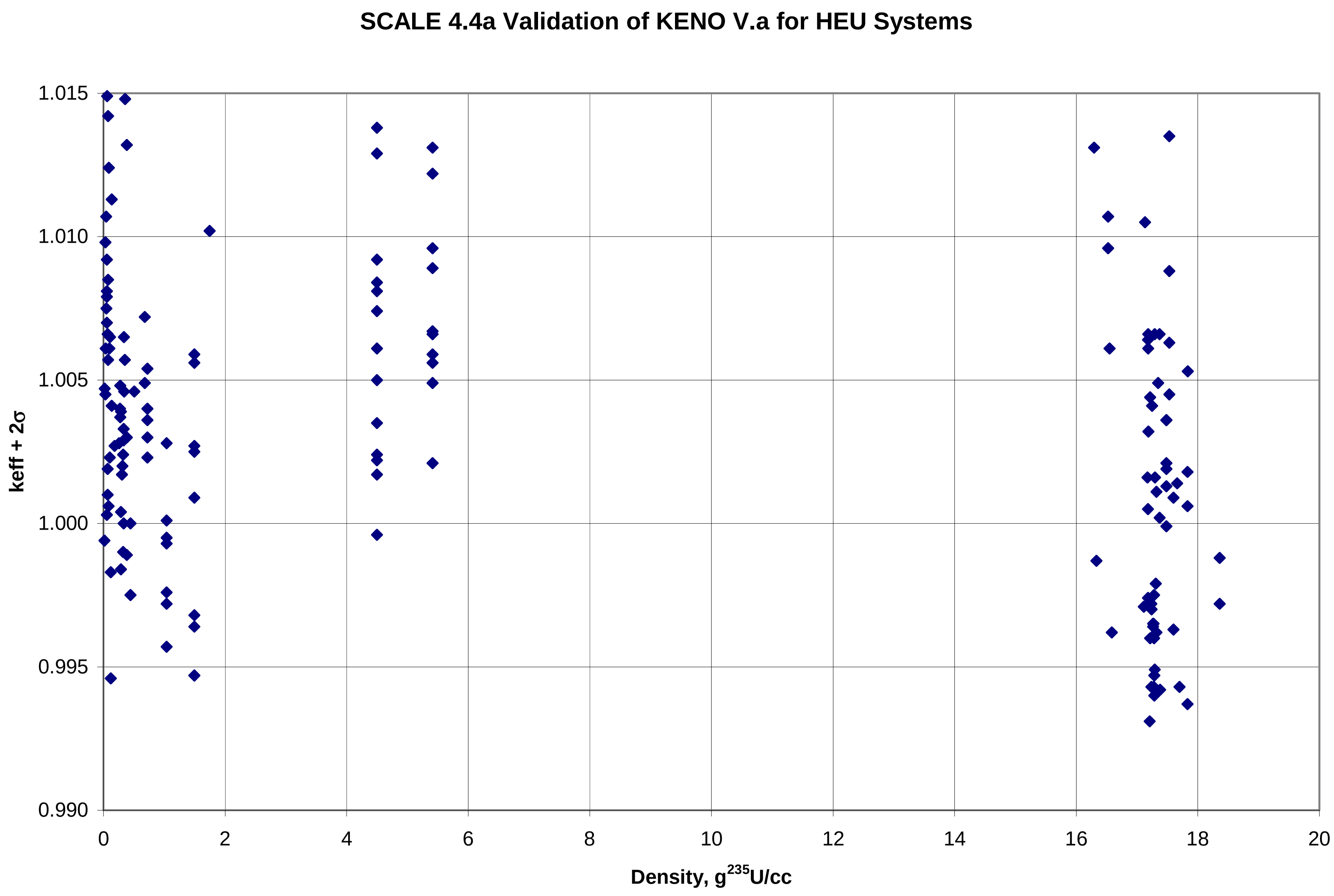


Figure 8, Plot of k_{eff} with the Fissile Denstiy (g ^{235}U/cc)

