Enclosure 3 to E-45372

TNF-XI SAR, Revision 11A;
Revision Log, Chapter 1, Chapter 6, Appendix A.6, Appendix B.6, Chapter 7, and Chapter 8

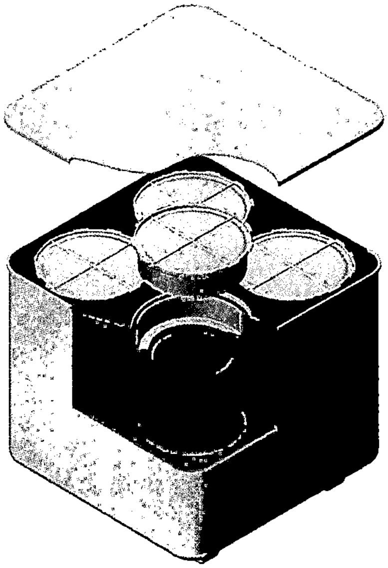
(Non-Proprietary Version)

NON-PROPRIETARY

AREVA

AREVA Inc.

TNF-XI Package



SAFETY ANALYSIS REPORT

Docket Number 71-9301

Revision 11A
October 2016

AREVA TN
7135 Minstrel Way, Suite 300 • Columbia, MD 21045

Revision Log

Rev. No.	*Date*	*Description*
0	*7/2002*	*Original Issue for CoC Revision 0*
1	*1/2002*	*Various Changes CoC Revision 0*
2	*2/2002*	*Various Changes CoC Revision 0*
3	*4/2002*	*Various Changes CoC Revision 0*
4	*7/2003*	*Application for CoC Revision 5*
5	*5/2011*	*Various Changes for CoC Revision 5*
6	*10/2011*	*Various Changes for CoC Revision 5*
7	*12/2011*	*Various Changes for CoC Revision 5*
8	*1/2012*	*Various Changes for CoC Revision 5*
9	*7/2013*	*Application for CoC Revision 6*
10	*11/2013*	*Various Changes for CoC Revision 6*
11	*12/2014*	*Application for CoC Revision 8*
11A	*8/2016*	*Application for CoC Revision 9* *Revised pages as follows:* *SAR pages 1-1 through 1-10, 6-1 through 6-136, A.6-i through A.6-iii, A.6-5 through A.6-7, A.6-65, 7-2, 7-4, 8-1 through 8-12, 8.3.A-i, 8.4.B-i, and 8.5.C-i* *New pages as follows:* *Proprietary Information Notice* *Revision Log* *SAR pages B.6-i, B.6-ii, B.6-1 through B.6-19*

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1.0 GENERAL INFORMATION

This chapter of the Transnuclear (TN) TNF-XI Packaging Safety Analysis Report presents a general introduction and description of the TNF-XI. The major components comprising the TNF-XI are presented in Figure 1-1. A detailed description of the major packaging and payload components is presented in the following sections. Several appendices are included which consist of English translations of Transnuclear licensing documents. Since all these documents use the metric SI units, this SAR is also written using only SI units to avoid confusion. Detailed drawings are presented in Appendix 1.3.1, *Packaging General Arrangement Drawings*.

1.1 Introduction

The TNF-XI Packaging is a transportation system designed to transport homogeneous oxide forms of uranium oxides (UO_2, UO_3 and U_3O_8) enriched to a maximum of 5 % (w/o). The packaging consists of a sheet metal outer box, made of 2 mm thick stainless steel sheet, equipped with a top face including four outer bayonets. Thermo-mechanical protection is provided by three types of phenolic foam: type 1, type 2, and type 3. Containment of the payload is provided by four internal wells, made of stainless steel sheets 1 mm thick enclosing a layer of neutron-poisoning resin. A primary lid closes each internal well. Each lid is made of stainless steel plate 6 mm thick and includes four outer bayonets, and sealed by an elastomer gasket. Four thermo-mechanical protection upper plugs protect the primary lids. Each upper plug includes an added stainless steel upper lip with internal bayonet. A flat seal closes the interface between the upper lip and the upper surface of the package. A polymer cleanness cover protects the upper face of the package.

The package is a Type A-fissile package. To provide criticality control, the inner wells include a layer of neutron-poisoning resin. The uranium oxide powder is contained in individual stainless steel pails contained in the inner wells. The uranium oxide powder, scraps or pellets, may be packaged in polyethylene bags or bags with hydrogen concentration less than polyethylene, that are then placed in the pails. The maximum hydrogen content of the bags within each cavity is 56g H, which is equivalent to a maximum mass of 390g polyethylene, considering all sources of hydrogenous material within each cavity. The uranium oxide powder may contain impurities (powder scrap). The Aluminum and Carbon impurities in the uranium oxide powder shall not exceed 5,000 ppm and 10,000 ppm, respectively.

Additionally, in accordance with Appendix B.6, the uranium oxides (UO_2, UO_3, or U_3O_8) in the form of powder and scraps may be mixed with residues consisting of incinerator ashes or earth, sand and residues from dissolution. The authorized quantity for this content is limited to 75 kg per cavity of the TNF-XI package and the uranium mass is less than 5 kg per cavity (or equivalent UO_2 mass less than 5.68 kg per cavity).

Authorization is sought for shipment of 300 kg of enriched uranium oxide powder (sometimes granules) of uranium oxides (UO_2, UO_3, U_3O_8), or scraps or pellets of UO_2 corresponding to enriched commercial grade uranium, following the ASTM-C 996-10 standard, with variable enrichment of up to 5% of U^{235} (per package) as a Type A(F)-96, fissile material package per the definitions delineated in 10 CFR §71.4[1]. The criticality safety index (CSI) for the package, determined in accordance with the definitions of 10 CFR §71.4 (and described in 10CFR 71.59), is determined for each shipment. The CSI is based on the number of packages for criticality control purposes (the method for the CSI determination is defined in Chapter 6.0, *Criticality Safety Evaluation*), Appendix A.6, *and Appendix B.6.*

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[1] Title 10, Code of Federal Regulations, Part 71 (10 CFR 71), *Packaging and Transportation of Radioactive Material.*

1.2 Package Description

This section presents a basic description of the TNF-XI package. General arrangement drawings of the TNF-XI package are presented in Appendix 1.3.1, *Packaging General Arrangement Drawings*.

1.2.1 Packaging

1.2.1.1 Packaging Description

The TNF-XI packaging is a Type A(F) package designed for transportation of uranium oxide powder that is enriched up to 5 w/o U^{235}. The maximum gross weight of the package is 1,050 kg and its primary components of construction are identified in Figure 1-1.1. The payload is enriched uranium oxide powder, and is described in Section 1.2.3, *Contents of Packaging*. Detailed drawings of the TNF-XI packaging are provided in Appendix 1.3.1, *Packaging General Arrangement Drawings*.

The TNF-XI packaging is comprised of the following components (see Sheet 1 of the *Packaging General Arrangement Drawings*):

- Pails, made of stainless steel, with a nominal wall thickness of 1.2 mm, retain the radioactive payload described in Chapter 6.0,
- four internal wells, made of stainless steel sheets 1 mm thick enclosing a layer of neutron-poisoning resin,
- four primary lids closing off each of the internal wells, made of stainless steel plate 6 mm thick including four outer bayonets, sealed with an elastomer gasket,
- four thermo-mechanical protection upper plugs, protecting the primary lids, and each one featuring an added stainless steel upper lip with internal bayonet,
- an outer box, made of 2 mm thick stainless steel sheet, equipped with a top face including four outer bayonets,
- between the wells and the outer box, thermo-mechanical protection consisting of two types of phenolic foam: type 1 and type 2,
- a polymer cleanness cover on the upper face of the package,
- forklift paths, made of stainless steel sheets 3 mm thick that also support the package.

These components are fully described in the following sections.

1.2.1.1.1 Pail

The fissile material is completely enclosed in pails (Item 32 of the *Packaging General Arrangement Drawings*). These are used in the handling of the payload but are not considered a part of the containment boundary. Typical characteristics of the pails are as follows:

- vertical axis cylindrical pail,
- material: stainless steel,
- nominal body diameter: 287.4 mm,
- a stainless steel lid equipped with a closure ring,
- nominal weight of an empty pail: 7 kg.

An example of a specific pail commonly used is the NFI pail manufactured per the NFI drawings E 215509 and NFI-NK 97-002-0100:

- a stainless steel body, cylindrical in shape, with a nominal wall thickness of 1.2 mm, an internal useful diameter of 285 mm and an internal useful height of 205 mm;
- a stainless steel lid locked to the upper face of the body of the pail using a closure ring.
- The pail is equipped with an inner stainless borated steel ring (natural boron content of 1 % in weight).
- The maximum height of the pail when plugged is 220 mm.

Three pails are stacked in each of the four inner cavities.

1.2.1.1.2 Inner Well

The inner wells each have internal diameter 354 mm and useful height of 675 mm.

Each vertical axis cylindrical inner well is comprised of the following components:

- an inner shell made of stainless steel plate 1 mm thick with a maximum inside diameter of 354 mm and a height of 681 mm constituting the cavity,
- an outer shell of stainless steel plate 1 mm thick, of outer diameter 426 mm, welded to the first upper fold of the inner shell,
- a flat bottom made of stainless steel plate 1 mm thick, welded to the shell. A disk made of borated stainless steel plate 2 mm thick with a diameter of 330 mm is glued to the shell base.

- a shell of neutron-poisoning resin with a minimum thickness of 34 mm, contained between two stainless steel shells, with a reference chemical composition called "BORA".
- a stainless steel flange in the upper part of the wells comprising four teeth so as to lock off the primary lid by a bayonet system.

1.2.1.1.3 Primary Lid

The four primary lids closing off the inner wells, are stainless steel circular plates 6 mm thick on the main part, and 10 mm thick on the periphery. On the periphery of the inner face, four bayonet teeth are welded to the primary lid to lock in the well flanges.

A primary lid locker is located between the well flange and the primary lid to prevent the rotation of the primary lid during the transport.

The primary lid and the well are sealed by an elastomer gasket set in a rectangular groove machined on the inner face of the primary lid.

1.2.1.1.4 Upper Plug

Each upper plug consists of a set of two thermal insulating disks (phenolic foam) with an internal stiffener disk made of aluminium alloy. This assembly is encapsulated inside a thin stainless steel envelope. The upper face also includes an added stainless steel upper lip to lock it using a bayonet system. This plug thermally insulates the cavity from the outside, and absorbs mechanical shocks. The plug and the body are made tight by means of a seal.

Each vertical axis cylindrical upper plug protects the primary lid and includes the following components:

- two disks of phenolic foam type 3, density of **[ ]** kg/m^3, with an outside diameter of 440.4 mm and thickness 47.1 mm,
- a perforated aluminum alloy reinforcing disk with an outside diameter of 440.4 mm and a thickness of 15 mm, located between the two disks of phenolic foam,
- a disk of borated stainless steel 3 mm thick, glued to the bottom of the envelope,
- a stainless steel envelope 0.8 mm thick, entirely containing all 3 stacked disks,
- an upper stainless steel plate 1.5 mm thick with the internal bayonet welded at its upper end. The envelope is also welded to its interior face,
- 2 fusible plugs on the upper face to release overpressure in the foam cavity in case of fire.

1.2.1.1.5 Packaging Body

The parallelipipedical packaging is made of the following parts:

- an outer stainless steel envelope with outside section 1100 × 1100 mm and thickness 2 mm, including a welded flat bottom made of 2 mm thick stainless steel plate.
- an internal piece, located on the upper part of the package, representing the assembly of several stainless steel plates 1 mm thick, "U" in shape. The inner face of the "U" is in the form of a quarter of a circle (the inner diameter being equal to 498 mm) with an external bayonet welded at its upper end and is welded to the upper fold of the inner shell of the well. The upper end of the outer face of the "U" is welded to the outer envelope.
- eight reinforcement tubes made of stainless steel, 60 mm in outer diameter, 3.9 mm thick, joining the outer shells of the four inner wells. The connection between the tubes and the outer shells is strengthened by means of stainless steel doubler plates 3 mm thick, welded to the two above-indicated elements.
- 8 fusible plugs on the lateral faces to release overpressure in resin in case of fire, and 6 on the upper face to release overpressure in the foam.
- a polymer cleanness cover clipped to the upper edge of the outer envelope that protects the packaging closure zone from the elements, in case of outdoor storage.

The main nominal dimensions are as follows:

- body nominal height: 940 mm,
- nominal overall height: 1040 mm,
- body section: 1100 × 1100 mm (=nominal overall section),

1.2.1.1.6 Thermo-mechanical protection

The thermo-mechanical protection comprises the following components:

- a plate of phenolic foam type 1, density of **[ ]** kg/m^3, inserted into the base of the overpack, with an outside section of 936 × 936 mm and a thickness of 104 mm,
- between the outer envelope and the plate of phenolic foam type 1, in the bottom edges, four blocks of phenolic foam type 2, density of **[ ]** kg/m^3, with a minimum thickness of 104 mm,
- inner volume of phenolic foam type 1, density of **[ ]** kg/m^3, incorporated between the overpack and each well outer shell,

- four triangular blocks of foam type 2, density of **[ ]** kg/m^3, in the upper corners of the package, which are each defined by an outer shell corner and separator plate. Each foam block has an isosceles right triangular cross section with a 360 mm hypotenuse. The height of the block is 180 mm.

- Two disks of phenolic foam type 3 in each upper plug, density of **[ ]** kg / m^3, with a thickness of 47.1 mm and an external diameter 444 mm.

1.2.1.1.7 Handling and Storage

The TNF-XI packages can be stacked by means of two stacking pins located on the upper face of the packaging body.

The TNF-XI is handled using forklift paths with the following features :

- three folded stainless steel sheets 3 mm thick,

- 8 protectors made of stainless steel corners 3 mm thick welded to the outer envelope in order to prevent perforations of the outer envelope by the forklift,

- 2 holes for the stacking pins that interlock the packages.

Assembling the packaging subassemblies, as described above, constitutes the fissile material isolation system as defined by the regulations.

1.2.1.2 Gross Weight

The gross shipping weight of a TNF-XI package is 1,050 kg. A further discussion of the gross weight is presented in Section 2.2, *Weights and Center of Gravity.*

1.2.1.3 Neutron Moderation and Absorption

Due to the fissile nature of the uranium oxide powder payload, neutron moderation and absorption design features are specifically incorporated into the TNF-XI package. The fissile content of the package is limited to 300 kg of uranium oxide *with or without residues*. To provide the criticality safety for this payload, a molded annular layer of a neutron-poisoning resin "BORA" is inserted between the inner and outer steel shells of the inner well. A disk of borated stainless steel is fixed to the bottom of each well. In addition, the outer plugs above each well also contain a disk of borated stainless steel. Secondary neutron moderation is provided by the rigid phenolic foam that surrounds the wells. Further discussion of the neutron moderation and absorption is provided in Chapter 6.0, *Criticality Safety Evaluation, and Appendices A.6 and B.6.*

The mass composition of the BORA resin is:

Element	H	Bnat	C	O	Al	Zn	Others
Mass composition η	[						]

The minimum density of the BORA resin for the analysis is [ ] g/cm^3.

The mass composition of the Type 304B4 borated stainless steel is (maximum values unless noted otherwise):

Element	C	Mn	P	S	Si	Cr	Ni	Boron	Other
Mass composition η	0.08	2.00	0.045	0.030	0.75	18.00-20.00	12.00-15.00	1.00-1.24	N 0.10 max

The chemical composition of the three foam types is the same, the only difference is the density. The phenolic foam is composed of a minimum [ ] water and [ ] dry foam. The minimal content of hydrogen is [ ] by mass. The other constituents are carbon ([ ] by mass) and oxygen ([ ] by mass).

The composition of the foam subsequent to fire conditions is provided in Section 3.6.6.

1.2.1.4 Receptacles, Valves, Testing and Sampling Ports

There are no receptacles, valves, or sampling ports utilized within the TNF-XI package.

1.2.1.5 Heat Dissipation

The uranium oxide payload produces a negligible thermal heat load. Therefore, no special devices or features are needed or utilized in the TNF-XI package to dissipate heat. A more detailed discussion of the package thermal characteristics is provided in Chapter 3.0, *Thermal*.

1.2.1.6 Coolants

Due to the passive design of the TNF-XI package with regard to heat transfer, there are no coolants utilized within the TNF-XI package.

1.2.1.7 Protrusions

The only significant protrusions on the TNF-XI package exterior are the stacking pins utilized for stacking one package on another. The stacking pins extend approximately 20 mm above the surface of the protective cover. These pins do not pose a hazard to the package safety function.

1.2.1.8 Lifting and Tie-down Devices

The TNF-XI package is lifted from beneath utilizing a standard forklift. Forklift paths are provided and consist of three folded stainless steel sheets 3 mm thick, 8 protectors made of stainless steel corners 3 mm thick welded to the outer envelope in order to prevent the punctures by the forklift. Therefore, there are no lifting devices utilized in the TNF-XI packaging.

The TNF-XI package is transported within an overseas shipping container. A structural frame that acts as the tie-down system is positioned between the TNF-XI packages and the inner walls of the container to secure the packages. There are no tie-down devices that are structural part of the TNF-XI package. For alignment of stacked packages, the TNF-XI packages can be stacked by means of two stacking pins located on the upper face of the packaging body. These pins, which are attached to the outer stainless steel sheet, interface with a hole in each foot of the upper package. A detailed discussion of this interface and its behavior is provided in Section 2.5, *Lifting and Tie-down Devices for All Packages*.

1.2.1.9 Pressure Relief System

There are no pressure relief systems included in the TNF-XI package design to relieve pressure from within the sealed inner wells. Fire-consumable vents in the form of polyethylene plugs are employed on the exterior surface of the body. These vents are included to release any gases generated by the phenolic foam in the Hypothetical Accident Condition (HAC) thermal event (fire). During the HAC fire, the plugs melt, thus allowing the release of any gasses generated. Eight plugs are used on the side of the outer body, and six are used on the top of the outer body.

1.2.1.10 Shielding

Due to the nature of the uranium oxide powder payload, no biological shielding is necessary or provided by the TNF-XI packaging.

1.2.2 Operational Features

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

1.2.3 Contents of Packaging

The TNF-XI is loaded with radioactive contents constituted of unirradiated uranium oxides (UO_2, UO_3 and U_3O_8) enriched to a maximum of 5 %. The maximum weight of the payload is 300 kg. The fissile material is completely enclosed in pails which are stacked inside four inner wells of the packaging body. Each inner well is closed by a primary lid and an upper plug.

The TNF-XI is also loaded with radioactive contents constituted of unirradiated uranium oxides (UO_2, UO_3 and U_3O_8) as powder scrap enriched to a maximum of 5% containing impurities such as aluminum and carbon not exceeding 5,000 ppm and 10,000 ppm, respectively. The maximum weight of the uranium oxides payload is 300 kg. The fissile material is completely enclosed in pails, which are stacked inside four inner wells of the packaging body. Each inner well is closed by a primary lid and an upper plug.

The TNF-XI is also loaded with radioactive contents constituted of unirradiated uranium oxides (UO_2*,* UO_3*, or* U_3O_8*) in the form of powder and scraps, enriched up to a maximum of 5.0 wt. %* U^{235} *mixed with residues consisting of incinerator ashes or earth, sand and residues from dissolution. The authorized quantity is limited to 5 kg uranium (or 5.67 kg uranium oxide) per cavity of the TNF-XI package and the authorized quantity is limited to 75 kg uranium oxides and residues per cavity. The maximum weight of the uranium and residues payload is 300 kg.*

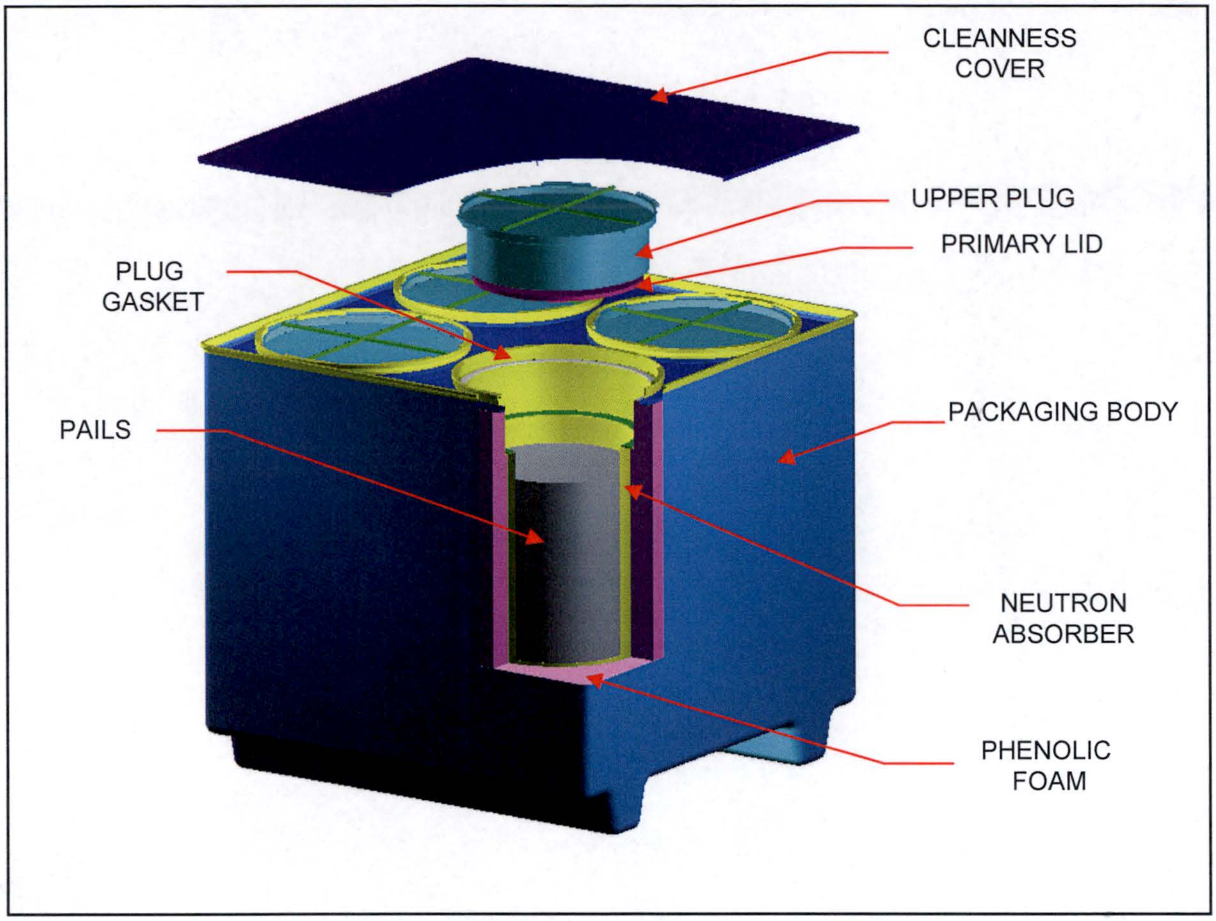

Figure 1 Overview of the TNF-XI Packaging

1.3 Appendix

1.3.1 Packaging General Arrangement Drawings

This section presents the TNF-XI packaging general arrangement drawing consisting of seven sheets entitled, TNF-XI Packaging SAR Drawing.