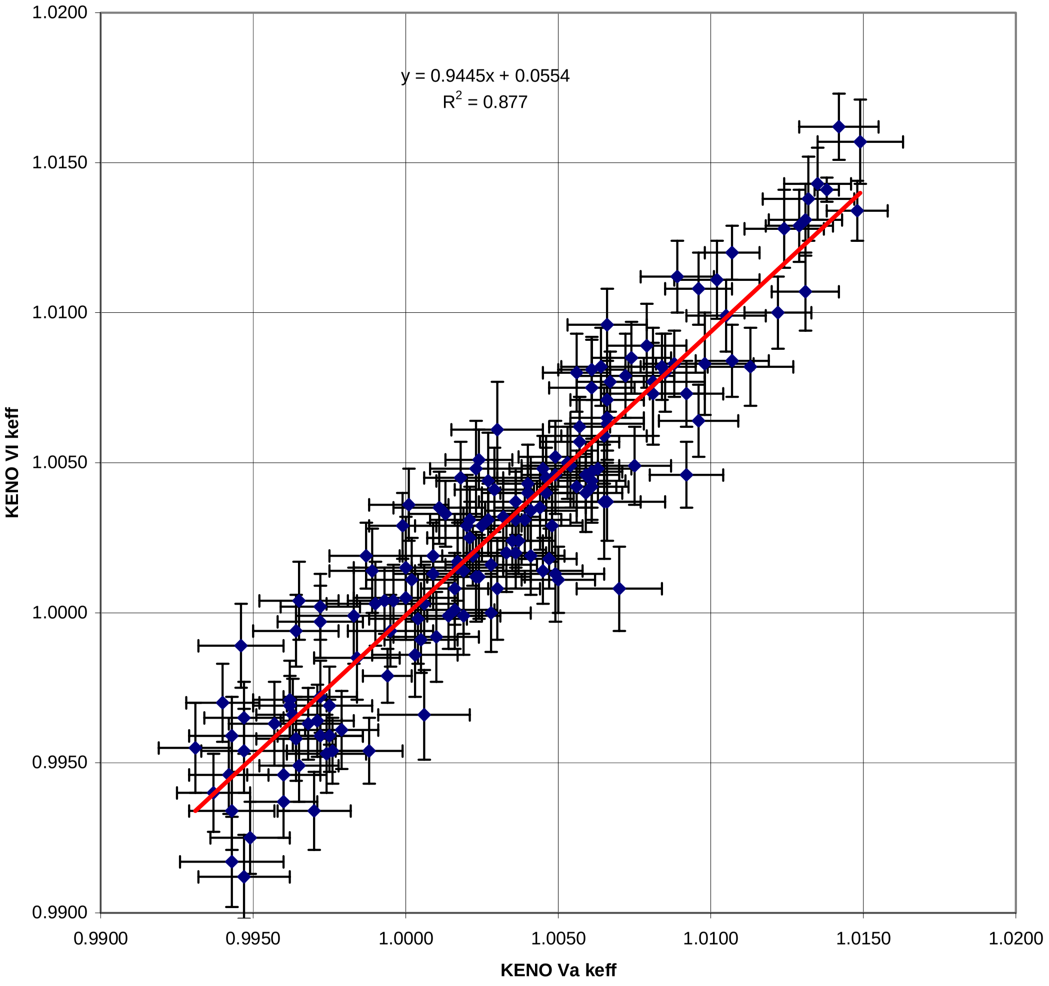


Figure 9, Plot of KENO VI k_{eff} with the KENO Va k_{eff}

APPENDIX A

SCALE INPUT CASES FOR DATA SETS 1 THROUGH 161 CRITICAL EXPERIMENTS

(This information available in electronic media only)

SECTION SEVEN

OPERATING PROCEDURES

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7.0 PACKAGE OPERATIONS

The Century Versa-Pac (US Patent Pending) Shipping Container is used to transport a variety of materials. It is to be loaded, inspected and handled in accordance with standard, plant operating procedures.

Due to the low specific activity and low abundance of gamma emitting radionuclides, dose rates from the contents of the package are minimal. As a result of the low dose rates, there are no special handling requirements for radiation protection.

As a minimum, the operating procedure should include the steps described in the subsequent sections.

7.1 PACKAGE LOADING

7.1.1 Preparation for Loading

Prior to loading the Century Versa-Pac, the packaging is inspected to ensure that it is in unimpaired physical condition. The inspection looks for damage, dents, corrosion, and missing hardware. Acceptance criteria and detailed loading procedures derived from this application are specified in user written procedures. These user procedures are specific to the authorized content of the package inspected to ensure packaging complies with Appendix 1.3.1, Packaging General Arrangement Drawings.

Components requiring repair will be fixed prior to shipping in accordance with approved procedures consistent with the quality program.

The User shall inspect the accessible surfaces of the closure and sealing devices in accordance with approved procedures prior to loading of the container to assure the following at a minimum:

a. Ensure that the most recent certification performed is in accordance with Section 8.2.

b. The contents are within the limits of the Certificate of Compliance.

c. The package inner and outer surfaces are visually free from damage that may impair the safe use of the package.

d. The Package is free of debris or other foreign matter that could interfere with the proper and safe use of the container.

e. Verify that the outer drum and visible inner plugs are in place.

f. Gaskets are in place and intact and are not deteriorated or damaged. Replace as needed.

g. The containment flange and outer drum cover and all mating surfaces are sound and fit properly.

h. Closure bolts are the proper type and size and that thread inserts are in working order.

i. Ensure that security seal holes are functional and capable of maintaining their integrity when seals are required.

7.1.2 Loading of Contents

The radioactive contents of the Century Versa-Pac package must be contained inside the containment area of the package. The maximum loading shall comply with the limits given in Section 1.2.2, Contents.

The User shall load the container in accordance with in-plant approved procedures and at a minimum include the following items:

a. Verify that the steps previously outlined by Section 7.1.1 have been completed at a minimum.

b. The contents may be pre-packaged within plastic jars, sealed metal cans, plastic bags, drums or other appropriate forms; however, these items are not required for transport.

c. Verify that no freestanding liquids or other volatile compounds are present in the containment area prior to loading of contents.

d. Carefully load the package content into the containment area.

7.1.3 Preparation for Transportation

a. Place the containment blind flange and gasket into place and tighten the bolts lock washers to the specified torque of 58 to 62 foot-pounds.

b. Place the outer gasket in place and carefully install the outer reinforced insulated drum cover.

c. Install the appropriate bolts and washers and tighten to the specified torque of 58 to 62 foot-pounds.

d. Secure the outer drum closure ring and tighten to 60 ±2 foot pounds and tighten the jam nut against the bolt lug.

e. Install the security seals and record their numbers, if applicable.

f. Complete a radiation and contamination survey in compliance with the applicable regulations.

g. Remove any old labels and re-label per the applicable regulations.

h. Records should be maintained in accordance with the appropriate regulations.

7.2 PACKAGE UNLOADING

The User shall unload the Century Versa-Pac in accordance with in-plant approved procedures and at a minimum include the following items:

7.2.1 Receipt of Package from Carrier

a. Complete a receiving report and complete any survey's that are appropriate.

b. Remove and record the package seal, if applicable.

7.2.2 Removal of Contents

a. Loosen and remove the outer drum lid closure ring, reinforcing ring blots and insulated drum cover.

b. Loosen and remove the bolts from the containment flange.

c. Remove the contents from the containment area.

7.3 PREPARATION OF EMPTY PACKAGE FOR TRANSPORT

Empty Century Versa-Pac packagings are prepared and transported per the requirements of 49 CFR §173.428. Prior to shipping as an empty Century Versa-Pac packaging, the packaging is surveyed to ensure that contamination levels are less than the 49 CFR §173.433(a) limit. The packaging is inspected to ensure that it is in an unimpaired condition and is securely closed so that there will be no leakage of material under conditions normally incident to transportation.

Any labels previously applied in conformance with subpart E of part 172 of this subchapter are removed, obliterated, or covered and the "Empty" label prescribed in 49 CFR §172.450 of this subchapter is affixed to the packaging.

7.4 OTHER OPERATIONS

Not Applicable.

7.5 APPENDIX

Not Applicable.

SECTION EIGHT

ACCEPTANCE TESTS AND MANTENANCE PROGRAM

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8.0 ACCEPTANCE AND MAINTENANCE PROGRAMS

Per the requirements of 10 CFR §71.85(c)[1], this section discusses the inspections and tests to be performed prior to first use of the Century Versa-Pac (U.S. Patent Pending) package.

8.1. FABRICATION ACCEPTANCE TESTS

All Century Versa-Pac packaging materials of construction shall be examined in accordance with the requirements delineated on the drawings in Appendix 1.3.1, *Packaging General Arrangement Drawings*, per the requirements of 10 CFR §71.85(a).

Source inspections and final release of the package will be performed, verifying the quality characteristics were inspected and that the packaging is acceptable. Any characteristic that is out of specification must be reported. It will then be dispositioned according to procedure. The following tests are performed by the fabricator prior to release of the packaging for use by the User.

8.1.1. Visual Inspection and Measurements

Prior to the initial use, a visual inspection is performed including the following items at a minimum:

a. Confirm that the package dimensions are in compliance with the appropriate drawings (This may be accomplished by a review of the Quality Assurance and Fabrication Records).

b. Insure that the visible seals (Internal and External) are in place.

c. Insure that all bolts and washers are the correct type and size per the drawing.

d. Insure that all gaskets are in place and are in compliance with the drawings.

e. Verify that the nameplates and markings are correct.

8.1.2. Weld Examinations

As part of the normal course of fabrication, the Century Versa-Pac Shipping Container is subjected to visual inspections of all welds and magnetic particle inspection of those welds shown on the fabrication drawings to insure that the welds of the package are in compliance with the applicable codes and standards required by the drawings and specifications of the Century Versa-Pac. These inspections are recorded on the Fabrication Control Record as part of the Quality Assurance program.

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[1] Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Material*, 1-1-98 Edition.

8.1.3. Structural and Pressure Tests

The Century Versa-Pac Shipping packaging does not contain any tie-down devices that are a structural part of the package. The Century Versa-Pac Shipping Container is handled, loaded, and unloaded using standard handling equipment.