10799-SARNP	1	3

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2	SEE DCN 1/1	BH	5/7/03
3	SEE DCN 1/2	BH	6/27/0

PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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			APPD		
			APPD		
			APPD		
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			QA	B. COUNTERMAN	10/28/02
			CHECK	F. STEINER	10/28/02
ITEM	QTY	NEXT ASSY	DRAWN	RI VAN LE	10/23/02

PACTEC

TNF-XI
PACKAGING
NON-PROPRIETARY SAR DRAWING

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WT. N/A
REV: 3
SHEET 1 OF 7
DWG SIZE D
DWG NO. 10799-SARNP
CADFILE: 10799SARNP013.DWG

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PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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			APPD		
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			QA	B. COUNTERMAN	10/28/02
			CHECK	F. STEINER	10/28/02
ITEM	QTY	NEXT ASSY	DRAWN	RI VAN LE	10/23/02

PACTEC

TNF-XI
PACKAGING
NON-PROPRIETARY SAR DRAWING

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PACTEC

TNF-XI
PACKAGING
NON-PROPRIETARY SAR DRAWING

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10799-SARNP	4	3

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PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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			CHECK	F. STEINER	10/28/02
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PACTEC

TNF-XI
PACKAGING
[✓ NON-PROPRIETARY] SAR DRAWING

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DWG SIZE D
DWG NO. 10799-SARNP
CADFILE: 10799SARNP043.DWG

10799-SARNP | 5 | 3

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PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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PACTEC

TNF-XI
PACKAGING
NON-PROPRIETARY SAR DRAWING

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REV: 3
SHEET 5 OF 7
DWG SIZE D
DWG NO. 10799-SARNP
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10799-SARNP	6	3

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PROPRIETARY AND
SECURITY RELATED INFORMATION
WITHHELD UNDER 10 CFR 2.390

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			CHECK F. STEINER	10/28/02
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PACTEC

TNF-XI
PACKAGING
NON-PROPRIETARY SAR DRAWING

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10799-SARNP	7	3

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PROPRIETARY AND SECURITY RELATED INFORMATION WITHHELD UNDER 10 CFR 2.390

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			APPD		
			APPD		
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			QA	B. COUNTERMAN	10/28/02
			CHECK	F. STEINER	10/28/02
ITEM	QTY	NEXT ASSY	DRAWN	RI VAN LE	10/23/02

PACTEC

TNF-XI
PACKAGING
[✓ NON-PROPRIETARY] SAR DRAWING

SCALE: FULL	WT. N/A
REV. 3	SHEET 7 OF 7
DWG SIZE D	DWG NO. 10799-SARNP
	CADFILE: 10799SARNP073.DWG

6.0 CRITICALITY SAFETY EVALUATION

6.1 General Description

This criticality safety analysis is performed to demonstrate safety of the Transnuclear, Inc. (TN) TNF-XI package. This package meets applicable 10 CFR 71 [1] and IAEA [2] requirements for a Type A fissile material shipping container for homogeneous and heterogeneous uranium dioxide enriched to a maximum of 5.0 wt. % U-235.

Homogeneous powders, such as fine powder, are those materials that were not subjected to any treatment that would lead to agglomeration. Heterogeneous materials, such as coarse powder, granulated powders, pellets and scrap, are those materials that do not meet the definition of homogeneous powders. In case of a mix of several forms of fissile material, this mix is considered heterogeneous material.

The packaging consists of a stainless steel outer shell and lid that encases a body of phenolic foam. Four individually sealed stainless steel inner wells are located in the body. The uranium oxide powder/compounds are positioned within these inner wells in pails.

Water exclusion from the package under accident conditions is not required for this package design. The contents of the package are analyzed in the damaged container under optimal moderation conditions and favorable geometry.

This analysis is performed for an enrichment range of 4.05 to 5.0 wt. % U-235 for homogeneous UO_2 powder and heterogeneous UO_2 material. This work demonstrates safety for a maximum homogeneous UO_2 powder or heterogeneous UO_2 material loading with water moderation (moderation provided by materials with a hydrogen content less than or equal to that provided by water) per TNF-XI package as shown in Table 6-1.

Appendix A.6 includes a separate criticality evaluation to determine the uranium loading limits that allows for the use of up to 390 g of polyethylene (or materials with a hydrogen content less than or equal to that of polyethylene) per cavity of the TNF-XI package and in the presence of impurities such as aluminum and carbon not exceeding 5,000 ppm and 10,000 ppm, respectively, in the UO_2 powder content. Other oxide forms (e.g., U_3O_8 or $UO_{x,\, x>2}$) are also equally valid provided the UO_2 equivalent total payload is not violated.

Appendix B.6 includes the criticality evaluation of the TNF-XI package with Content 7 using the simplified TNF-XI model. Content 7 consists of uranium oxides (UO_2, UO_3, or U_3O_8) in the form of powder and scrap, enriched up to a maximum of 5 wt. % U-235 mixed with residues consisting of incinerator ashes or earth, sand and residues from dissolution. The simplified packaging model contains the radioactive material in a single cylindrical cavity wrapped by a layer of BORA resin which is enclosed between two cylindrical steel walls. The authorized quantity is limited to 5 kg uranium (5.67 kg uranium oxide) per cavity of the TNF-XI package. The authorized quantity is limited to 75 kg uranium oxides and residues per cavity of the TNF-XI package. The radioactive material is placed in plastic bags made with a material more hydrogenated than water and less than or equal to polyethylene.

Table 6-1. Uranium Dioxide Weight Limits per TNF-XI Package

^{235}U Enrichment	Homogeneous UO_2 Powder Maximum Loading, kg	Heterogeneous UO_2 Material Maximum Loading, kg
4.05%	300	300
4.10%	300	293
4.15%	300	287
4.25%	300	271
4.35%	300	259
4.45%	300	247
4.55%	294	238
4.65%	281	228
4.75%	265	219
4.85%	255	208
4.95%	244	202
5.00%	239	197

Based on the current analysis, the Criticality Safety Index (CSI) for the TNF-XI package with the *contents analyzed in this chapter and Appendix A.6* is shown in Table 6-2. The number of undamaged or damaged (10 CFR §71.73) packages that will remain subcritical in any arrangement with close water reflection and optimum interspersed hydrogenous moderation is 216. Using the rounded CSI result of 50/108 = 0.5, the maximum allowable number of packages per non-exclusive use vehicle is 50/0.5 = 100.

Table 6-2. Criticality Safety Index for Nuclear Criticality Control

Case	N	Array Size	Packages	CSI
Normal Conditions of Transport	115	8×9×8	576	0.5
Hypothetical Accident Conditions	108	6×6×6	216	0.5

The Criticality Safety Index (CSI) for the TNF-XI package with the content analyzed in Appendix B.6 is 0.0.

6.2 Package Fuel Loading

6.2.1 Contents

The package shall be used to transport homogeneous uranium in oxide form (UO_2, U_3O_8, or $UO_{x,\ x>2}$) which meet the requirements for Enriched Commercial Grade Uranium defined in ASTM C996-10. The uranium isotopic distribution is shown in Table 6-3.

This analysis demonstrates safety for UO_2 powder over the entire range of UO_2 densities. The maximum net UO_2 equivalent payload demonstrated safe in the TNF-XI is presented in Table 6-1.

Table 6-3. Uranium Isotopic Distribution

Isotope	wt %	Modeled wt %
^{234}U	0.0054 - 0.0500	0.0000
^{235}U	0.7110 - 5.0000	4.0500 to 5.0000
^{236}U	0.0000 - 0.0250	0.0000
^{238}U	99.2836 - 94.9295	95.9500 to 95.0000

6.2.2 Packaging

A discussion of the TNF-XI package designed for transportation of UO_2 enriched up to 5% ^{235}U is provided in Section 1.2.1, *Packaging*. A detailed set of drawings of the TNF-XI package is provided in the general packaging arrangement drawings (refer to Appendix 1.3.1, *Packaging General Arrangement Drawings*).

Table 6-4 provides a listing of the applicable material specifications used in the TNF-XI model construct. Atomic density is calculated by the SCALE package [3] for the KENO-Va results.

Table 6-4. Material Specifications for the TNF-XI Shipping Package

Material	Density (g/cm^3)	Constituent	Atomic Density KENO-Va (atoms/b-cm)
UO_2	≤10.96	^{235}U	variable
		^{238}U	variable
		O	variable
Water	1.00	H	6.67692E-02
		O	3.33846E-02
Borated Stainless Steel	7.85	B10	6.37374E-04
		B11	2.64080E-03
		C	3.12795E-04
		Si	1.67060E-03
		P	6.81655E-05
		Cr	1.71450E-02
		Mn	1.70808E-03
		Fe	5.74468E-02
		Ni	7.59507E-03
BORA Resin	[		
Phenolic Foam [ ]			
Phenolic Foam [ ]			
Charred [ ] (accident model only)			]
Aluminum Honeycomb	1.08	Al	2.41048E-02
Stainless Steel 304	7.94	C	3.18772E-04
		Si	1.70252E-03
		P	6.94680E-05
		Cr	1.74726E-02
		Mn	1.74071E-03
		Fe	5.85446E-02
		Ni	7.74020E-03

6.3 Model Specification

6.3.1 Description of the KENO-Va Calculational Models

An axially finite model of the normal geometry of the TNF-XI package is provided in Figure 6-1. This figure shows the material constituent radial and axial dimensions. The model construct consists of four cavities inserted into the primary body of phenolic foam **[ ]** (Type 1) using the hole function in KENO. Each cavity is surrounded by BORA resin, which acts as a neutron absorber. At the bottom of each cavity is a borated stainless steel disk upon which a pails rests. Each pail is modeled as a sealed stainless steel can that contains the fuel/water mixture and is lined with borated stainless steel. Void is present between the pail and canister wall., and between the top of the pail and bottom of the lid. The lid to each cavity consists of layers of phenolic foam **[ ]** (Type 3), aluminum honeycomb, and **[ ]** The entire package is surrounded by a thin layer of stainless steel. The single package model is then placed in an array.

Phenolic foam **[ ]** (Type 2) is used in the corners of the package. For simplicity, it is modeled as **[ ]** in KENO. Also, for simplicity the phenolic foam **[ ]** in the top disk is modeled as **[ ]** in KENO. Impacts on the reactivity as a result of these minor simplifications are within the statistical uncertainty of the methods used.

An axially finite model of the damaged geometry of the TNF-XI package is provided in Figure 6-2. The effects of the certification test results are incorporated in the damaged model. The axial crush of the package was modeled as a 1.5 cm decrease in height. This is applied to the model construct by reducing the thickness of the bottom foam 1.5 cm. The side crush of the body results in a 2 cm reduction in this direction. This reduction was incorporated in the model by reducing each lateral face by 1 cm. Damage by a punch bar is modeled as a hole on one side, 3.9 cm deep and 15 cm in diameter. In addition, it is assumed that 2.7 cm of foam is consumed in fire on all surfaces and therefore is modeled as charred foam and that the top foam disk for each canister is also charred. One of the four canister lids also has charred foam in the bottom disk. In the damaged model, the fuel/water mixture exists both inside and outside the pail, and void space with the package not containing the fuel/water mixture contains water.

The model is considered conservative for the following reasons:

- Only 75% credit is taken for the B-10 in the chemical composition of the BORA resin and for all the borated stainless steel material.
- The most reactive pail position (all pails pushed to the center of the package) is utilized.
- Fuel is optimally moderated with water in both the normal and accident geometry scenarios. Heterogeneous material is modeled as cylinders of solid UO_2 of optimum diameter in an optimum rectangular lattice.
- The TNF-XI undamaged and package arrays are modeled as close fitting and in virtual contact when in fact deformation and bowing would provide additional (x-y) and axial (x-z) center-top-center spacing between individual packages, especially in an accident condition.

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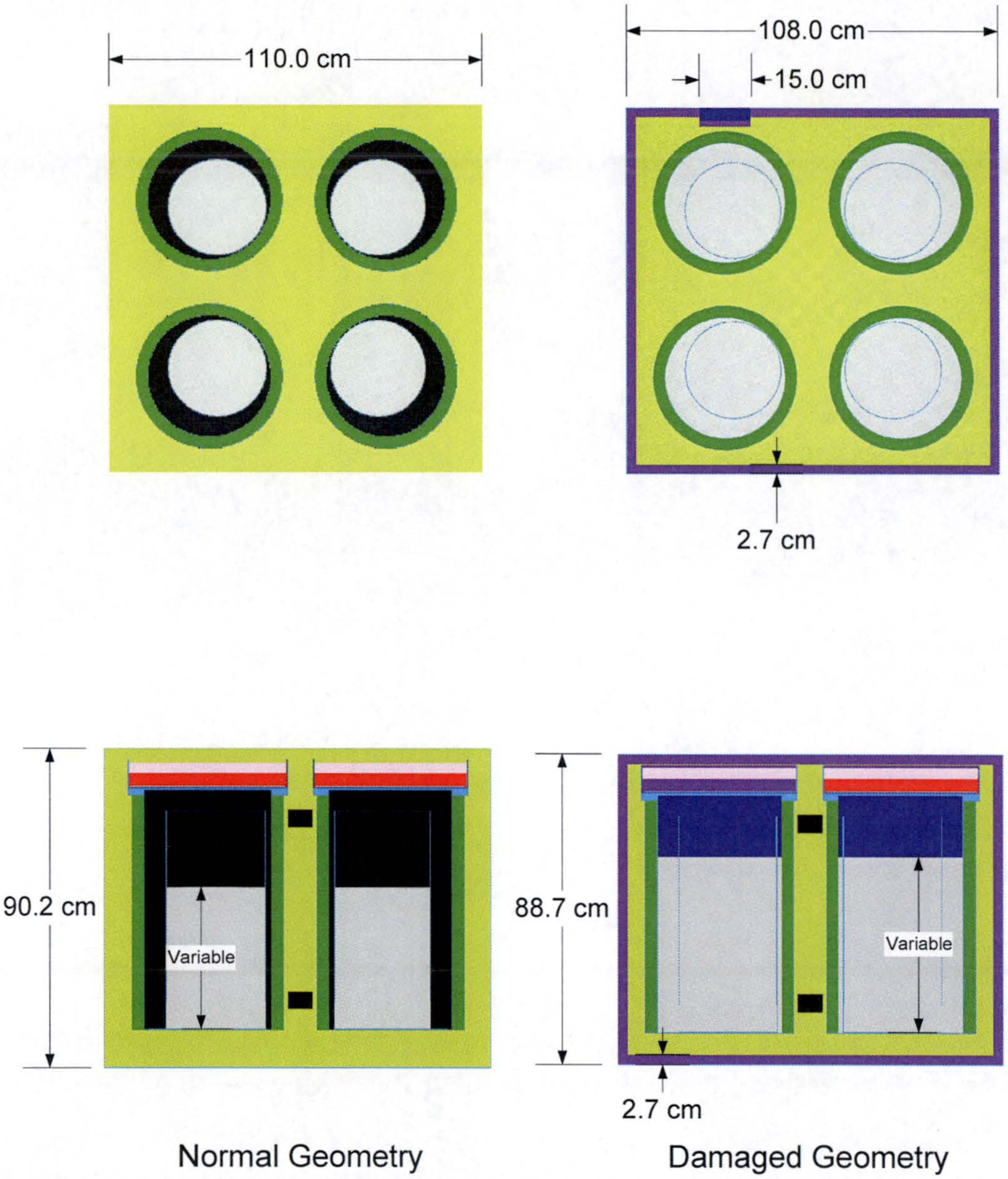

Figure 6-2. TNF-XI Package Accident Model Dimensions

6.3.2 Materials

Figures 6-3 and 6-4 show the material assignments for the normal case. Figures 6-5 and 6-6 show the material assignments for the accident case. The color coding for these figures is provided in Table 6-5.

Table 6-5. Material Mapping

KENO Material No.	Description	Color
0	Void	Black
1	Fuel/water	Grey
2	Water	Dark Blue
3	Borated Stainless Steel	Light blue
4	BORA Resin	Green
5	Phenolic foam **[ ]**	Yellow
6	Phenolic foam **[ ]**	Red
7	Charred **[ ]**	Purple
8	Not Used	NA
9	Aluminum honeycomb	Pink
10	Stainless steel 304	Blue

The UO_2 mixture (fuel) material specifications used in the TNF-XI criticality safety demonstrations are dependent upon the case being modeled. The treatment of the fueled region is limited to the following parametric studies:

1. Undamaged array of homogeneous mixtures of UO_2 powder and water
2. Damaged array of homogeneous mixtures of UO_2 powder and water
3. Single container cases for homogenous fuel mixtures
4. Undamaged array of heterogeneous UO_2
5. Damaged array of heterogeneous UO_2
6. Single container cases for heterogeneous fuel mixtures

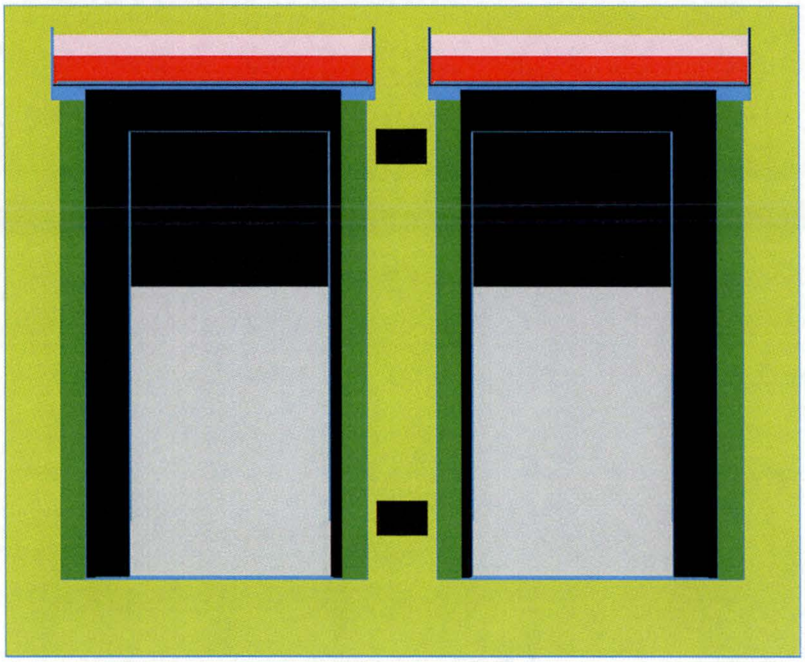

Figure 6-3. Normal Case Model - Side View

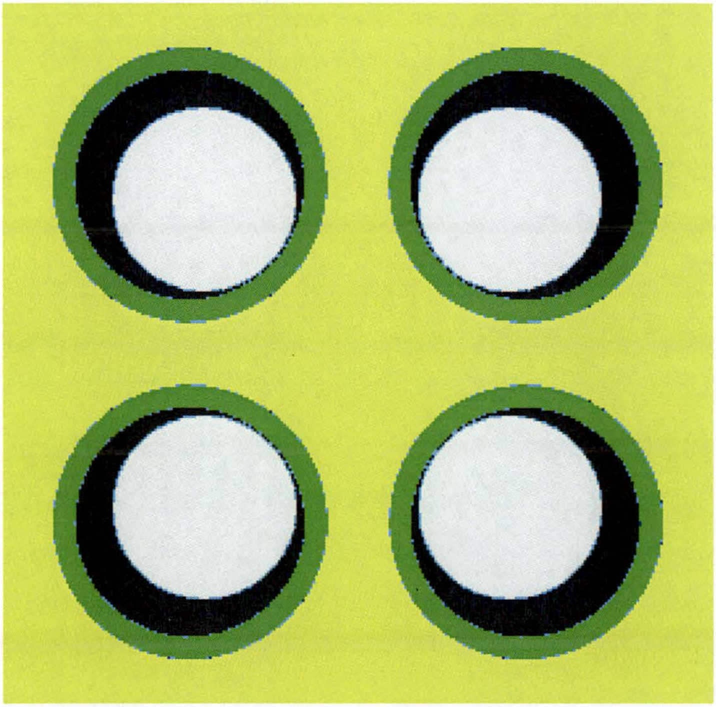

Figure 6-4. Normal Case Model - Plane View

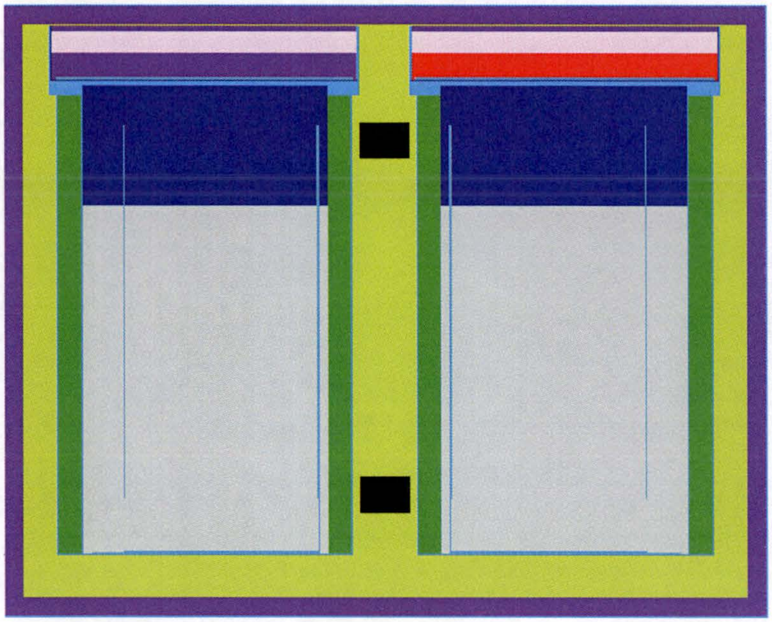

Figure 6-5. Accident Case Model - Side View

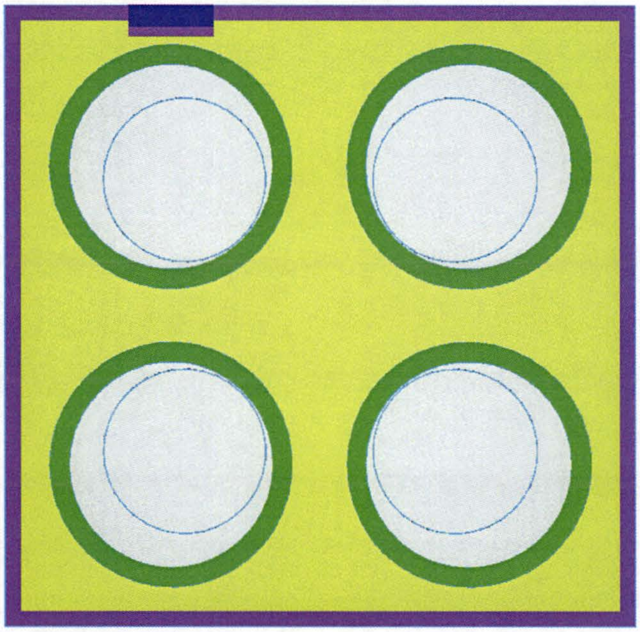

Figure 6-6. Accident Case Model - Plane View

In the first set of cases, the $UO_2 + H_2O$ mixture is modeled as a pure theoretical mixture of UO_2 powder (10.96 g/cm^3) and water. The volume fraction of water is altered by varying the height of the mixture while keeping the mass of the UO_2 constant. In this way optimum moderation for the fully reflected undamaged and damaged array is achieved.

In the second set of cases, the heterogeneous UO_2 is modeled as a series of water moderated cylindrical rods. The volume fraction of water inside the package is altered by varying the diameter of the fuel, the pitch, and the stack height. In this way optimum moderation for the fully reflected undamaged and damaged array is achieved. Note that in the heterogeneous cases, fuel pellets are not explicitly modeled in the three-dimensional KENO model. Rather, XSDRN is used to generate cell-averaged cross sections for the given heterogeneous unit cell and these cell-averaged cross sections are utilized in the KENO model.

6.3.3 Models – Actual Package Differences

- The criticality safety analysis model of the loaded TNF-XI package differs from the actual package in the allowance for water intrusion into the containment. The fuel region is modeled with variable UO_2 mass and variable H_2O content. The UO_2 mass and the water content are varied to optimally moderate the package. As the contents of the package have been demonstrated to remain 'dry' under hypothetical accident conditions, the optimal internal moderation treatment is a very large conservatism.
- By ignoring spatial effects, the TNF-XI undamaged and damaged arrays are modeled as close fitting and in virtual contact when in fact structure deformation and bowing would provide additional (x-y) and axial (x-z) center-top-center spacing between individual packages.
- The aluminum honeycomb in the top lid is modeled as solid aluminum with a reduced density for simplicity.
- The upper phenolic foam disk **[ ]** in the lid is modeled as 0.4 cm thinner than actual and as charred **[ ]** foam instead of **[ ]** (for the damaged package). The difference in charred foam densities is negligible and the reduction in the disk thickness is conservative.
- The contents in the actual package are contained within pails loaded into four compartments in the package. Each individual compartment contains three pails, each 20.5 cm high with a borated stainless steel liner 18.0 in height and 0.2 cm thick starting 2.5 cm from the bottom of each can. The three pails are modeled as a single can with a height of 61.5 cm with a borated stainless steel liner 54.0 cm in height starting 7.5 cm from the container bottom.
- The phenolic foam **[ ]** in the bottom corner of the package is modeled as **[ ]** for simplicity.
- The perforated aluminum disk is modeled as 3.0 cm thick, although the actual thickness is 1.5 cm. This difference is demonstrated to be within the statistical uncertainty of the methods employed.

6.3.4 Package Arrays

Two basic package array model constructs are included in this evaluation – damaged and undamaged for both homogeneous UO_2 powder and heterogeneous UO_2 material. Single package models are also developed, although the results of the single package are bounded by the array results.

The first package array model consists of an 8×9×8 array of undamaged, normal condition TNF-XI packages. IAEA and 10 CFR §71.59 standards for arrays of fissile material packages stipulates undamaged package arrays are to be evaluated with void between the packages and fully reflected. The undamaged array is modeled using single units containing a homogeneous mixture of UO_2 powder and various volume fractions of water or heterogeneous UO_2 modeled as cylindrical stacks of pellets. The array is modeled with optimum moderation within each package and full water reflection around the array.

The damaged package array models a 6×6×6 array of damaged TNF-XI packages. As required by IAEA and 10 CFR §71.59, the damaged package array are evaluated as if each package was subjected to the tests specified in 10 CFR §71.73, hypothetical accident conditions, with optimum moderation within each package and full water reflection around the array.

6.4 Criticality Calculation

This evaluation demonstrates the subcriticality of an array of packages during normal conditions of transport and hypothetical accident conditions. The determined CSI for criticality control of damaged and undamaged shipment is given in Section 6.4.3. All calculations were performed for the range of allowable ^{235}U enrichment of 4.05 wt.% to 5.0 wt.% to ensure maximum reactivity. The analysis results are summarized in Table 6-6 through Table 6-11.

6.4.1 Calculational or Experimental Method

The effective neutron multiplication factor (k_{eff}) was calculated using the CSAS25 module of the SCALE 4.4 Code with the 44-group ENDF/B-V cross-section library for the homogeneous powder cases and CSAS2X module of the SCALE 4.4 Code with the 44-group ENDF/B-V cross-section library for the heterogeneous cases [3]. The control module CSAS25 includes the three dimensional criticality code KENO-Va and the preprocessing codes BONAMI-S, NITAWL-II and XSDRNPM-S. To represent the package loaded with pellets and/or scrap material, the CSAS2X sequence is used. In CSAS2X, the lattice unit cell option is required in the input so the XSDRNPM code can generate cell-weighted cross sections for the fuel/water pin cell. Those cross-sections are then used in the entire fuel region.

KENO Va, in conjunction with a suitable working library of nuclear cross section data, is used to calculate the k_{eff} of systems of fissile material. It can also compute lifetime and generation time, energy dependent leakages, energy and region-dependent absorptions, fissions, fluxes, and fission densities. KENO Va utilizes a three-dimensional Monte-Carlo computation scheme. BONAMI-S has the function of performing Bondarenko calculations for resonance self-shielding. The main function of NITAWL-II is to change the format of the master cross-section libraries to one that the criticality code (KENO Va) can access. It also provides the Nordheim Integral Treatment for resonance self-shielding.

The criticality analysis was performed assuming a mixture of UO_2 powder and water and heterogeneous UO_2 material as described in Section 6.3. Calculations were performed using the range of ^{235}U enrichment from 4.05% through 5.0%. In order to meet the requirements of 10 CFR §71.55 and 10 CFR §71.57, the KENO models were specified with 100% water albedo on all four sides. Further discussion regarding the models can be found in Section 6.3 and in Section 6.6.

6.4.2 Criticality Results

This section presents the results of the analyses used to demonstrate the acceptability of transporting UO_2 material in the TNF-XI package under normal and accident conditions. Uncertainties are addressed and are applied to the nominal calculated k_{eff} value. The final k_{eff} value produced represents a maximum with a 95 % probability at a 95 % confidence level (95/95), or $k_{eff}+2\sigma$ as required by ANSI/ANS-57.2-1983 [4].

ANS/ANSI-8.1 [5] recommends that calculational methods used in determining criticality safety limits for applications outside reactors are validated by comparison with appropriate critical experiments. An upper subcritical limit (USL) provides a high degree of confidence that a given system is subcritical if a criticality calculation based on the system yields a keff below the USL. In Section 6.5.1, the minimum USL for the homogeneous cases is determined to be 0.9360. For the heterogeneous cases, the USL is 0.9370 for a water to fuel volume ratio $z \leq 7.008$, $0.9448+(-1.1113\times10^{-3}z)$ for a water to fuel volume ratio $z > 7.0081$.

The analysis provided verifies that in normal and accident conditions, $k_{eff} + 2\sigma \leq$ USL. Therefore, the fuel will remain subcritical under all conditions. Conclusions regarding specific aspects of the methods used or the analyses presented can be drawn from the quantitative results presented in the associated tables.

Reactivity calculations were performed to determine the maximum UO_2 loading in the TNF-XI that would meet the USL under both normal and accident conditions for both the homogeneous and heterogeneous material loading. The limiting results are presented in Table 6-6 through Table 6-11.

Table 6-6. Summary of Limiting Criticality Evaluations (KENO Va) for the TNF-XI Package, Homogeneous Material, Hypothetical Accident Condition (HAC), Array

Enrich.	UO_2 Mass (kg)	keff	σ	keff+2σ	USL
4.05	300	Bounded by 4.45 case			0.9360
4.10	300	Bounded by 4.45 case			0.9360
4.15	300	Bounded by 4.45 case			0.9360
4.25	300	Bounded by 4.45 case			0.9360
4.35	300	Bounded by 4.45 case			0.9360
4.45	300	0.9320	0.0004	0.9328	0.9360
4.55	294	0.9350	0.0004	0.9358	0.9360
4.65	281	0.9350	0.0005	0.9360	0.9360
4.75	265	0.9345	0.0006	0.9356	0.9360
4.85	255	0.9350	0.0005	0.9360	0.9360
4.95	244	0.9349	0.0005	0.9359	0.9360
5.00	239	0.9349	0.0005	0.9359	0.9360

Table 6-7. Summary of Limiting Criticality Evaluations (KENO Va) for the TNF-XI Package, Heterogeneous Material, Hypothetical Accident Condition (HAC), Array

Enrich.	UO_2 Mass (kg)	keff	σ	keff+2σ	USL
4.05	300	0.9352	0.0005	0.9362	0.9370
4.10	293	0.9356	0.0005	0.9366	0.9370
4.15	287	0.9358	0.0005	0.9368	0.9370
4.25	271	0.9353	0.0005	0.9363	0.9370
4.35	259	0.9356	0.0005	0.9366	0.9370
4.45	247	0.9359	0.0005	0.9369	0.9370
4.55	238	0.9358	0.0005	0.9368	0.9370
4.65	228	0.9353	0.0006	0.9365	0.9369
4.75	219	0.9356	0.0005	0.9366	0.9370
4.85	208	0.9353	0.0004	0.9361	0.9369
4.95	202	0.9353	0.0005	0.9363	0.9367
5.00	197	0.9343	0.0006	0.9355	0.9369

Table 6-8. Summary of Limiting Criticality Evaluations (KENO Va) for the TNF-XI Package, Homogeneous Material, Normal Condition of Transport (NCT), Array

Enrich.	UO_2 Mass (kg)	keff	σ	keff+2σ	USL
4.05	300	Bounded by 4.45 case			0.9360
4.10	300	Bounded by 4.45 case			0.9360
4.15	300	Bounded by 4.45 case			0.9360
4.25	300	Bounded by 4.45 case			0.9360
4.35	300	Bounded by 4.45 case			0.9360
4.45	300	0.9071	0.0005	0.9081	0.9360
4.55	294	0.9066	0.0004	0.9074	0.9360
4.65	281	0.9097	0.0005	0.9107	0.9360
4.75	265	0.9120	0.0005	0.9130	0.9360
4.85	255	0.9146	0.0005	0.9156	0.9360
4.95	244	0.9164	0.0006	0.9176	0.9360
5.00	239	0.9170	0.0006	0.9182	0.9360

Table 6-9. Summary of Limiting Criticality Evaluations (KENO Va) for the TNF-XI Package, Heterogeneous Material, Normal Condition of Transport (NCT), Array

Enrich.	UO_2 Mass (kg)	keff	σ	keff+2σ	USL
4.05	300	0.9151	0.0005	0.9161	0.9370
4.10	293	0.9160	0.0005	0.9170	0.9370
4.15	287	0.9163	0.0005	0.9173	0.9370
4.25	271	0.9194	0.0005	0.9204	0.9370
4.35	259	0.9198	0.0005	0.9208	0.9370
4.45	247	0.9210	0.0005	0.9220	0.9370
4.55	238	0.9231	0.0005	0.9241	0.9370
4.65	228	0.9239	0.0005	0.9249	0.9370
4.75	219	0.9240	0.0005	0.9250	0.9370
4.85	208	0.9236	0.0005	0.9246	0.9370
4.95	202	0.9250	0.0006	0.9262	0.9370
5.00	197	0.9253	0.0005	0.9263	0.9370

Table 6-10. Summary of Limiting Criticality Evaluations (KENO Va) for the TNF-XI Package, Homogeneous Material, Normal Condition of Transport (NCT), Single Package

Enrich.	UO_2 Mass (kg)	keff	σ	keff+2σ	USL
4.05	300	Bounded by 4.45 case			0.9360
4.10	300	Bounded by 4.45 case			0.9360
4.15	300	Bounded by 4.45 case			0.9360
4.25	300	Bounded by 4.45 case			0.9360
4.35	300	Bounded by 4.45 case			0.9360
4.45	300	0.8892	0.0005	0.8902	0.9360
4.55	294	0.8908	0.0005	0.8918	0.9360
4.65	281	0.8937	0.0005	0.8947	0.9360
4.75	265	0.8948	0.0005	0.8958	0.9360
4.85	255	0.8976	0.0005	0.8986	0.9360
4.95	244	0.8997	0.0006	0.9009	0.9360
5.00	239	0.9007	0.0005	0.9017	0.9360

Table 6-11. Summary of Limiting Criticality Evaluations (KENO Va) for the TNF-XI Package, Heterogeneous Material, Normal Condition of Transport (NCT), Single Package

Enrich.	UO_2 Mass (kg)	keff	σ	keff+2σ	USL
4.05	300	0.8978	0.0006	0.8990	0.9370
4.10	293	0.8999	0.0005	0.9009	0.9370
4.15	287	0.9005	0.0005	0.9015	0.9370
4.25	271	0.9018	0.0005	0.9028	0.9370
4.35	259	0.9031	0.0005	0.9041	0.9370
4.45	247	0.9043	0.0005	0.9053	0.9370
4.55	238	0.9067	0.0006	0.9079	0.9370
4.65	228	0.9079	0.0005	0.9089	0.9370
4.75	219	0.9085	0.0005	0.9095	0.9370
4.85	208	0.9080	0.0006	0.9092	0.9370
4.95	202	0.9098	0.0006	0.9110	0.9370
5.00	197	0.9080	0.0006	0.9092	0.9370

6.4.2.1 Homogeneous Material Results

The system k_{eff} as a function of the fuel height for the 6x6x6 array HAC cases is provided in Table 6-12 through Table 6-18 and is shown graphically in Figure 6-7 through 6-13 for homogeneous powder of various enrichments. The homogeneous mass limits were determined based upon these cases. For this reason, most of these cases are intentionally close to the USL.

During the course of the calculations, the precise composition of the foam to be used in the HAC models was obtained by experiment. The final values were slightly different than the values used in these calculations.

The measured weight percents are as follows:

Element		
C		
H		
O		

To assess the impact of using the foam compositions slightly different than the measured values, representative calculations are performed with the measured foam for 5.0% enriched powder, and variable stack height. The results provided in Table 6-19 indicate that the reactivity changes resulting from these small perturbations in the foam composition are within the statistical uncertainty of the code and are inconsequential.

For the HAC cases it is assumed that no water is present in the charred foam. It was assumed that this would be the most reactive configuration because adding water to the foam would likely decrease communication between the packages. The validity of this assumption is documented below.

Two sets of HAC calculations with water in the foam are performed for the most reactive 5.0% enriched powder case. The first set considers water only in the charred foam. The second considers water in both the charred and uncharred foam, as well as water in the perforated aluminum disk. It is assumed that water content varies uniformly throughout the foam and disk. When water is added to these regions in increasing density, the reactivity decreases due to decreased communication between packages, confirming that no interspersed moderation is the most reactive configuration. These results are provided in Table 6-20 and Table 6-21.

During the course of the calculations, the thickness of the aluminum disk changed from 3.0 cm to 1.5 cm, although the KENO models were not updated. The diameter of the 61 holes in the aluminum disk also changed from 4.4 cm to 3.3 cm, resulting in a homogenized density change from 1.08 to 1.78 g/cm^3.

A representative case using 5.0% powder was modeled with the correct aluminum thickness of 1.5 cm and homogenized density of 1.78 g/cm^3. The fuel height is allowed to vary between 40 and 52 cm. The results are provided in Table 6-22. The change in reactivity with the change in the aluminum disk thickness and density are within the statistical uncertainty of the method.

The system k_{eff} as a function of the fuel height for the 8x9x8 array NOC cases is provided in Table 6-23 through Table 6-29 and is shown graphically in Figure 6-14 through 6-20 for homogeneous powder of various enrichments. The system k_{eff} as a function of the fuel height for the single package NOC cases is provided in Table 6-30 through Table 6-36 and is shown graphically in Figure 6-21 through 6-27 for homogeneous powder of various enrichments.

These calculations show that both a single package and arrays of packages of homogeneous powder remain subcritical under general requirements for fissile material packages under both normal conditions of transport and hypothetical accident conditions. KENO results plus 2σ are less than or equal to the USL for all cases.

Table 6-12. HAC, 6x6x6 Array, 4.45% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
300	56	0.9283	0.0005	0.9293
300	55	0.9293	0.0006	0.9305
300	54	0.9297	0.0005	0.9307
300	53	0.9304	0.0004	0.9312
300	**52**	**0.9320**	**0.0004**	**0.9328**
300	51	0.9296	0.0005	0.9306
300	50	0.9310	0.0005	0.9320
300	49	0.9311	0.0005	0.9321
300	48	0.9297	0.0005	0.9307
300	47	0.9295	0.0005	0.9305
300	46	0.9291	0.0005	0.9301
300	45	0.9291	0.0004	0.9299
300	44	0.9283	0.0005	0.9293
300	43	0.9274	0.0004	0.9282
300	42	0.9258	0.0005	0.9268
300	41	0.9237	0.0005	0.9247
300	40	0.9209	0.0006	0.9221
300	38	0.9164	0.0005	0.9174
300	36	0.9094	0.0005	0.9104

Table 6-13. HAC, 6x6x6 Array, 4.55% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
294	54	0.9332	0.0005	0.9342
294	53	0.9338	0.0005	0.9348
294	52	0.9335	0.0005	0.9345
294	**51**	**0.9350**	**0.0004**	**0.9358**
294	50	0.9344	0.0005	0.9354
294	49	0.9345	0.0005	0.9355
294	48	0.9337	0.0005	0.9347
294	**47**	**0.9348**	**0.0005**	**0.9358**
294	46	0.9331	0.0005	0.9341
294	45	0.9330	0.0005	0.9340
294	44	0.9325	0.0005	0.9335

Table 6-14. HAC, 6x6x6 Array, 4.65% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
281	55	0.9329	0.0005	0.9339
281	54	0.9343	0.0005	0.9353
281	53	0.9336	0.0005	0.9346
281	52	0.9343	0.0005	0.9353
281	51	0.9338	0.0004	0.9346
281	**50**	**0.9350**	**0.0005**	**0.9360**
281	49	0.9349	0.0004	0.9357
281	48	0.9339	0.0005	0.9349
281	47	0.9340	0.0005	0.9350
281	46	0.9347	0.0005	0.9357
281	45	0.9329	0.0005	0.9339
281	44	0.9330	0.0005	0.9340
281	43	0.9320	0.0005	0.9330

Table 6-15. HAC, 6x6x6 Array, 4.75% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
265	54	0.9309	0.0005	0.9319
265	53	0.9327	0.0005	0.9337
265	52	0.9326	0.0005	0.9336
265	51	0.9324	0.0005	0.9334
265	50	0.9335	0.0004	0.9343
265	49	0.9334	0.0005	0.9344
265	**48**	**0.9345**	**0.0006**	**0.9356**
265	47	0.9338	0.0005	0.9348
265	46	0.9339	0.0005	0.9349
265	45	0.9329	0.0006	0.9341
265	44	0.9315	0.0005	0.9325
265	43	0.9321	0.0005	0.9331

Table 6-16. HAC, 6x6x6 Array, 4.85% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
255	54	0.9293	0.0005	0.9303
255	53	0.9325	0.0005	0.9335
255	52	0.9318	0.0005	0.9328
255	51	0.9324	0.0005	0.9334
255	50	0.9339	0.0005	0.9349
255	49	0.9342	0.0005	0.9352
255	48	0.9346	0.0005	0.9356
255	47	0.9348	0.0006	0.9360
255	46	0.9349	0.0005	0.9359
255	**45**	**0.9350**	**0.0005**	**0.9360**
255	44	0.9343	0.0005	0.9353
255	43	0.9323	0.0005	0.9333