The Century Versa-Pac Shipping package is not a pressure-retaining package and no per unit pressure testing is required prior to use. As identified in Section 2.2.1, Mechanical Properties and Specifications, the drum design is qualified with a hydrostatic pressure, 29 psig (200 kPa), as part of the UN drum qualification testing.

No other Structural or Pressure testing is performed.

8.1.4. Leakage Tests

The Century Versa-Pac Shipping packaging does not contain any seals or containment boundaries that require leak testing. Therefore, this section is not applicable.

8.1.5. Component and Materials Tests

The closed cell polyurethane foam, alumina silica paper, and gasket materials are acceptance in accordance with the drawing requirements. Inspect package containment components for any damage that would prove detrimental to their ability to properly function as required.

8.1.6. Tests for Shielding Integrity

Shielding tests are not applicable to the Century Versa-Pac Shipping Container. The Century Versa-Pac Shipping packaging does not contain any biological shielding.

8.1.7. Thermal Acceptance Tests

The material properties utilized in Chapter 3.0, *Thermal*, are consistently conservative for the Normal Conditions of Transport (NCT) and Hypothetical Accident Condition (HAC) thermal analyses. As such, with the exception of the tests required for specific packaging components, as discussed in Section 8.1.5, *Component and Material Tests,* specific acceptance tests for material thermal properties are not required or performed.

8.1.8. Miscellaneous Tests

No other additional tests are required prior to use of the Century Versa-Pac Shipping Container.

8.2. MAINTENANCE PROGRAM

This section describes the maintenance program used to ensure continued performance of the Century Versa-Pac Shipping packaging. The Century Versa-Pac Shipping packaging is maintained consistent with a 10 CFR 71 subpart H QA program. Packagings that do not conform to the license drawings are removed from service until they are brought back into compliance. Repairs are performed in accordance with approved procedures and consistent with the quality assurance program.

The User shall establish written procedures for the periodic maintenance and inspection of the Century Versa-Pac Shipping Container requiring the following as a minimum:

8.2.1. Structural and Pressure Tests

The Century Versa-Pac Shipping packaging does not contain any lifting/tie-down devices that require load testing. No pressure tests are necessary to ensure continued performance of the Century Versa-Pac Shipping packaging.

8.2.2. Leakage Tests

No leakage tests are necessary to ensure continued performance of the Century Versa-Pac Shipping packaging.

8.2.3. Component and Material Tests

8.2.3.1. Prior to Each Use

The following items shall be performed as a minimum prior to each package use for shipment:

a. Visually inspect the outer and inner surfaces as appropriate for rust or other superficial discontinuities. Properly trained personnel should repair any adverse indications as necessary in accordance with the drawing requirements.

b. Visually inspect all gaskets and pads for wear and/or deterioration and replace as necessary.

c. Inspect all sealing surfaces for damage that would interfere with the safe use of the package.

d. During visual inspection the exterior surfaces of the package should be inspected for any corrosion, if found, these areas should be evaluated in accordance with 8.2.3.2d below.

8.2.3.2. Every Five Years

The Owner of the individual Century Versa-Pac Shipping Container shall perform and maintain a record of the following inspections at a minimum:

a. All inspections listed in Section 8.2.3.1.

b. Full visual of all accessible surfaces and welds for the presence of cracks or other unacceptable discontinuities. Any questionable condition of a weld shall be subject to further examination to assure proper compliance. Any weld defects shall be repaired in accordance with the appropriate procedures.

c. Check flanges and covers for warpage and/or distortion that prevent proper closure.

d. During the visual inspection of exterior surfaces, if areas are suspected of having corrosion, the inspection should insure that corrosion has not reduced the outer package wall thickness by more than 10% of the nominal thickness over a 6” square area. When visual inspection cannot assure sufficient wall thickness, other methods of inspection should be utilized, such as ultrasonic testing, to assure acceptability.

e. All repairs shall be performed by sources that are competent and properly trained. Allowable repairs shall include repairs made to welds and base metal. Repairs that require welding shall be made by welders that are qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code and/or Section 5 of AWS D1.1. The repair shop shall provide certification of weld procedures and welder qualifications.

f. Weigh the container to verify that the container is within 10 pounds of the original fabrication weight recorded on the nameplate.

g. If the package contains payload or is in transit at the test due date, the inspection may be deferred to allow unloading and/or transport of the package, as necessary.

8.2.4. Thermal Tests

No thermal tests are necessary to ensure continued performance of the Century Versa-Pac packaging.

8.2.5. Miscellaneous Tests

Localized deformations in the outer drum of the Century Versa-Pac packaging are permitted up to 1-inch provided the shell material is not breached. The packaging may be repaired in accordance with the drawings in Appendix 1.3.1, *Packaging General Arrangement Drawings*.

8.3. List of Appendices

Not applicable to the Century Versa-Pac packaging.