Table 6-17. HAC, 6x6x6 Array, 4.95% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
244	52	0.9309	0.0005	0.9319
244	51	0.9318	0.0005	0.9328
244	50	0.9331	0.0005	0.9341
244	49	0.9337	0.0005	0.9347
244	48	0.9336	0.0005	0.9346
244	47	0.9341	0.0004	0.9349
244	46	0.9347	0.0005	0.9357
244	**45**	**0.9349**	**0.0005**	**0.9359**
244	44	0.9343	0.0006	0.9355
244	43	0.9344	0.0004	0.9352
244	42	0.9336	0.0006	0.9348
244	41	0.9317	0.0005	0.9327

Table 6-18. HAC, 6x6x6 Array, 5.00% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
239	52	0.9316	0.0005	0.9326
239	51	0.9318	0.0005	0.9328
239	50	0.9322	0.0005	0.9332
239	49	0.9343	0.0005	0.9353
239	48	0.9324	0.0005	0.9334
239	47	0.9335	0.0005	0.9345
239	46	0.9348	0.0005	0.9358
239	45	0.9340	0.0005	0.9350
239	**44**	**0.9349**	**0.0005**	**0.9359**
239	43	0.9339	0.0005	0.9349
239	42	0.9339	0.0005	0.9349
239	41	0.9332	0.0004	0.9340
239	40	0.9324	0.0005	0.9334

Table 6-19. 239 kg Powder, 5.00% Enriched, Modified Foam Composition

Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
52	0.9306	0.0005	0.9316
51	0.9320	0.0005	0.9330
50	0.9331	0.0005	0.9341
49	0.9341	0.0005	0.9351
48	0.9338	0.0005	0.9348
47	**0.9350**	**0.0005**	**0.9360**
46	**0.9350**	**0.0005**	**0.9360**
45	0.9343	0.0005	0.9353
44	0.9343	0.0005	0.9353
43	0.9345	0.0005	0.9355
42	0.9336	0.0005	0.9346
41	0.9337	0.0005	0.9347
40	0.9328	0.0005	0.9338

Table 6-20. 239 kg Powder, 5.00% Enriched, Water in Charred Foam

Water Fraction in Charred Foam[1]	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
0.0	**44**	**0.9349**	**0.0005**	**0.9359**
0.1	44	0.9328	0.0005	0.9338
0.2	44	0.9324	0.0005	0.9334
0.3	44	0.9311	0.0006	0.9323
0.4	44	0.9304	0.0005	0.9314
0.5	44	0.9311	0.0005	0.9321
0.6	44	0.9297	0.0004	0.9305
0.7	44	0.9292	0.0005	0.9302
0.8	44	0.9293	0.0006	0.9305
0.9	44	0.9284	0.0005	0.9294
1.0	44	0.9278	0.0005	0.9288

Table 6-21. 239 kg Powder, 5.00% Enriched, Water in All Foam

Water Fraction in Foam[2]	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
0.0	**44**	**0.9349**	**0.0005**	**0.9359**
0.1	44	0.9295	0.0005	0.9305
0.2	44	0.9264	0.0005	0.9274
0.3	44	0.9247	0.0006	0.9259
0.4	44	0.9250	0.0006	0.9262
0.5	44	0.9230	0.0005	0.9240
0.6	44	0.9222	0.0005	0.9232
0.7	44	0.9220	0.0005	0.9230
0.8	44	0.9226	0.0005	0.9236
0.9	44	0.9218	0.0005	0.9228
1.0	44	0.9213	0.0005	0.9223

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[1] The "water fraction in charred foam" is the density of water in the foam divided by the nominal density of water. Note that the carbon density in the foam is constant, i.e., water does not replace carbon.

[2] The "water fraction in foam" is the density of water in the foam divided by the nominal density of water. Note that the carbon density in the foam is constant, i.e., water does not replace carbon.

Table 6-22. 239 kg Powder, 5.00% Enriched, Modified Aluminum Disk

Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
52	0.9309	0.0005	0.9319
51	0.9316	0.0005	0.9326
50	0.9332	0.0005	0.9342
49	0.9333	0.0006	0.9345
48	0.9334	0.0006	0.9346
47	0.9343	0.0005	0.9353
46	0.9340	0.0005	0.9350
45	0.9346	0.0005	0.9356
44	**0.9349**	**0.0005**	**0.9359**
43	0.9333	0.0005	0.9343
42	0.9339	0.0005	0.9349
41	0.9330	0.0005	0.9340
40	0.9317	0.0006	0.9329

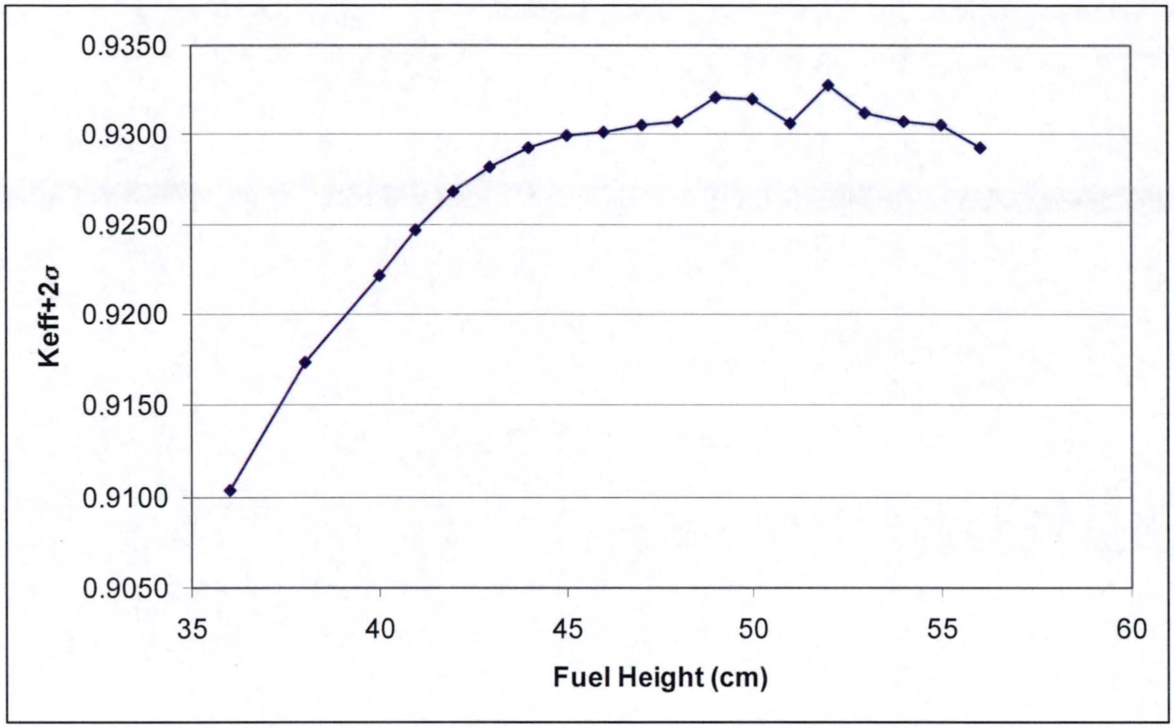

Figure 6-7. HAC, 6x6x6 Array, 4.45 wt. % Homogeneous Powder

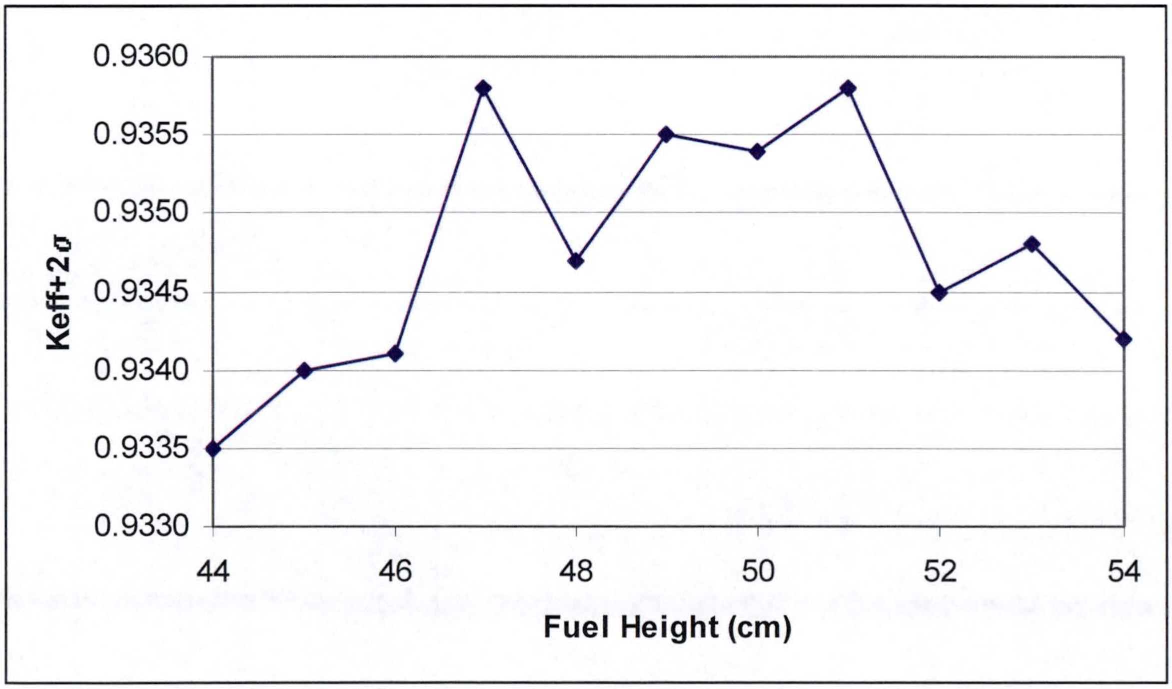

Figure 6-8. HAC, 6x6x6 Array, 4.55 wt. % Homogeneous Powder

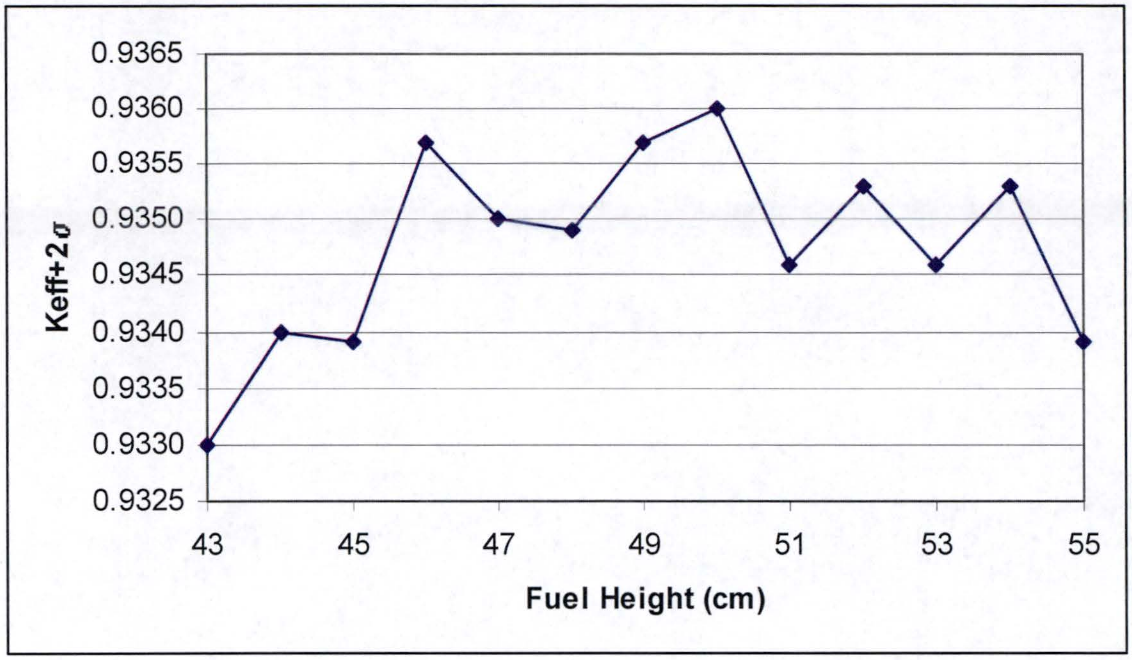

Figure 6-9. HAC, 6x6x6 Array, 4.65 wt.% Homogeneous Powder

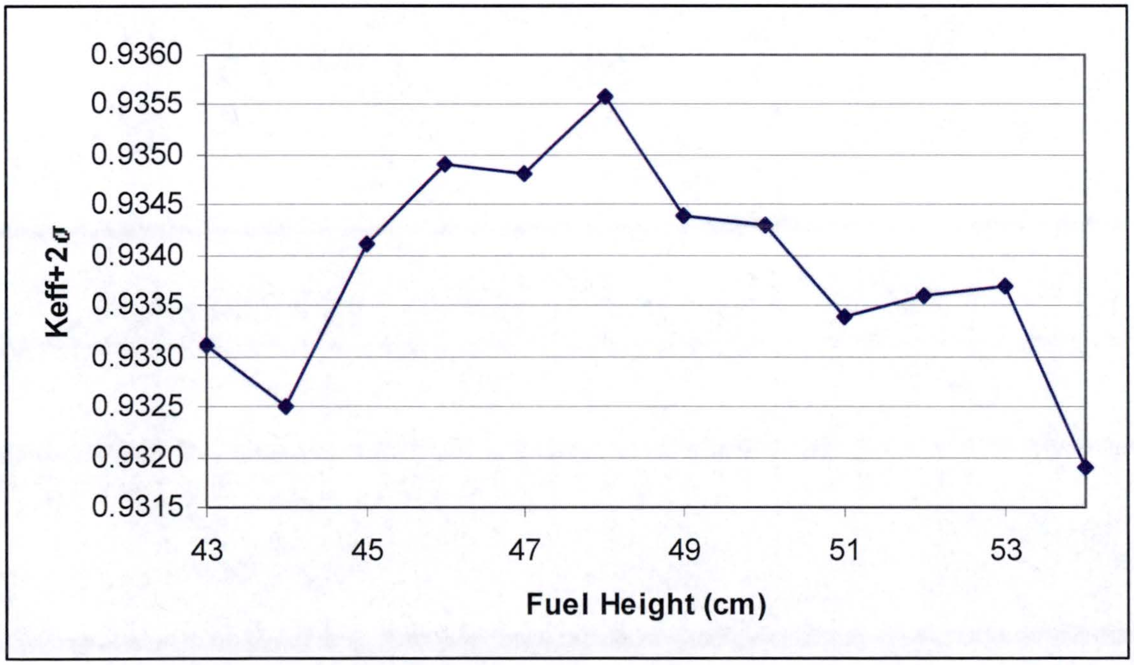

Figure 6-10. HAC, 6x6x6 Array, 4.75 wt.% Homogeneous Powder

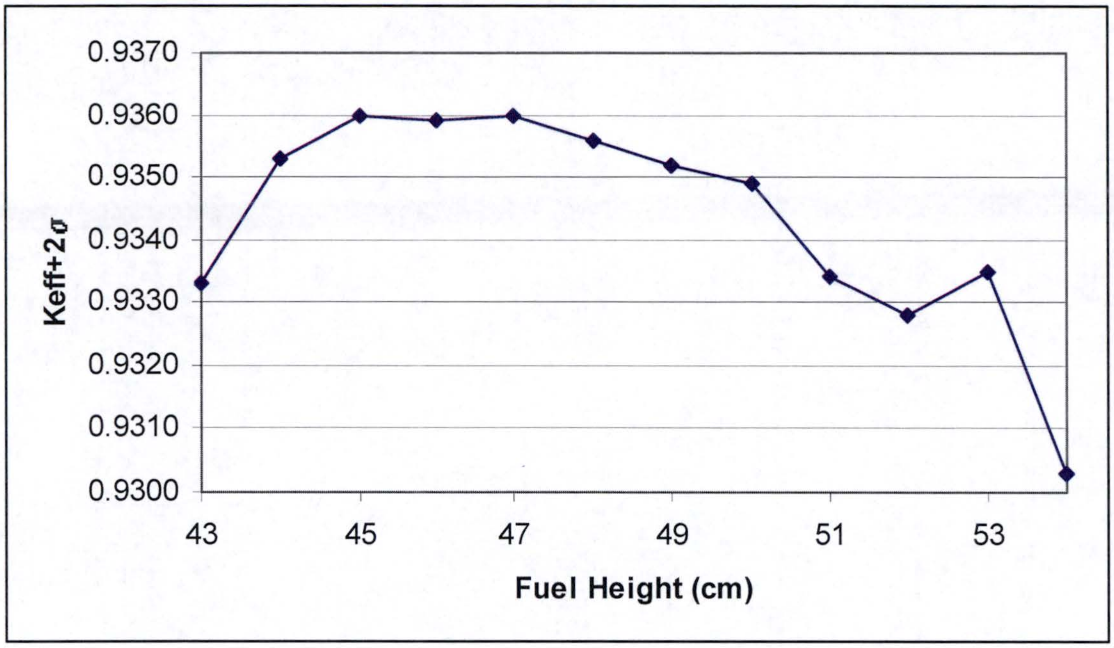

Figure 6-11. HAC, 6x6x6 Array, 4.85 wt.% Homogeneous Powder

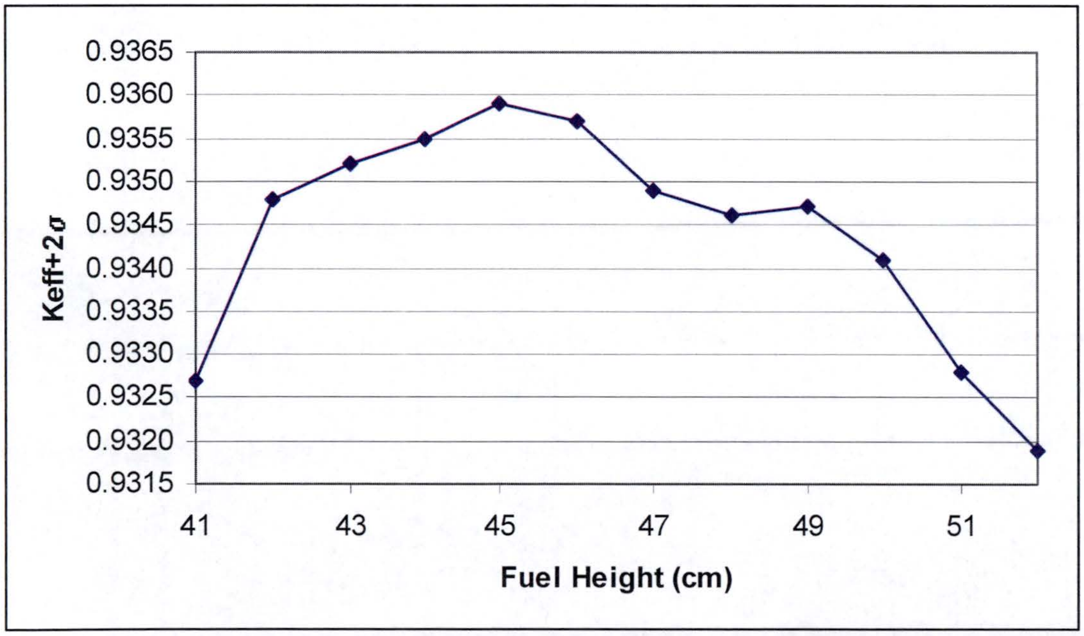

Figure 6-12. HAC, 6x6x6 Array, 4.95 wt.% Homogeneous Powder

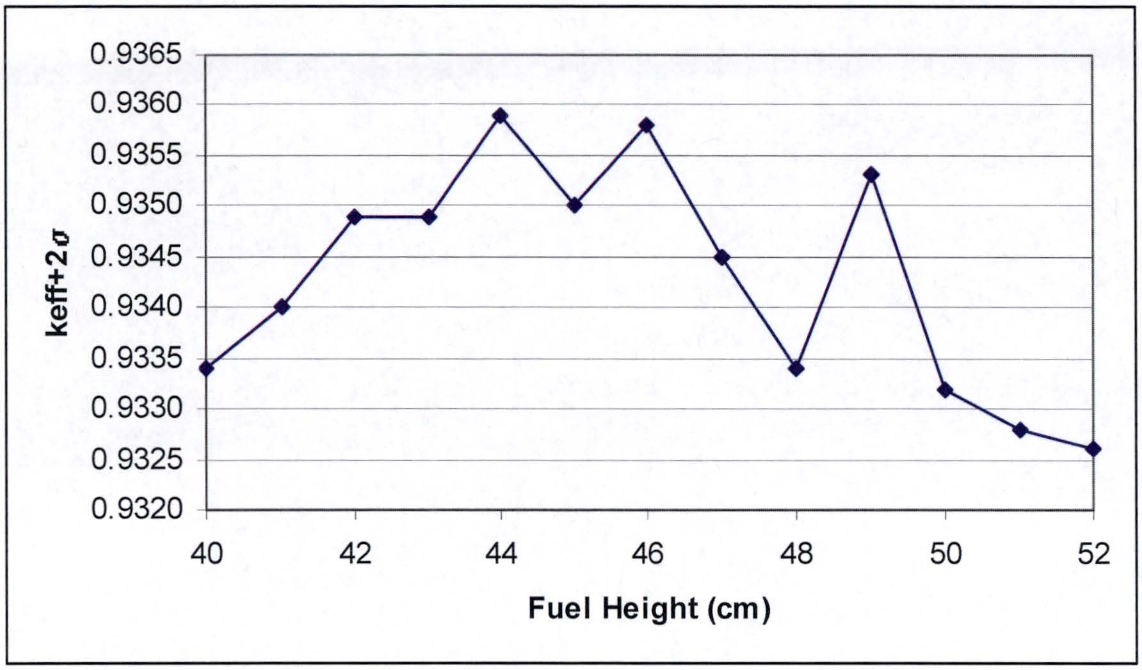

Figure 6-13. HAC, 6x6x6 Array, 5.0 wt.% Homogeneous Powder

Table 6-23. NOC, 8x9x8 Array, 4.45% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
300	61.4999	0.9071	0.0005	0.9081
300	60	0.9044	0.0005	0.9054
300	58	0.9021	0.0005	0.9031
300	56	0.8980	0.0005	0.8990
300	54	0.8940	0.0005	0.8950
300	52	0.8887	0.0005	0.8897
300	50	0.8838	0.0005	0.8848
300	48	0.8767	0.0004	0.8775
300	46	0.8700	0.0005	0.8710
300	44	0.8611	0.0004	0.8619
300	42	0.8495	0.0004	0.8503
300	40	0.8389	0.0005	0.8399

Table 6-24. NOC, 8x9x8 Array, 4.55% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
294	61.4999	0.9066	0.0004	0.9074
294	60	0.9061	0.0005	0.9071
294	58	0.9014	0.0005	0.9024
294	56	0.8987	0.0005	0.8997
294	54	0.8952	0.0005	0.8962
294	52	0.8902	0.0005	0.8912
294	50	0.8848	0.0005	0.8858
294	48	0.8785	0.0005	0.8795
294	46	0.8706	0.0005	0.8716
294	44	0.8624	0.0006	0.8636
294	42	0.8523	0.0005	0.8533
294	40	0.8406	0.0006	0.8418

Table 6-25. NOC, 8x9x8 Array, 4.65% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
281	61.4999	0.9097	0.0005	0.9107
281	60	0.9092	0.0005	0.9102
281	58	0.9055	0.0005	0.9065
281	56	0.9023	0.0005	0.9033
281	54	0.8983	0.0005	0.8993
281	52	0.8934	0.0005	0.8944
281	50	0.8889	0.0006	0.8901
281	48	0.8829	0.0005	0.8839
281	46	0.8768	0.0005	0.8778
281	44	0.8682	0.0005	0.8692
281	42	0.8580	0.0005	0.8590
281	40	0.8475	0.0005	0.8485

Table 6-26. NOC, 8x9x8 Array, 4.75% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
265	61.4999	0.9120	0.0005	0.9130
265	60	0.9101	0.0005	0.9111
265	58	0.9082	0.0005	0.9092
265	56	0.9048	0.0005	0.9058
265	54	0.9025	0.0005	0.9035
265	52	0.8981	0.0005	0.8991
265	50	0.8941	0.0005	0.8951
265	48	0.8886	0.0005	0.8896
265	46	0.8810	0.0005	0.8820
265	44	0.8740	0.0005	0.8750
265	42	0.8657	0.0004	0.8665
265	40	0.8542	0.0006	0.8554

Table 6-27. NOC, 8x9x8 Array, 4.85% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
255	61.4999	0.9146	0.0005	0.9156
255	60	0.9136	0.0005	0.9146
255	58	0.9097	0.0005	0.9107
255	56	0.9079	0.0005	0.9089
255	54	0.9050	0.0005	0.9060
255	52	0.9020	0.0005	0.9030
255	50	0.8974	0.0005	0.8984
255	48	0.8920	0.0006	0.8932
255	46	0.8867	0.0005	0.8877
255	44	0.8783	0.0005	0.8793
255	42	0.8713	0.0006	0.8725
255	40	0.8594	0.0005	0.8604

Table 6-28. NOC, 8x9x8 Array, 4.95% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
244	61.4999	0.9164	0.0006	0.9176
244	60	0.9160	0.0005	0.9170
244	58	0.9124	0.0005	0.9134
244	56	0.9113	0.0005	0.9123
244	54	0.9073	0.0005	0.9083
244	52	0.9047	0.0005	0.9057
244	50	0.9005	0.0005	0.9015
244	48	0.8966	0.0005	0.8976
244	46	0.8909	0.0005	0.8919
244	44	0.8823	0.0005	0.8833
244	42	0.8753	0.0005	0.8763
244	40	0.8658	0.0005	0.8668

Table 6-29. NOC, 8x9x8 Array, 5.00% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
239	61.4999	0.9170	0.0006	0.9182
239	60	0.9150	0.0005	0.9160
239	58	0.9145	0.0005	0.9155
239	56	0.9115	0.0006	0.9127
239	54	0.9103	0.0005	0.9113
239	52	0.9058	0.0005	0.9068
239	50	0.9019	0.0005	0.9029
239	48	0.8972	0.0005	0.8982
239	46	0.8917	0.0005	0.8927
239	44	0.8854	0.0005	0.8864
239	42	0.8759	0.0005	0.8769
239	40	0.8685	0.0005	0.8695

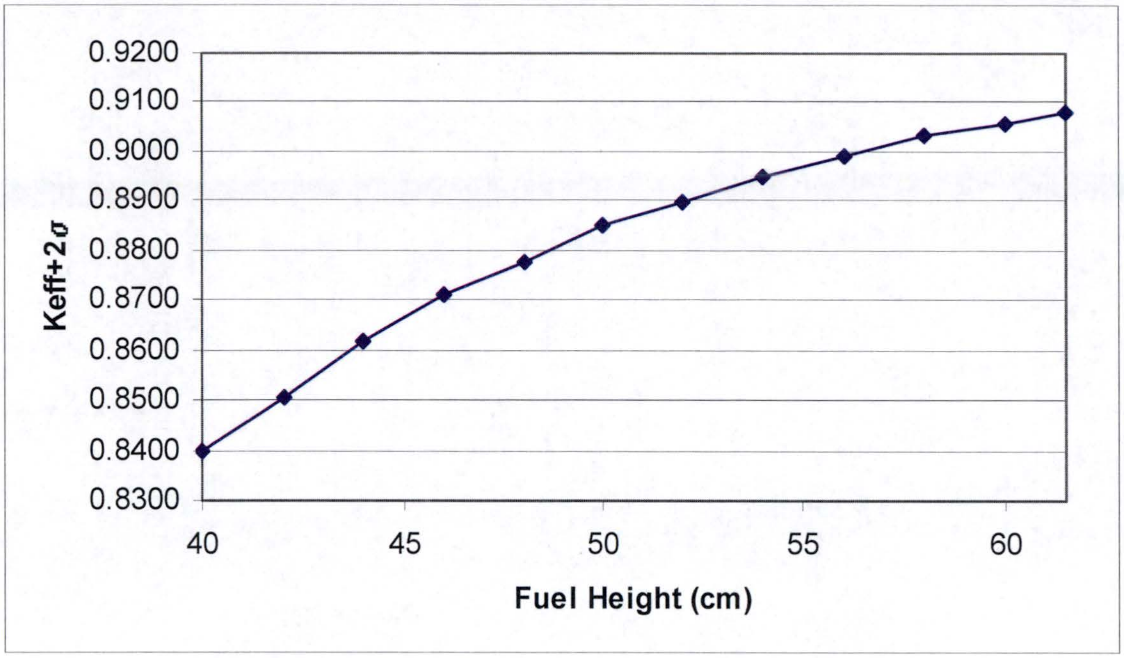

Figure 6-14. NOC, 8x9x8 Array, 4.45 wt.% Homogeneous Powder

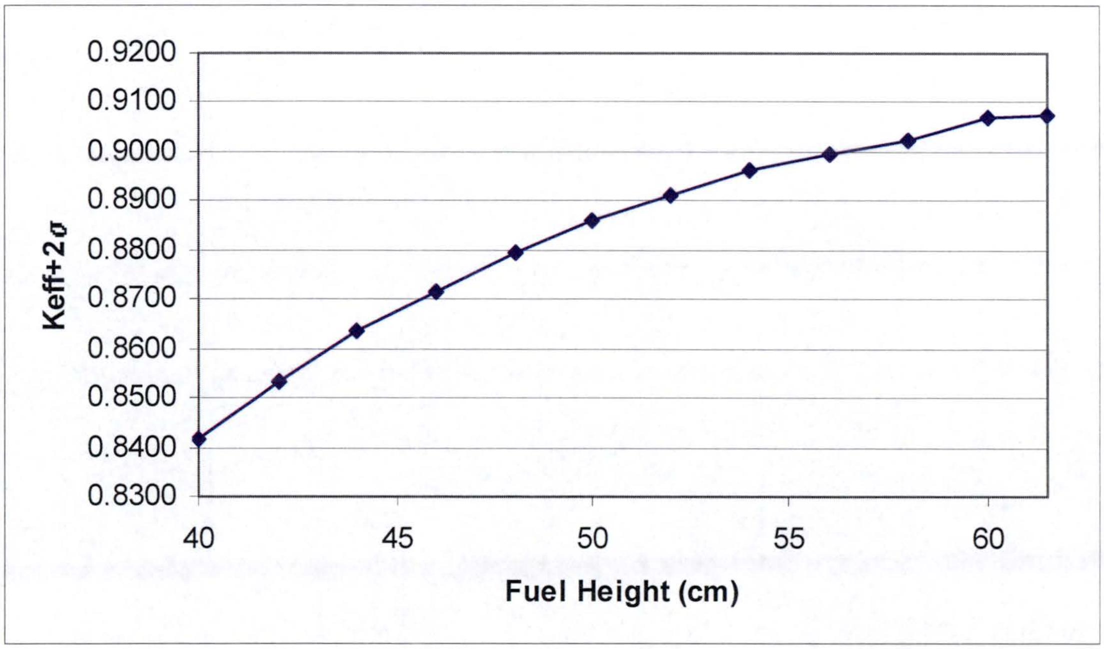

Figure 6-15. NOC, 8x9x8 Array, 4.55 wt.% Homogeneous Powder

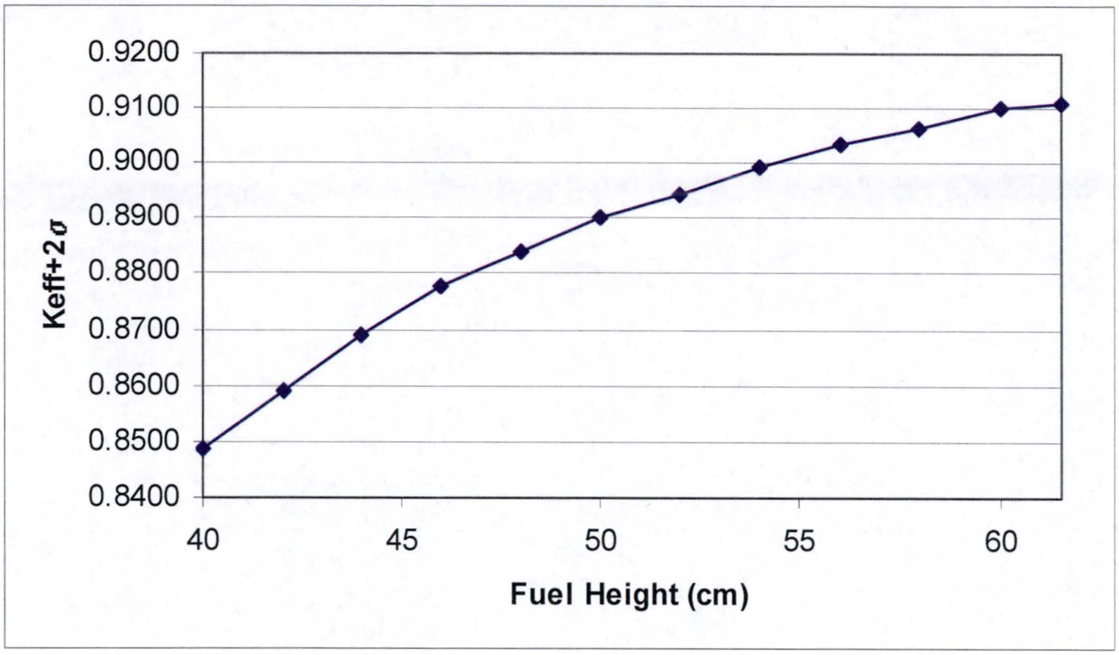

Figure 6-16. NOC, 8x9x8 Array, 4.65 wt.% Homogeneous Powder

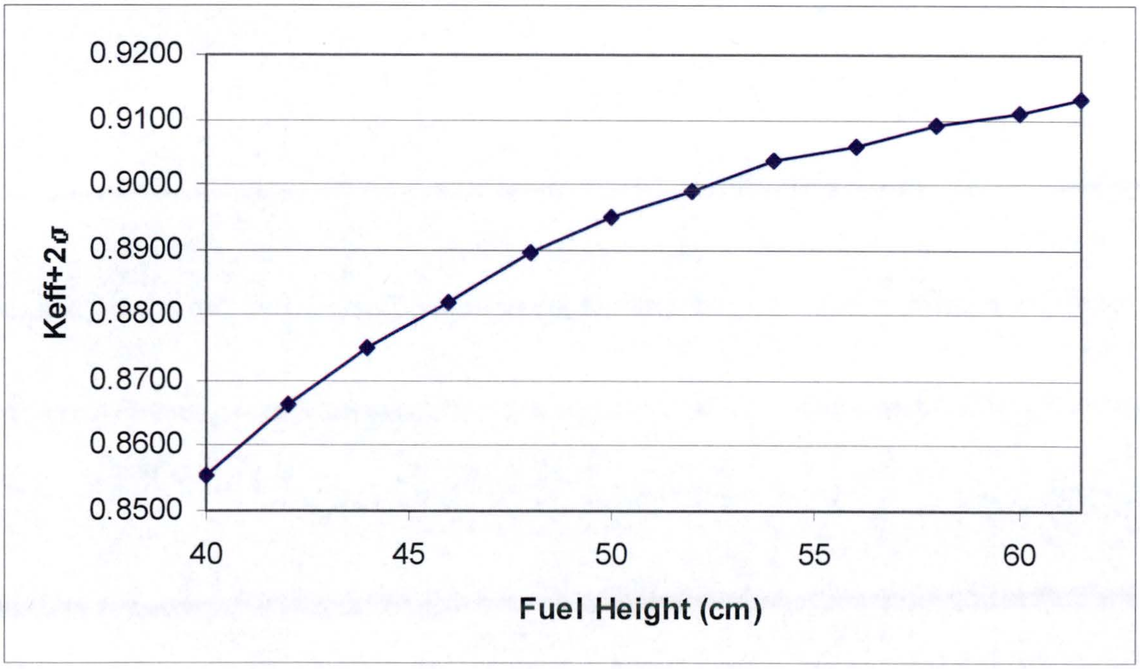

Figure 6-17. NOC, 8x9x8 Array, 4.75 wt.% Homogeneous Powder

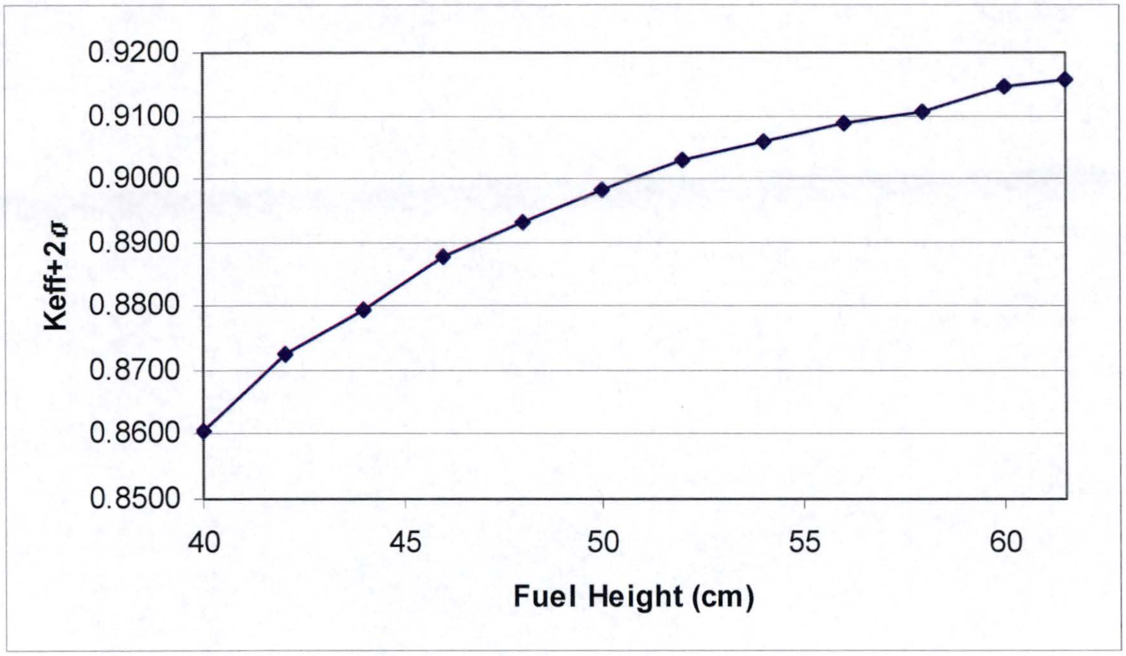

Figure 6-18. NOC, 8x9x8 Array, 2.85 wt.% Homogeneous Powder

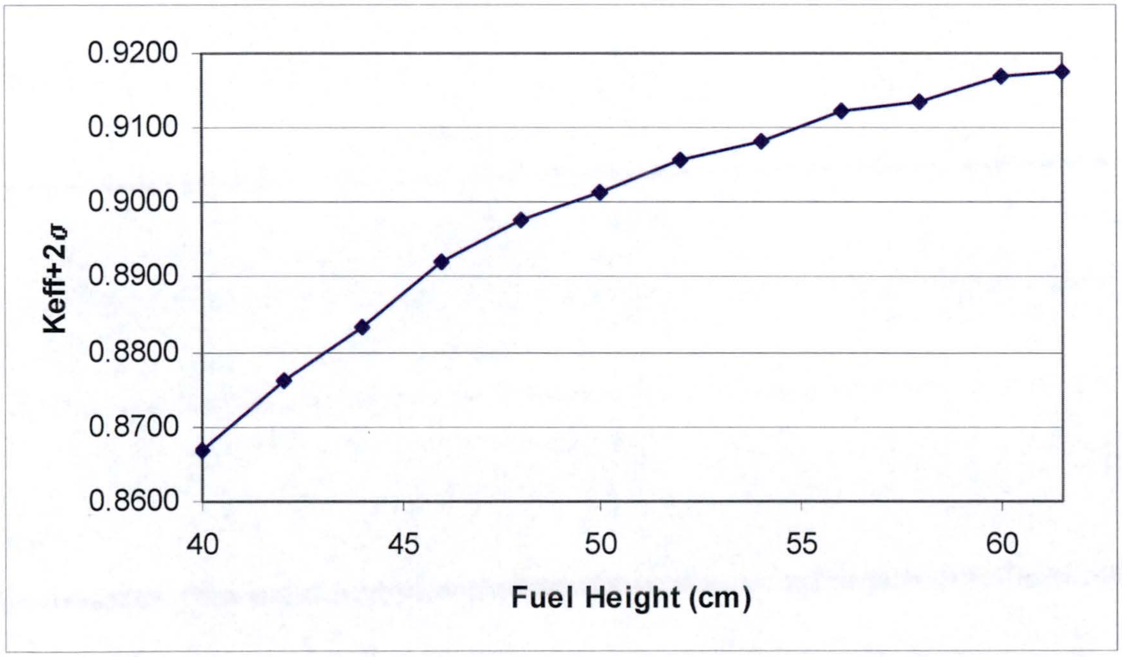

Figure 6-19. NOC, 8x9x8 Array, 2.95 wt.%, Homogeneous Powder

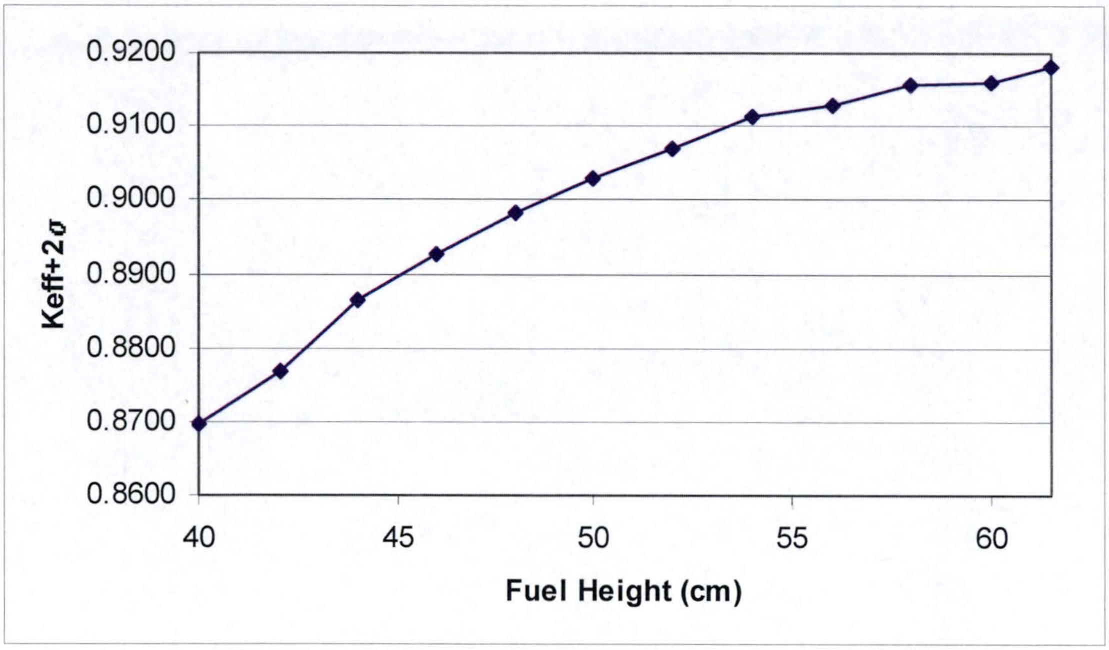

Figure 6-20. NOC, 8x9x8 Array, 5.00 wt.% Homogeneous Powder

Table 6-30. NOC, Single Package, 4.45% Enriched Homogeneous Powder

Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
300	61.4999	0.8892	0.0005	0.8902
300	60	0.8888	0.0005	0.8898
300	58	0.8856	0.0005	0.8866
300	56	0.8830	0.0005	0.8840
300	54	0.8781	0.0004	0.8789
300	52	0.8737	0.0006	0.8749
300	50	0.8683	0.0005	0.8693
300	48	0.8614	0.0006	0.8626
300	46	0.8546	0.0005	0.8556
300	44	0.8466	0.0005	0.8476
300	42	0.8361	0.0006	0.8373
300	40	0.8241	0.0005	0.8251

Table 6-31. NOC, Single Package, 4.55% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
294	61.4999	0.8908	0.0005	0.8918
294	60	0.8885	0.0006	0.8897
294	58	0.8864	0.0006	0.8876
294	56	0.8821	0.0005	0.8831
294	54	0.8784	0.0005	0.8794
294	52	0.8746	0.0005	0.8756
294	50	0.8695	0.0005	0.8705
294	48	0.8616	0.0005	0.8626
294	46	0.8560	0.0005	0.8570
294	44	0.8481	0.0005	0.8491
294	42	0.8366	0.0006	0.8378
294	40	0.8253	0.0005	0.8263

Table 6-32. NOC, Single Package, 4.65% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
281	61.4999	0.8937	0.0005	0.8947
281	60	0.8918	0.0006	0.8930
281	58	0.8890	0.0005	0.8900
281	56	0.8872	0.0006	0.8884
281	54	0.8832	0.0005	0.8842
281	52	0.8792	0.0005	0.8802
281	50	0.8731	0.0005	0.8741
281	48	0.8685	0.0005	0.8695
281	46	0.8599	0.0006	0.8611
281	44	0.8530	0.0005	0.8540
281	42	0.8434	0.0005	0.8444
281	40	0.8335	0.0005	0.8345

Table 6-33. NOC, Single Package, 4.75% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
265	61.4999	0.8948	0.0005	0.8958
265	60	0.8940	0.0005	0.8950
265	58	0.8925	0.0005	0.8935
265	56	0.8897	0.0005	0.8907
265	54	0.8867	0.0005	0.8877
265	52	0.8828	0.0005	0.8838
265	50	0.8780	0.0005	0.8790
265	48	0.8720	0.0005	0.8730
265	46	0.8659	0.0005	0.8669
265	44	0.8599	0.0005	0.8609
265	42	0.8493	0.0005	0.8503
265	40	0.8402	0.0005	0.8412

Table 6-34. NOC, Single Package, 4.85% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
255	61.4999	0.8976	0.0005	0.8986
255	60	0.8968	0.0005	0.8978
255	58	0.8945	0.0005	0.8955
255	56	0.8923	0.0006	0.8935
255	54	0.8895	0.0005	0.8905
255	52	0.8863	0.0005	0.8873
255	50	0.8819	0.0005	0.8829
255	48	0.8765	0.0005	0.8775
255	46	0.8707	0.0006	0.8719
255	44	0.8641	0.0005	0.8651
255	42	0.8553	0.0005	0.8563
255	40	0.8460	0.0005	0.8470

Table 6-35. NOC, Single Package, 4.95% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
244	61.4999	0.8997	0.0006	0.9009
244	60	0.8974	0.0005	0.8984
244	58	0.8972	0.0005	0.8982
244	56	0.8955	0.0005	0.8965
244	54	0.8930	0.0005	0.8940
244	52	0.8903	0.0005	0.8913
244	50	0.8858	0.0005	0.8868
244	48	0.8798	0.0005	0.8808
244	46	0.8753	0.0005	0.8763
244	44	0.8681	0.0006	0.8693
244	42	0.8596	0.0004	0.8604
244	40	0.8507	0.0005	0.8517

Table 6-36. NOC, Single Package, 5.00% Enriched Homogeneous Powder

UO_2 Mass, kg	Fuel/Water Mixture Height, cm	k_{eff}	σ	$k_{eff}+2\sigma$
239	61.4999	0.9007	0.0005	0.9017
239	60	0.8993	0.0005	0.9003
239	58	0.8979	0.0005	0.8989
239	56	0.8968	0.0006	0.8980
239	54	0.8932	0.0005	0.8942
239	52	0.8903	0.0005	0.8913
239	50	0.8876	0.0005	0.8886
239	48	0.8827	0.0005	0.8837
239	46	0.8763	0.0005	0.8773
239	44	0.8699	0.0005	0.8709
239	42	0.8621	0.0005	0.8631
239	40	0.8530	0.0005	0.8540

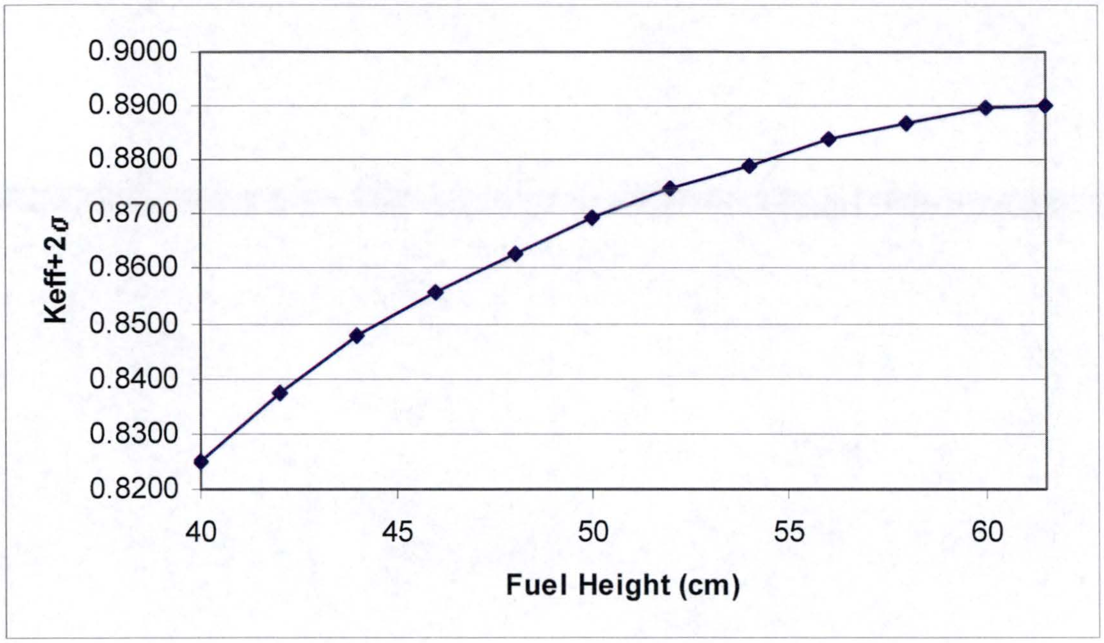

Figure 6-21. NOC, Single Package, 4.45 wt.% Homogeneous Powder

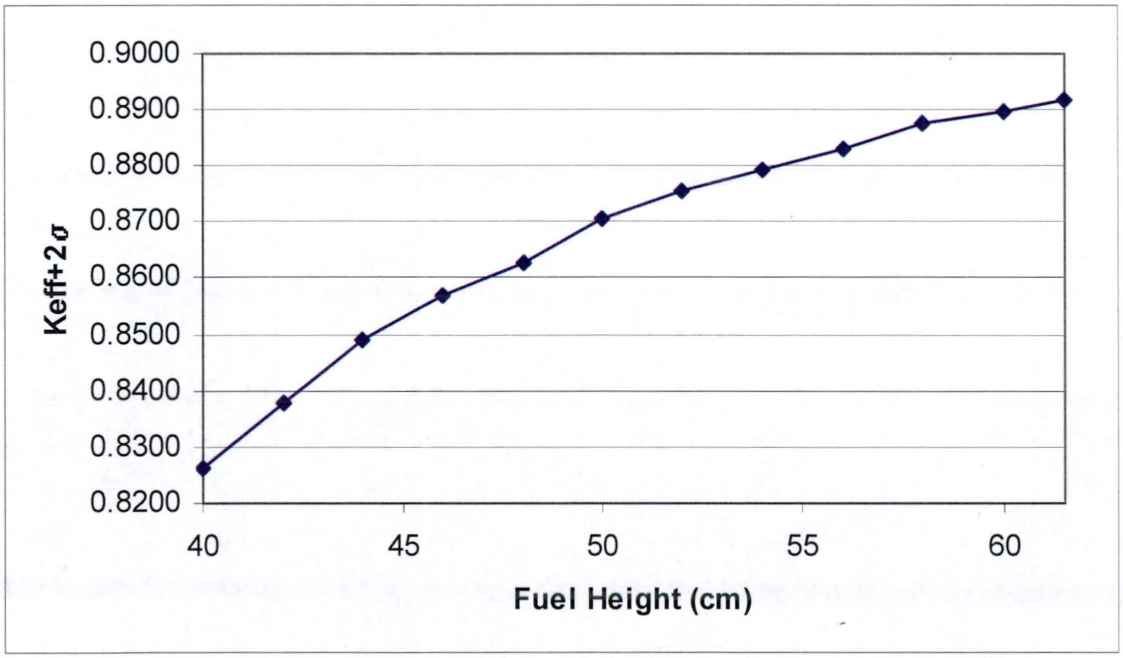

Figure 6-22. NOC, Single Package, 4.55 wt.% Homogeneous Powder

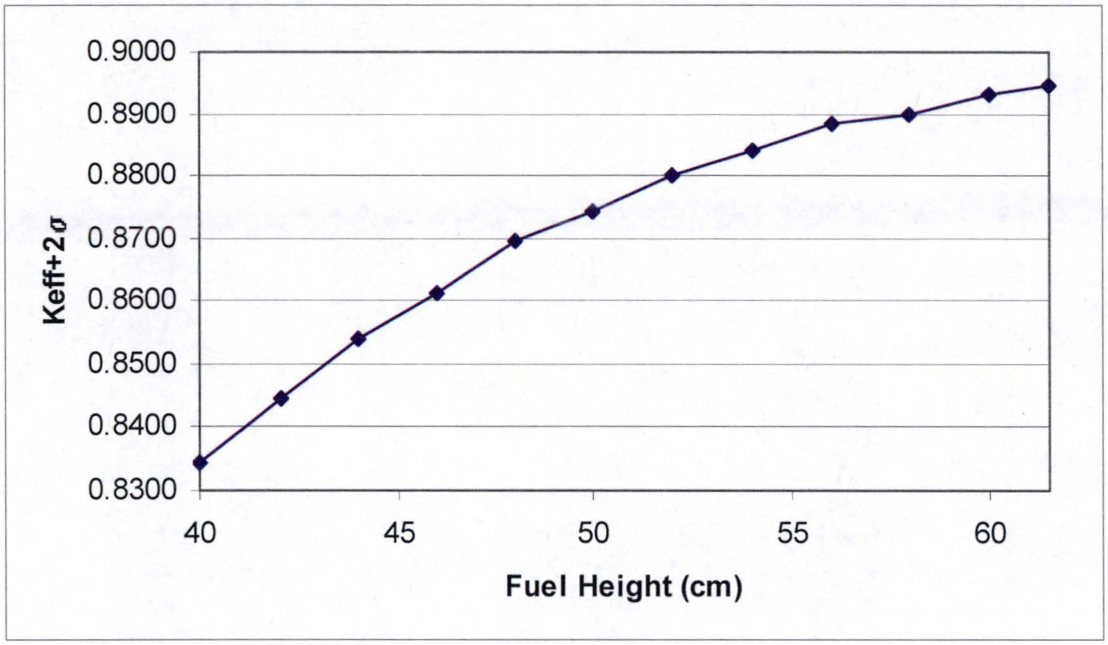

Figure 6-23. HOC, Single Package, 4.65 wt.% Homogeneous Powder

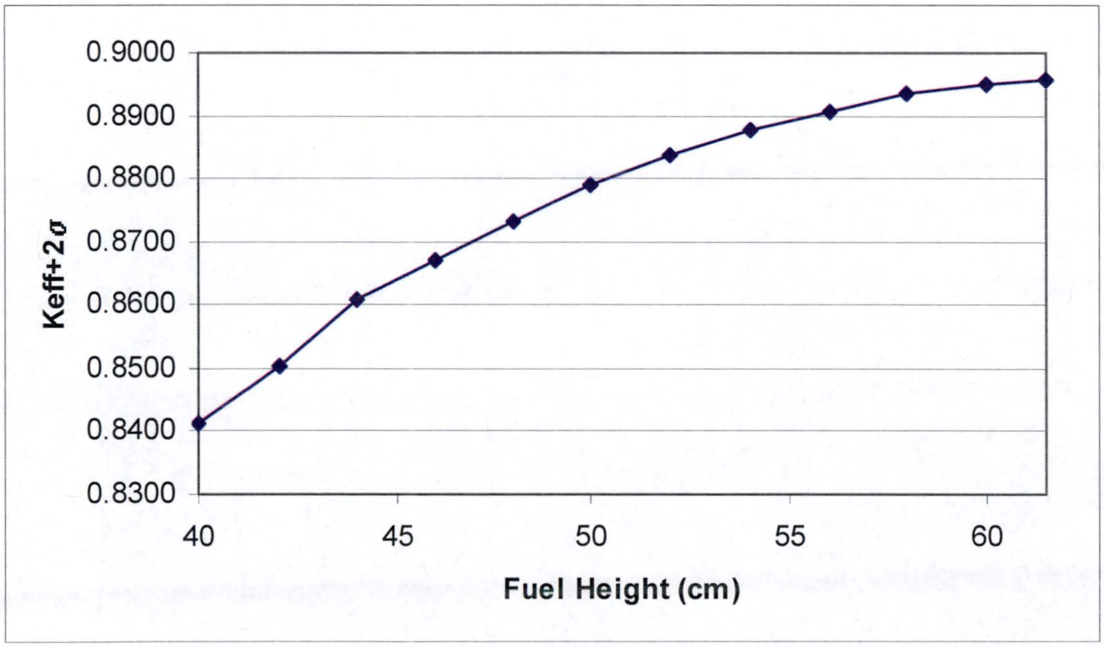

Figure 6-24. HOC, Single Package, 4.65 wt.% Homogeneous Powder

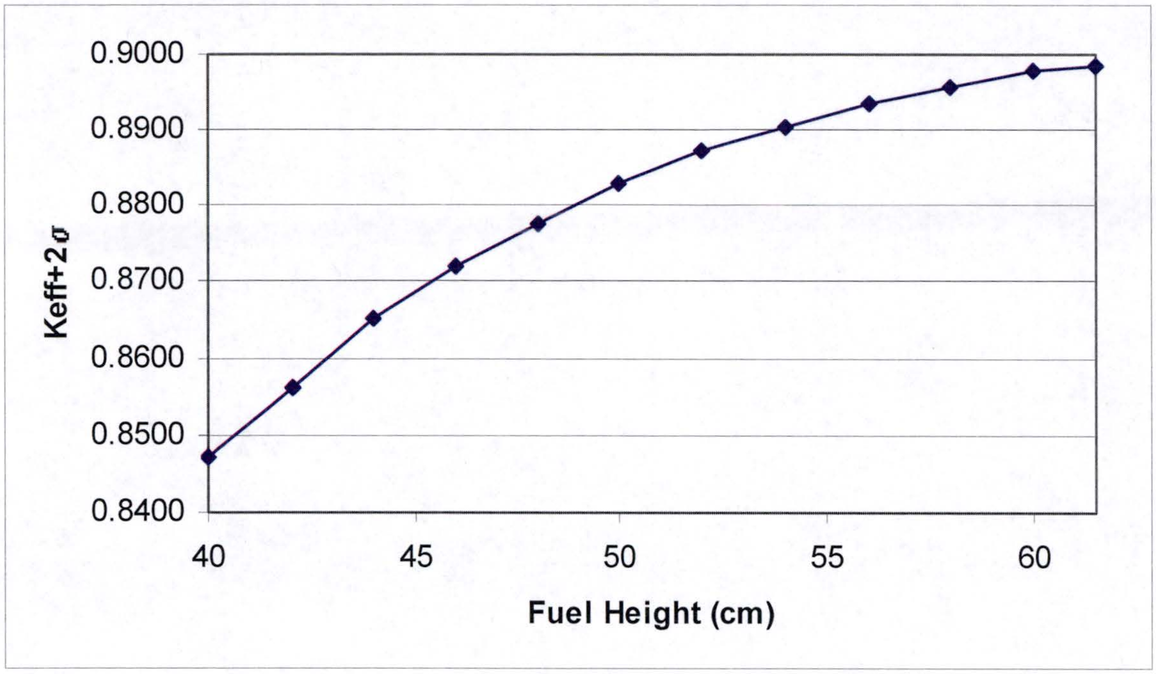

Figure 6-25. NOC, Single Package, 4.85 wt.% Homogeneous Powder

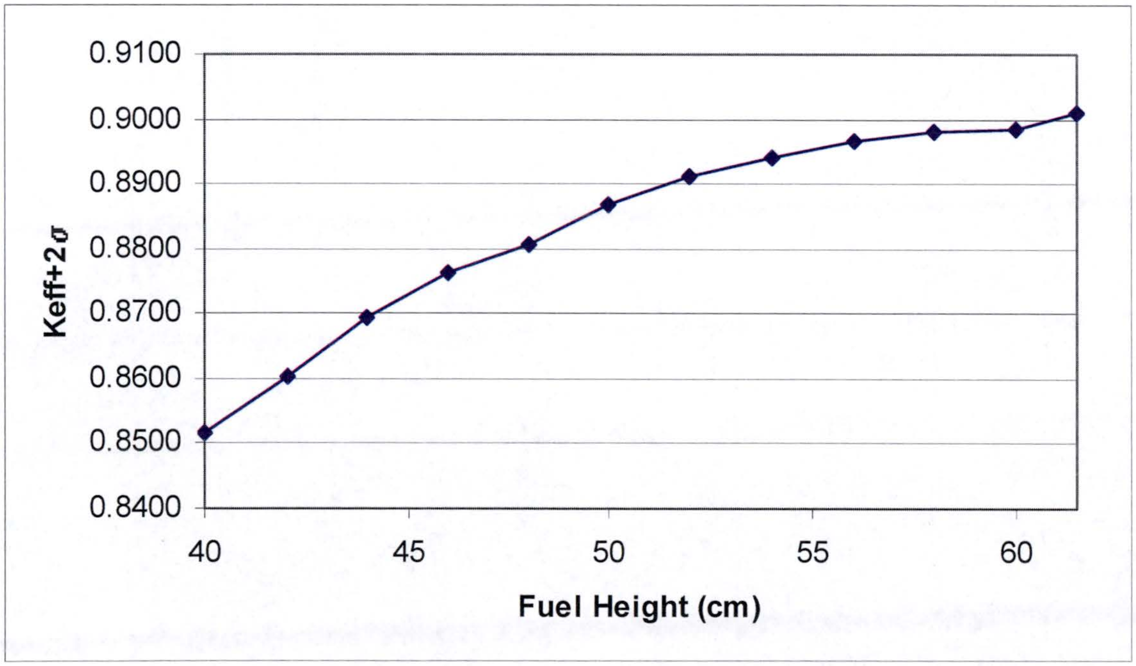

Figure 6-26. NOC, Single Package, 4.95 wt.% Homogeneous Powder

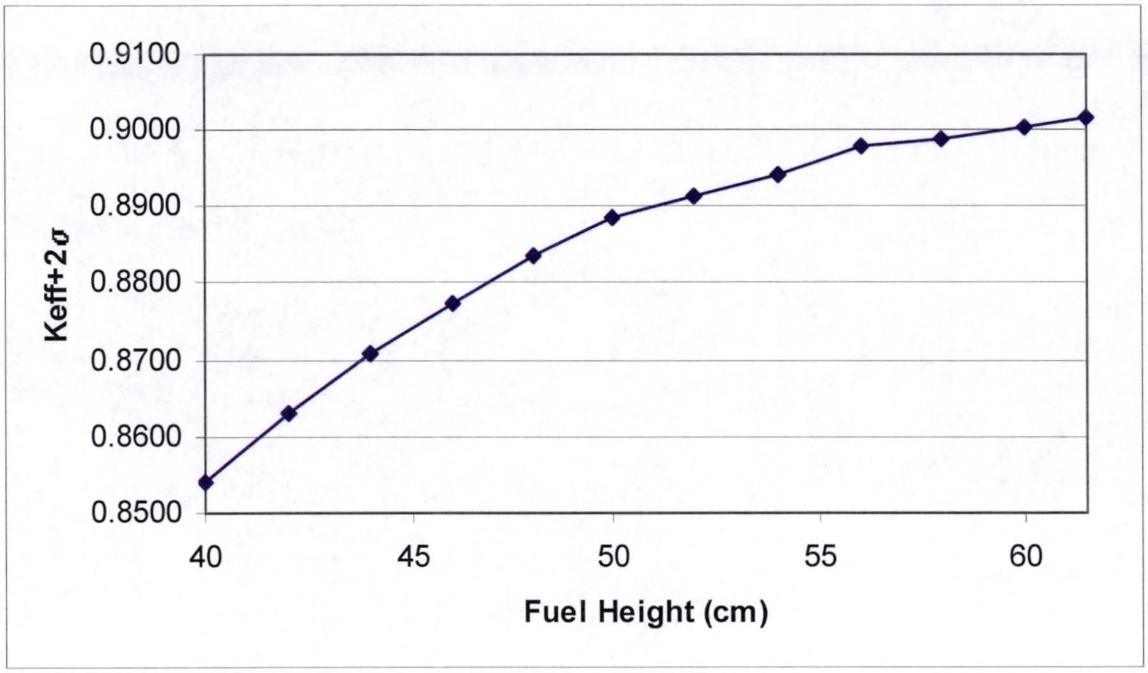

Figure 6-27. NOC, Single Package, 5.00 wt.% Homogeneous Powder

6.4.2.2 Heterogeneous Material Results

The system k_{eff} as a function of the fuel height for the 6x6x6 array HAC cases is provided in Table 6-37 through Table 6-48 and is shown graphically in Figure 6-28 through 6-39 for heterogeneous material of various enrichments. The heterogeneous mass limits were determined based upon these cases. For this reason, most of these cases are intentionally close to the USL.

During the course of the calculations, the precise composition of the foam to be used in the HAC models was obtained by experiment. The final values were slightly different than the values used in these calculations.

The measured weight percents are as follows:

Element	
C	
H	
O	

To assess the impact of using the foam compositions slightly different than the measured values, representative calculations are performed with the measured foam for 5.0% enriched pellets, a pellet diameter of 0.18 cm, and variable stack height. The results provided in Table 6-49 indicate that the reactivity changes resulting from these small perturbations in the foam composition are within the statistical uncertainty of the code and are inconsequential.

For the HAC cases it is assumed that no water is present in the charred foam. It was assumed that this would be the most reactive configuration because adding water to the foam would likely decrease communication between the packages. The validity of this assumption is documented below.

Two sets of HAC calculations with water in the foam are performed for the most reactive 5.0% enriched pellet case. The first set considers water only in the charred foam. The second considers water in both the charred and uncharred foam, as well as water in the perforated aluminum disk. It is assumed that water content varies uniformly throughout the foam and disk. When water is added to these regions in increasing density, the reactivity decreases due to decreased communication between packages, confirming that no interspersed moderation is the most reactive configuration. These results are provided in Table 6-50 and Table 6-51.

During the course of the calculations, the thickness of the aluminum disk changed from 3.0 cm to 1.5 cm, although the KENO models were not updated. The diameter of the 61 holes in the aluminum disk also changed from 4.4 cm to 3.3 cm, resulting in a homogenized density change from 1.08 to 1.78 g/cm^3.

A representative case using 5.0% enriched pellets was modeled with the correct aluminum thickness of 1.5 cm and homogenized density of 1.78 g/cm^3. The fuel height is allowed to vary between 30 and 50 cm. The results are provided in Table 6-52. The change in reactivity with the change in the aluminum disk thickness and density are within the statistical uncertainty of the method.

The system k_{eff} as a function of the fuel height for the 8x9x8 array NOC cases is provided in Table 6-53 through Table 6-64 and is shown graphically in Figure 6-40 through 6-51 for heterogeneous material of various enrichments. The system k_{eff} as a function of the fuel height for the single package NOC cases is provided in Table 6-65 through Table 6-76 and is shown graphically in Figure 6-52 through 6-63 for heterogeneous material of various enrichments.

These calculations show that both a single package and arrays of packages of heterogeneous material remain subcritical under general requirements for fissile material packages under both normal conditions of transport and hypothetical accident conditions. KENO results plus 2σ are less than or equal to the USL for all cases.

Table 6-37. HAC, 6x6x6 Array, 300 kg UO_2, 4.05% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.3148	46	5.4362	0.9324	0.0005	0.9334	0.9370
0.14	0.3215	48	5.7160	0.9320	0.0005	0.9330	0.9370
0.14	0.3282	50	5.9959	0.9322	0.0005	0.9332	0.9370
0.14	0.3347	52	6.2757	0.9312	0.0005	0.9322	0.9370
0.18	0.3958	44	5.1564	0.9328	0.0005	0.9338	0.9370
0.18	0.4047	46	5.4362	0.9328	0.0005	0.9338	0.9370
0.18	0.4134	48	5.7160	0.9333	0.0006	0.9345	0.9370
0.18	0.4219	50	5.9959	0.9337	0.0005	0.9347	0.9370
0.18	0.4303	52	6.2757	0.9319	0.0005	0.9329	0.9370
0.22	0.4838	44	5.1564	0.9339	0.0005	0.9349	0.9370
0.22	0.4946	46	5.4362	0.9350	0.0005	0.9360	0.9370
0.22	**0.5053**	**48**	**5.7160**	**0.9352**	**0.0005**	**0.9362**	**0.9370**
0.22	0.5157	50	5.9959	0.9337	0.0005	0.9347	0.9370
0.22	0.5259	52	6.2757	0.9333	0.0005	0.9343	0.9370
0.26	0.5717	44	5.1564	0.9339	0.0005	0.9349	0.9370
0.26	0.5846	46	5.4362	0.9339	0.0005	0.9349	0.9370
0.26	0.5971	48	5.7160	0.9348	0.0005	0.9358	0.9370
0.26	0.6095	50	5.9959	0.9343	0.0005	0.9353	0.9370
0.26	0.6215	52	6.2757	0.9324	0.0005	0.9334	0.9370
0.3	0.6597	44	5.1564	0.9347	0.0005	0.9357	0.9370
0.3	0.6745	46	5.4362	0.9348	0.0005	0.9358	0.9370
0.3	0.6890	48	5.7160	0.9342	0.0005	0.9352	0.9370
0.3	0.7032	50	5.9959	0.9331	0.0005	0.9341	0.9370
0.3	0.7171	52	6.2757	0.9316	0.0005	0.9326	0.9370

Table 6-38. HAC, 6x6x6 Array, 293 kg UO_2, 4.10% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.3185	46	5.5900	0.9329	0.0005	0.9339	0.9370
0.14	0.3254	48	5.8765	0.9334	0.0005	0.9344	0.9370
0.14	0.3321	50	6.1630	0.9333	0.0005	0.9343	0.9370
0.14	0.3386	52	6.4495	0.9324	0.0005	0.9334	0.9370
0.18	0.4005	44	5.3034	0.9341	0.0005	0.9351	0.9370
0.18	0.4095	46	5.5900	0.9345	0.0005	0.9355	0.9370
0.18	0.4183	48	5.8765	0.9345	0.0005	0.9355	0.9370
0.18	0.4269	50	6.1630	0.9338	0.0005	0.9348	0.9370
0.18	0.4354	52	6.4495	0.9322	0.0005	0.9332	0.9370
0.22	0.4895	44	5.3034	0.9343	0.0005	0.9353	0.9370
0.22	**0.5005**	**46**	**5.5900**	**0.9356**	**0.0005**	**0.9366**	**0.9370**
0.22	0.5113	48	5.8765	0.9349	0.0004	0.9357	0.9370
0.22	0.5218	50	6.1630	0.9337	0.0006	0.9349	0.9370
0.22	0.5321	52	6.4495	0.9322	0.0005	0.9332	0.9370
0.26	0.5785	44	5.3034	0.9339	0.0005	0.9349	0.9370
0.26	0.5915	46	5.5900	0.9350	0.0005	0.9360	0.9370
0.26	0.6042	48	5.8765	0.9348	0.0005	0.9358	0.9370
0.26	0.6167	50	6.1630	0.9344	0.0005	0.9354	0.9370
0.26	0.6289	52	6.4495	0.9325	0.0005	0.9335	0.9370
0.3	0.6675	44	5.3034	0.9346	0.0006	0.9358	0.9370
0.3	0.6825	46	5.5900	0.9350	0.0005	0.9360	0.9370
0.3	0.6972	48	5.8765	0.9343	0.0004	0.9351	0.9370
0.3	0.7116	50	6.1630	0.9338	0.0005	0.9348	0.9370
0.3	0.7257	52	6.4495	0.9322	0.0005	0.9332	0.9370

Table 6-39. HAC, 6x6x6 Array, 287 kg UO_2, 4.15% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.3218	46	5.7277	0.9336	0.0005	0.9346	0.9370
0.14	0.3287	48	6.0202	0.9345	0.0005	0.9355	0.9370
0.14	0.3355	50	6.3128	0.9335	0.0005	0.9345	0.9370
0.14	0.3422	52	6.6053	0.9326	0.0004	0.9334	0.9370
0.18	0.4047	44	5.4352	0.9344	0.0005	0.9354	0.9370
0.18	0.4138	46	5.7277	0.9349	0.0005	0.9359	0.9370
0.18	0.4227	48	6.0202	0.9350	0.0005	0.9360	0.9370
0.18	0.4314	50	6.3128	0.9345	0.0006	0.9357	0.9370
0.18	0.4399	52	6.6053	0.9326	0.0005	0.9336	0.9370
0.22	0.4946	44	5.4352	0.9347	0.0005	0.9357	0.9370
0.22	0.5057	46	5.7277	0.9355	0.0005	0.9365	0.9370
0.22	0.5166	48	6.0202	0.9353	0.0005	0.9363	0.9370
0.22	0.5272	50	6.3128	0.9346	0.0005	0.9356	0.9370
0.22	0.5377	52	6.6053	0.9337	0.0005	0.9347	0.9370
0.26	0.5711	42	5.1427	0.9333	0.0005	0.9343	0.9370
0.26	0.5845	44	5.4352	0.9356	0.0005	0.9366	0.9370
0.26	**0.5977**	**46**	**5.7277**	**0.9358**	**0.0005**	**0.9368**	**0.9370**
0.26	0.6105	48	6.0202	0.9350	0.0005	0.9360	0.9370
0.26	0.6231	50	6.3128	0.9349	0.0005	0.9359	0.9370
0.26	0.6354	52	6.6053	0.9334	0.0005	0.9344	0.9370
0.3	0.6744	44	5.4352	0.9353	0.0005	0.9363	0.9370
0.3	0.6896	46	5.7277	0.9356	0.0005	0.9366	0.9370
0.3	0.7044	48	6.0202	0.9343	0.0006	0.9355	0.9370
0.3	0.7190	50	6.3128	0.9324	0.0005	0.9334	0.9370
0.3	0.7332	52	6.6053	0.9321	0.0005	0.9331	0.9370

Table 6-40. HAC, 6x6x6 Array, 271 kg UO$_2$, 4.25% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.3239	44	5.8152	0.9334	0.0005	0.9344	0.9370
0.14	0.3312	46	6.1249	0.9343	0.0005	0.9353	0.9370
0.14	0.3383	48	6.4347	0.9329	0.0004	0.9337	0.9370
0.14	0.3453	50	6.7445	0.9323	0.0005	0.9333	0.9370
0.18	0.4069	42	5.5054	0.9332	0.0005	0.9342	0.9370
0.18	0.4164	44	5.8152	0.9334	0.0004	0.9342	0.9370
0.18	0.4258	46	6.1249	0.9339	0.0005	0.9349	0.9370
0.18	0.4350	48	6.4347	0.9343	0.0005	0.9353	0.9370
0.18	0.4439	50	6.7445	0.9327	0.0005	0.9337	0.9370
0.22	0.4973	42	5.5054	0.9337	0.0004	0.9345	0.9370
0.22	**0.5090**	**44**	**5.8152**	**0.9353**	**0.0005**	**0.9363**	**0.9370**
0.22	0.5204	46	6.1249	0.9343	0.0005	0.9353	0.9370
0.22	0.5316	48	6.4347	0.9351	0.0005	0.9361	0.9370
0.22	0.5426	50	6.7445	0.9329	0.0005	0.9339	0.9370
0.26	0.5877	42	5.5054	0.9346	0.0005	0.9356	0.9370
0.26	0.6015	44	5.8152	0.9348	0.0005	0.9358	0.9370
0.26	0.6150	46	6.1249	0.9347	0.0005	0.9357	0.9370
0.26	0.6283	48	6.4347	0.9337	0.0005	0.9347	0.9370
0.26	0.6412	50	6.7445	0.9323	0.0005	0.9333	0.9370
0.3	0.6781	42	5.5054	0.9339	0.0005	0.9349	0.9370
0.3	0.6941	44	5.8152	0.9340	0.0005	0.9350	0.9370
0.3	0.7097	46	6.1249	0.9348	0.0004	0.9356	0.9370
0.3	0.7249	48	6.4347	0.9323	0.0005	0.9333	0.9370
0.3	0.7399	50	6.7445	0.9303	0.0005	0.9313	0.9370

Table 6-41. HAC, 6x6x6 Array, 259 kg UO_2, 4.35% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.3237	42	5.8068	0.9329	0.0006	0.9341	0.9370
0.14	0.3313	44	6.1309	0.9335	0.0005	0.9345	0.9370
0.14	0.3388	46	6.4551	0.9341	0.0005	0.9351	0.9370
0.14	0.3461	48	6.7792	0.9341	0.0005	0.9351	0.9370
0.14	0.3532	50	7.1033	0.9320	0.0006	0.9332	0.9369
0.18	0.4162	42	5.8068	0.9342	0.0006	0.9354	0.9370
0.18	0.4260	44	6.1309	0.9346	0.0005	0.9356	0.9370
0.18	0.4356	46	6.4551	0.9336	0.0005	0.9346	0.9370
0.18	0.4449	48	6.7792	0.9341	0.0005	0.9351	0.9370
0.18	0.4541	50	7.1033	0.9327	0.0005	0.9337	0.9369
0.22	0.5087	42	5.8068	0.9346	0.0005	0.9356	0.9370
0.22	0.5206	44	6.1309	0.9351	0.0005	0.9361	0.9370
0.22	0.5323	46	6.4551	0.9352	0.0005	0.9362	0.9370
0.22	0.5438	48	6.7792	0.9328	0.0005	0.9338	0.9370
0.22	0.5550	50	7.1033	0.9322	0.0005	0.9332	0.9369
0.26	0.5867	40	5.4827	0.9336	0.0005	0.9346	0.9370
0.26	**0.6012**	**42**	**5.8068**	**0.9356**	**0.0005**	**0.9366**	**0.9370**
0.26	0.6153	44	6.1309	0.9354	0.0005	0.9364	0.9370
0.26	0.6291	46	6.4551	0.9332	0.0005	0.9342	0.9370
0.26	0.6427	48	6.7792	0.9326	0.0005	0.9336	0.9370
0.26	0.6559	50	7.1033	0.9315	0.0005	0.9325	0.9369
0.3	0.6769	40	5.4827	0.9335	0.0005	0.9345	0.9370
0.3	0.6936	42	5.8068	0.9351	0.0005	0.9361	0.9370
0.3	0.7100	44	6.1309	0.9339	0.0005	0.9349	0.9370
0.3	0.7259	46	6.4551	0.9333	0.0005	0.9343	0.9370
0.3	0.7415	48	6.7792	0.9320	0.0005	0.9330	0.9370
0.3	0.7568	50	7.1033	0.9293	0.0005	0.9303	0.9369

Table 6-42. HAC, 6x6x6 Array, 247 kg UO_2, 4.45% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.1	0.2001	30	4.0982	0.9016	0.0005	0.9026	0.9370
0.1	0.2130	34	4.7780	0.9183	0.0005	0.9193	0.9370
0.1	0.2192	36	5.1178	0.9236	0.0005	0.9246	0.9370
0.1	0.2252	38	5.4577	0.9282	0.0006	0.9294	0.9370
0.1	0.2311	40	5.7976	0.9319	0.0005	0.9329	0.9370
0.1	0.2368	42	6.1375	0.9321	0.0006	0.9333	0.9370
0.1	0.2423	44	6.4774	0.9335	0.0005	0.9345	0.9370
0.1	0.2478	46	6.8172	0.9320	0.0005	0.9330	0.9370
0.1	0.2583	50	7.4970	0.9302	0.0005	0.9312	0.9365
0.14	0.2801	30	4.0982	0.9030	0.0005	0.9040	0.9370
0.14	0.2982	34	4.7780	0.9205	0.0006	0.9217	0.9370
0.14	0.3069	36	5.1178	0.9264	0.0005	0.9274	0.9370
0.14	0.3153	38	5.4577	0.9294	0.0006	0.9306	0.9370
0.14	0.3235	40	5.7976	0.9321	0.0005	0.9331	0.9370
0.14	0.3315	42	6.1375	0.9343	0.0004	0.9351	0.9370
0.14	0.3393	44	6.4774	0.9336	0.0005	0.9346	0.9370
0.14	0.3469	46	6.8172	0.9350	0.0005	0.9360	0.9370
0.14	0.3617	50	7.4970	0.9309	0.0005	0.9319	0.9365
0.18	0.3602	30	4.0982	0.9040	0.0005	0.9050	0.9370
0.18	0.3834	34	4.7780	0.9218	0.0005	0.9228	0.9370
0.18	0.3946	36	5.1178	0.9262	0.0005	0.9272	0.9370
0.18	0.4054	38	5.4577	0.9303	0.0005	0.9313	0.9370
0.18	0.4159	40	5.7976	0.9332	0.0005	0.9342	0.9370
0.18	0.4262	42	6.1375	0.9335	0.0005	0.9345	0.9370
0.18	**0.4362**	**44**	**6.4774**	**0.9359**	**0.0005**	**0.9369**	**0.9370**
0.18	0.4460	46	6.8172	0.9331	0.0005	0.9341	0.9370
0.18	0.4650	50	7.4970	0.9294	0.0005	0.9304	0.9365
0.22	0.4402	30	4.0982	0.9073	0.0006	0.9085	0.9370
0.22	0.4687	34	4.7780	0.9234	0.0005	0.9244	0.9370
0.22	0.4822	36	5.1178	0.9283	0.0005	0.9293	0.9370
0.22	0.4955	38	5.4577	0.9312	0.0006	0.9324	0.9370
0.22	0.5083	40	5.7976	0.9335	0.0005	0.9345	0.9370
0.22	0.5209	42	6.1375	0.9348	0.0005	0.9358	0.9370
0.22	0.5331	44	6.4774	0.9350	0.0004	0.9358	0.9370
0.22	0.5451	46	6.8172	0.9352	0.0005	0.9362	0.9370
0.22	0.5683	50	7.4970	0.9296	0.0005	0.9306	0.9365

(continued)

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.26	0.5203	30	4.0982	0.9078	0.0005	0.9088	0.9370
0.26	0.5539	34	4.7780	0.9228	0.0005	0.9238	0.9370
0.26	0.5699	36	5.1178	0.9283	0.0005	0.9293	0.9370
0.26	0.5855	38	5.4577	0.9330	0.0005	0.9340	0.9370
0.26	0.6008	40	5.7976	0.9340	0.0005	0.9350	0.9370
0.26	0.6156	42	6.1375	0.9340	0.0005	0.9350	0.9370
0.26	0.6301	44	6.4774	0.9339	0.0005	0.9349	0.9370
0.26	0.6442	46	6.8172	0.9335	0.0005	0.9345	0.9370
0.26	0.6717	50	7.4970	0.9288	0.0005	0.9298	0.9365
0.3	0.6003	30	4.0982	0.9097	0.0005	0.9107	0.9370
0.3	0.6391	34	4.7780	0.9231	0.0005	0.9241	0.9370
0.3	0.6576	36	5.1178	0.9295	0.0005	0.9305	0.9370
0.3	0.6756	38	5.4577	0.9316	0.0005	0.9326	0.9370
0.3	0.6932	40	5.7976	0.9326	0.0005	0.9336	0.9370
0.3	0.7103	42	6.1375	0.9341	0.0005	0.9351	0.9370
0.3	0.7270	44	6.4774	0.9333	0.0005	0.9343	0.9370
0.3	0.7433	46	6.8172	0.9320	0.0005	0.9330	0.9370
0.3	0.7750	50	7.4970	0.9276	0.0006	0.9288	0.9365
0.34	0.6803	30	4.0982	0.9075	0.0006	0.9087	0.9370
0.34	0.7243	34	4.7780	0.9246	0.0005	0.9256	0.9370
0.34	0.7453	36	5.1178	0.9285	0.0004	0.9293	0.9370
0.34	0.7657	38	5.4577	0.9320	0.0005	0.9330	0.9370
0.34	0.7856	40	5.7976	0.9335	0.0005	0.9345	0.9370
0.34	0.8050	42	6.1375	0.9329	0.0005	0.9339	0.9370
0.34	0.8239	44	6.4774	0.9319	0.0005	0.9329	0.9370
0.34	0.8425	46	6.8172	0.9307	0.0005	0.9317	0.9370
0.34	0.8783	50	7.4970	0.9242	0.0004	0.9250	0.9365

Table 6-43. HAC, 6x6x6 Array, 238 kg UO$_2$, 4.55% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.1	0.2039	30	4.2910	0.9049	0.0005	0.9059	0.9370
0.1	0.2170	34	4.9965	0.9202	0.0005	0.9212	0.9370
0.1	0.2233	36	5.3492	0.9249	0.0005	0.9259	0.9370
0.1	0.2294	38	5.7019	0.9302	0.0005	0.9312	0.9370
0.1	0.2354	40	6.0547	0.9330	0.0005	0.9340	0.9370
0.1	0.2412	42	6.4074	0.9329	0.0005	0.9339	0.9370
0.1	0.2469	44	6.7601	0.9334	0.0006	0.9346	0.9370
0.1	0.2524	46	7.1129	0.9341	0.0005	0.9351	0.9369
0.1	0.2632	50	7.8183	0.9305	0.0005	0.9315	0.9361
0.14	0.2854	30	4.2910	0.9072	0.0005	0.9082	0.9370
0.14	0.3038	34	4.9965	0.9231	0.0005	0.9241	0.9370
0.14	0.3126	36	5.3492	0.9274	0.0005	0.9284	0.9370
0.14	0.3212	38	5.7019	0.9320	0.0005	0.9330	0.9370
0.14	0.3295	40	6.0547	0.9335	0.0005	0.9345	0.9370
0.14	0.3377	42	6.4074	0.9354	0.0005	0.9364	0.9370
0.14	0.3456	44	6.7601	0.9348	0.0005	0.9358	0.9370
0.14	0.3534	46	7.1129	0.9352	0.0005	0.9362	0.9369
0.14	0.3684	50	7.8183	0.9309	0.0005	0.9319	0.9361
0.18	0.3669	30	4.2910	0.9092	0.0004	0.9100	0.9370
0.18	0.3906	34	4.9965	0.9239	0.0005	0.9249	0.9370
0.18	0.4020	36	5.3492	0.9295	0.0005	0.9305	0.9370
0.18	0.4130	38	5.7019	0.9314	0.0005	0.9324	0.9370
0.18	0.4237	40	6.0547	0.9330	0.0005	0.9340	0.9370
0.18	0.4342	42	6.4074	0.9355	0.0005	0.9365	0.9370
0.18	0.4444	44	6.7601	0.9348	0.0005	0.9358	0.9370
0.18	0.4544	46	7.1129	0.9335	0.0005	0.9345	0.9369
0.18	0.4737	50	7.8183	0.9307	0.0005	0.9317	0.9361
0.22	0.4485	30	4.2910	0.9095	0.0005	0.9105	0.9370
0.22	0.4774	34	4.9965	0.9245	0.0005	0.9255	0.9370
0.22	0.4913	36	5.3492	0.9305	0.0005	0.9315	0.9370
0.22	0.5047	38	5.7019	0.9331	0.0005	0.9341	0.9370
0.22	0.5179	40	6.0547	0.9354	0.0005	0.9364	0.9370
0.22	**0.5306**	**42**	**6.4074**	**0.9358**	**0.0005**	**0.9368**	**0.9370**
0.22	0.5431	44	6.7601	0.9343	0.0005	0.9353	0.9370
0.22	0.5553	46	7.1129	0.9343	0.0005	0.9353	0.9369
0.22	0.5790	50	7.8183	0.9297	0.0005	0.9307	0.9361

(continued)

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.26	0.5300	30	4.2910	0.9120	0.0005	0.9130	0.9370
0.26	0.5642	34	4.9965	0.9253	0.0005	0.9263	0.9370
0.26	0.5806	36	5.3492	0.9311	0.0006	0.9323	0.9370
0.26	0.5965	38	5.7019	0.9326	0.0005	0.9336	0.9370
0.26	0.6120	40	6.0547	0.9349	0.0006	0.9361	0.9370
0.26	0.6271	42	6.4074	0.9350	0.0005	0.9360	0.9370
0.26	0.6419	44	6.7601	0.9351	0.0005	0.9361	0.9370
0.26	0.6563	46	7.1129	0.9338	0.0005	0.9348	0.9369
0.26	0.6842	50	7.8183	0.9280	0.0005	0.9290	0.9361

Table 6-44. HAC, 6x6x6 Array, 228 kg UO_2, 4.65% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.1	0.2217	34	5.2595	0.9229	0.0006	0.9241	0.9370
0.1	0.2282	36	5.6277	0.9277	0.0005	0.9287	0.9370
0.1	0.2344	38	5.9959	0.9330	0.0005	0.9340	0.9370
0.1	0.2405	40	6.3641	0.9337	0.0005	0.9347	0.9370
0.1	0.2464	42	6.7323	0.9345	0.0005	0.9355	0.9370
0.1	0.2522	44	7.1005	0.9337	0.0005	0.9347	0.9369
0.1	0.2579	46	7.4687	0.9328	0.0005	0.9338	0.9365
0.1	0.2689	50	8.2051	0.9296	0.0005	0.9306	0.9357
0.14	0.3104	34	5.2595	0.9248	0.0005	0.9258	0.9370
0.14	0.3194	36	5.6277	0.9292	0.0005	0.9302	0.9370
0.14	0.3282	38	5.9959	0.9327	0.0005	0.9337	0.9370
0.14	0.3367	40	6.3641	0.9342	0.0005	0.9352	0.9370
0.14	0.3450	42	6.7323	0.9349	0.0005	0.9359	0.9370
0.14	0.3531	44	7.1005	0.9351	0.0005	0.9361	0.9369
0.14	0.3611	46	7.4687	0.9330	0.0006	0.9342	0.9365
0.14	0.3764	50	8.2051	0.9288	0.0005	0.9298	0.9357
0.18	0.3991	34	5.2595	0.9270	0.0005	0.9280	0.9370
0.18	0.4107	36	5.6277	0.9318	0.0005	0.9328	0.9370
0.18	0.4219	38	5.9959	0.9337	0.0005	0.9347	0.9370
0.18	0.4329	40	6.3641	0.9344	0.0005	0.9354	0.9370
0.18	0.4436	42	6.7323	0.9350	0.0005	0.9360	0.9370
0.18	**0.4540**	**44**	**7.1005**	**0.9353**	**0.0006**	**0.9365**	**0.9369**
0.18	0.4642	46	7.4687	0.9339	0.0004	0.9347	0.9365
0.18	0.4840	50	8.2051	0.9282	0.0005	0.9292	0.9357
0.22	0.4878	34	5.2595	0.9274	0.0005	0.9284	0.9370
0.22	0.5019	36	5.6277	0.9296	0.0005	0.9306	0.9370
0.22	0.5157	38	5.9959	0.9335	0.0006	0.9347	0.9370
0.22	0.5291	40	6.3641	0.9336	0.0005	0.9346	0.9370
0.22	0.5422	42	6.7323	0.9349	0.0005	0.9359	0.9370
0.22	0.5549	44	7.1005	0.9349	0.0005	0.9359	0.9369
0.22	0.5674	46	7.4687	0.9322	0.0005	0.9332	0.9365
0.22	0.5915	50	8.2051	0.9279	0.0005	0.9289	0.9357
0.26	0.5765	34	5.2595	0.9278	0.0005	0.9288	0.9370
0.26	0.5932	36	5.6277	0.9317	0.0005	0.9327	0.9370
0.26	0.6095	38	5.9959	0.9332	0.0005	0.9342	0.9370
0.26	0.6253	40	6.3641	0.9346	0.0005	0.9356	0.9370
0.26	0.6407	42	6.7323	0.9346	0.0005	0.9356	0.9370
0.26	0.6558	44	7.1005	0.9335	0.0005	0.9345	0.9369
0.26	0.6705	46	7.4687	0.9326	0.0005	0.9336	0.9365
0.26	0.6991	50	8.2051	0.9272	0.0004	0.9280	0.9357

(continued)

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.3	0.6652	34	5.2595	0.9270	0.0006	0.9282	0.9370
0.3	0.6845	36	5.6277	0.9316	0.0005	0.9326	0.9370
0.3	0.7032	38	5.9959	0.9335	0.0006	0.9347	0.9370
0.3	0.7215	40	6.3641	0.9345	0.0006	0.9357	0.9370
0.3	0.7393	42	6.7323	0.9339	0.0005	0.9349	0.9370
0.3	0.7567	44	7.1005	0.9318	0.0005	0.9328	0.9369
0.3	0.7737	46	7.4687	0.9306	0.0005	0.9316	0.9365
0.3	0.8066	50	8.2051	0.9245	0.0005	0.9255	0.9357

Table 6-45. HAC, 6x6x6 Array, 219 kg UO_2, 4.75% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.06	0.1275	30	4.7500	0.9084	0.0006	0.9096	0.9370
0.06	0.1357	34	5.5167	0.9230	0.0005	0.9240	0.9370
0.06	0.1397	36	5.9000	0.9285	0.0005	0.9295	0.9370
0.06	0.1435	38	6.2834	0.9302	0.0005	0.9312	0.9370
0.06	0.1472	40	6.6667	0.9336	0.0006	0.9348	0.9370
0.06	0.1509	42	7.0500	0.9336	0.0005	0.9346	0.9370
0.06	0.1544	44	7.4334	0.9336	0.0005	0.9346	0.9365
0.06	0.1579	46	7.8167	0.9320	0.0005	0.9330	0.9361
0.06	0.1646	50	8.5834	0.9289	0.0005	0.9299	0.9353
0.1	0.2125	30	4.7500	0.9106	0.0005	0.9116	0.9370
0.1	0.2262	34	5.5167	0.9242	0.0005	0.9252	0.9370
0.1	0.2328	36	5.9000	0.9298	0.0005	0.9308	0.9370
0.1	0.2392	38	6.2834	0.9323	0.0005	0.9333	0.9370
0.1	0.2454	40	6.6667	0.9347	0.0006	0.9359	0.9370
0.1	0.2514	42	7.0500	0.9335	0.0006	0.9347	0.9370
0.1	0.2574	44	7.4334	0.9339	0.0006	0.9351	0.9365
0.1	0.2631	46	7.8167	0.9331	0.0005	0.9341	0.9361
0.1	0.2743	50	8.5834	0.9298	0.0005	0.9308	0.9353
0.14	0.2975	30	4.7500	0.9114	0.0005	0.9124	0.9370
0.14	0.3167	34	5.5167	0.9274	0.0005	0.9284	0.9370
0.14	0.3259	36	5.9000	0.9303	0.0005	0.9313	0.9370
0.14	0.3348	38	6.2834	0.9332	0.0005	0.9342	0.9370
0.14	0.3435	40	6.6667	0.9342	0.0005	0.9352	0.9370
0.14	**0.3520**	**42**	**7.0500**	**0.9356**	**0.0005**	**0.9366**	**0.9370**
0.14	0.3603	44	7.4334	0.9346	0.0005	0.9356	0.9365
0.14	0.3684	46	7.8167	0.9334	0.0005	0.9344	0.9361
0.14	0.3841	50	8.5834	0.9293	0.0005	0.9303	0.9353
0.18	0.3825	30	4.7500	0.9143	0.0005	0.9153	0.9370
0.18	0.4072	34	5.5167	0.9280	0.0006	0.9292	0.9370
0.18	0.4190	36	5.9000	0.9323	0.0005	0.9333	0.9370
0.18	0.4305	38	6.2834	0.9338	0.0005	0.9348	0.9370
0.18	0.4417	40	6.6667	0.9348	0.0005	0.9358	0.9370
0.18	0.4526	42	7.0500	0.9354	0.0005	0.9364	0.9370
0.18	0.4633	44	7.4334	0.9347	0.0006	0.9359	0.9365
0.18	0.4737	46	7.8167	0.9332	0.0005	0.9342	0.9361
0.18	0.4938	50	8.5834	0.9285	0.0005	0.9295	0.9353

(continued)

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.22	0.4675	30	4.7500	0.9146	0.0006	0.9158	0.9370
0.22	0.4977	34	5.5167	0.9287	0.0005	0.9297	0.9370
0.22	0.5121	36	5.9000	0.9318	0.0005	0.9328	0.9370
0.22	0.5262	38	6.2834	0.9343	0.0005	0.9353	0.9370
0.22	0.5398	40	6.6667	0.9354	0.0005	0.9364	0.9370
0.22	0.5532	42	7.0500	0.9349	0.0005	0.9359	0.9370
0.22	0.5662	44	7.4334	0.9331	0.0004	0.9339	0.9365
0.22	0.5789	46	7.8167	0.9324	0.0004	0.9332	0.9361
0.22	0.6036	50	8.5834	0.9251	0.0005	0.9261	0.9353
0.26	0.5525	30	4.7500	0.9156	0.0005	0.9166	0.9370
0.26	0.5882	34	5.5167	0.9289	0.0005	0.9299	0.9370
0.26	0.6053	36	5.9000	0.9328	0.0005	0.9338	0.9370
0.26	0.6218	38	6.2834	0.9338	0.0006	0.9350	0.9370
0.26	0.6380	40	6.6667	0.9334	0.0005	0.9344	0.9370
0.26	0.6538	42	7.0500	0.9341	0.0006	0.9353	0.9370
0.26	0.6691	44	7.4334	0.9330	0.0005	0.9340	0.9365
0.26	0.6842	46	7.8167	0.9313	0.0005	0.9323	0.9361
0.26	0.7133	50	8.5834	0.9236	0.0005	0.9246	0.9353

Table 6-46. HAC, 6x6x6 Array, 208 kg UO$_2$, 4.85% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.06	0.1308	30	5.0541	0.9101	0.0006	0.9113	0.9370
0.06	0.1393	34	5.8613	0.9247	0.0006	0.9259	0.9370
0.06	0.1433	36	6.2649	0.9292	0.0005	0.9302	0.9370
0.06	0.1472	38	6.6685	0.9309	0.0005	0.9319	0.9370
0.06	0.1511	40	7.0722	0.9316	0.0006	0.9328	0.9369
0.06	0.1548	42	7.4758	0.9316	0.0005	0.9326	0.9365
0.06	0.1584	44	7.8794	0.9319	0.0005	0.9329	0.9360
0.06	0.1620	46	8.2830	0.9301	0.0005	0.9311	0.9356
0.06	0.1689	50	9.0902	0.9250	0.0004	0.9258	0.9347
0.1	0.2181	30	5.0541	0.9119	0.0005	0.9129	0.9370
0.1	0.2321	34	5.8613	0.9255	0.0005	0.9265	0.9370
0.1	0.2389	36	6.2649	0.9295	0.0005	0.9305	0.9370
0.1	0.2454	38	6.6685	0.9323	0.0005	0.9333	0.9370
0.1	0.2518	40	7.0722	0.9329	0.0006	0.9341	0.9369
0.1	0.2580	42	7.4758	0.9333	0.0005	0.9343	0.9365
0.1	0.2641	44	7.8794	0.9326	0.0005	0.9336	0.9360
0.1	0.2700	46	8.2830	0.9308	0.0004	0.9316	0.9356
0.1	0.2815	50	9.0902	0.9250	0.0004	0.9258	0.9347
0.14	0.3053	30	5.0541	0.9138	0.0005	0.9148	0.9370
0.14	0.3250	34	5.8613	0.9276	0.0005	0.9286	0.9370
0.14	0.3344	36	6.2649	0.9304	0.0005	0.9314	0.9370
0.14	0.3436	38	6.6685	0.9319	0.0005	0.9329	0.9370
0.14	0.3525	40	7.0722	0.9347	0.0005	0.9357	0.9369
0.14	0.3612	42	7.4758	0.9339	0.0004	0.9347	0.9365
0.14	0.3697	44	7.8794	0.9321	0.0005	0.9331	0.9360
0.14	0.3780	46	8.2830	0.9305	0.0005	0.9315	0.9356
0.14	0.3941	50	9.0902	0.9250	0.0005	0.9260	0.9347
0.18	0.3925	30	5.0541	0.9156	0.0005	0.9166	0.9370
0.18	0.4179	34	5.8613	0.9283	0.0005	0.9293	0.9370
0.18	0.4300	36	6.2649	0.9313	0.0005	0.9323	0.9370
0.18	0.4417	38	6.6685	0.9327	0.0005	0.9337	0.9370
0.18	0.4475	39	6.8703	0.9326	0.0005	0.9336	0.9370
0.18	**0.4532**	**40**	**7.0722**	**0.9353**	**0.0004**	**0.9361**	**0.9369**
0.18	0.4589	41	7.2740	0.9337	0.0005	0.9347	0.9367
0.18	0.4644	42	7.4758	0.9336	0.0005	0.9346	0.9365
0.18	0.4753	44	7.8794	0.9320	0.0005	0.9330	0.9360
0.18	0.4860	46	8.2830	0.9294	0.0005	0.9304	0.9356
0.18	0.5067	50	9.0902	0.9237	0.0005	0.9247	0.9347

(continued)

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.22	0.4797	30	5.0541	0.9167	0.0005	0.9177	0.9370
0.22	0.5107	34	5.8613	0.9292	0.0005	0.9302	0.9370
0.22	0.5255	36	6.2649	0.9314	0.0006	0.9326	0.9370
0.22	0.5399	38	6.6685	0.9331	0.0005	0.9341	0.9370
0.22	0.5539	40	7.0722	0.9332	0.0005	0.9342	0.9369
0.22	0.5676	42	7.4758	0.9323	0.0005	0.9333	0.9365
0.22	0.5810	44	7.8794	0.9302	0.0006	0.9314	0.9360
0.22	0.5940	46	8.2830	0.9279	0.0006	0.9291	0.9356
0.22	0.6193	50	9.0902	0.9218	0.0004	0.9226	0.9347
0.26	0.5669	30	5.0541	0.9173	0.0006	0.9185	0.9370
0.26	0.6036	34	5.8613	0.9279	0.0006	0.9291	0.9370
0.26	0.6211	36	6.2649	0.9304	0.0005	0.9314	0.9370
0.26	0.6381	38	6.6685	0.9313	0.0006	0.9325	0.9370
0.26	0.6547	40	7.0722	0.9321	0.0005	0.9331	0.9369
0.26	0.6708	42	7.4758	0.9314	0.0005	0.9324	0.9365
0.26	0.6866	44	7.8794	0.9299	0.0005	0.9309	0.9360
0.26	0.7020	46	8.2830	0.9265	0.0005	0.9275	0.9356
0.26	0.7319	50	9.0902	0.9191	0.0005	0.9201	0.9347

Table 6-47. HAC, 6x6x6 Array, 202 kg UO_2, 4.95% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.06	0.1328	30	5.2339	0.9131	0.0004	0.9139	0.9370
0.06	0.1413	34	6.0651	0.9270	0.0005	0.9280	0.9370
0.06	0.1454	36	6.4807	0.9291	0.0005	0.9301	0.9370
0.06	0.1494	38	6.8963	0.9326	0.0005	0.9336	0.9370
0.06	0.1533	40	7.3119	0.9337	0.0006	0.9349	0.9367
0.06	0.1571	42	7.7275	0.9327	0.0006	0.9339	0.9362
0.06	0.1608	44	8.1431	0.9322	0.0005	0.9332	0.9358
0.06	0.1644	46	8.5587	0.9310	0.0005	0.9320	0.9353
0.06	0.1714	50	9.3899	0.9265	0.0005	0.9275	0.9344
0.1	0.2213	30	5.2339	0.9155	0.0005	0.9165	0.9370
0.1	0.2356	34	6.0651	0.9282	0.0005	0.9292	0.9370
0.1	0.2424	36	6.4807	0.9307	0.0005	0.9317	0.9370
0.1	0.2490	38	6.8963	0.9341	0.0005	0.9351	0.9370
0.1	0.2555	40	7.3119	0.9343	0.0005	0.9353	0.9367
0.1	0.2618	42	7.7275	0.9350	0.0005	0.9360	0.9362
0.1	0.2680	44	8.1431	0.9330	0.0005	0.9340	0.9358
0.1	0.2740	46	8.5587	0.9302	0.0005	0.9312	0.9353
0.1	0.2857	50	9.3899	0.9252	0.0005	0.9262	0.9344
0.14	0.3098	30	5.2339	0.9167	0.0005	0.9177	0.9370
0.14	0.3298	34	6.0651	0.9289	0.0005	0.9299	0.9370
0.14	0.3393	36	6.4807	0.9322	0.0005	0.9332	0.9370
0.14	0.3486	38	6.8963	0.9328	0.0005	0.9338	0.9370
0.14	0.3577	40	7.3119	0.9350	0.0005	0.9360	0.9367
0.14	0.3665	42	7.7275	0.9349	0.0006	0.9361	0.9362
0.14	0.3752	44	8.1431	0.9332	0.0005	0.9342	0.9358
0.14	0.3836	46	8.5587	0.9296	0.0004	0.9304	0.9353
0.14	0.3999	50	9.3899	0.9259	0.0005	0.9269	0.9344
0.18	0.3983	30	5.2339	0.9180	0.0005	0.9190	0.9370
0.18	0.4240	34	6.0651	0.9297	0.0005	0.9307	0.9370
0.18	0.4363	36	6.4807	0.9335	0.0006	0.9347	0.9370
0.18	0.4483	38	6.8963	0.9341	0.0005	0.9351	0.9370
0.18	**0.4599**	**40**	**7.3119**	**0.9353**	**0.0005**	**0.9363**	**0.9367**
0.18	0.4713	42	7.7275	0.9342	0.0004	0.9350	0.9362
0.18	0.4824	44	8.1431	0.9326	0.0005	0.9336	0.9358
0.18	0.4932	46	8.5587	0.9300	0.0005	0.9310	0.9353
0.18	0.5142	50	9.3899	0.9232	0.0005	0.9242	0.9344

(continued)

Diameter, cm	**pitch, cm**	**Stack height, cm**	**W/F Ratio**	**keff**	**σ**	**keff+2σ**	**USL**
0.22	0.4868	30	5.2339	0.9181	0.0006	0.9193	0.9370
0.22	0.5182	34	6.0651	0.9306	0.0006	0.9318	0.9370
0.22	0.5333	36	6.4807	0.9332	0.0006	0.9344	0.9370
0.22	0.5479	38	6.8963	0.9350	0.0005	0.9360	0.9370
0.22	0.5621	40	7.3119	0.9341	0.0007	0.9355	0.9367
0.22	0.5760	42	7.7275	0.9341	0.0005	0.9351	0.9362
0.22	0.5895	44	8.1431	0.9312	0.0006	0.9324	0.9358
0.22	0.6028	46	8.5587	0.9288	0.0005	0.9298	0.9353
0.22	0.6285	50	9.3899	0.9221	0.0005	0.9231	0.9344
0.26	0.5753	30	5.2339	0.9200	0.0006	0.9212	0.9370
0.26	0.6125	34	6.0651	0.9302	0.0005	0.9312	0.9370
0.26	0.6302	36	6.4807	0.9320	0.0005	0.9330	0.9370
0.26	0.6475	38	6.8963	0.9335	0.0005	0.9345	0.9370
0.26	0.6643	40	7.3119	0.9342	0.0005	0.9352	0.9367
0.26	0.6807	42	7.7275	0.9312	0.0006	0.9324	0.9362
0.26	0.6967	44	8.1431	0.9287	0.0005	0.9297	0.9358
0.26	0.7124	46	8.5587	0.9267	0.0005	0.9277	0.9353
0.26	0.7427	50	9.3899	0.9190	0.0005	0.9200	0.9344

Table 6-48. HAC, 6x6x6 Array, 197 kg UO_2, 5.00% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.06	0.1344	30	5.3922	0.9134	0.0005	0.9144	0.9370
0.06	0.1431	34	6.2444	0.9252	0.0005	0.9262	0.9370
0.06	0.1473	36	6.6706	0.9297	0.0005	0.9307	0.9370
0.06	0.1513	38	7.0967	0.9322	0.0005	0.9332	0.9369
0.06	0.1552	40	7.5229	0.9335	0.0005	0.9345	0.9364
0.06	0.1591	42	7.9490	0.9316	0.0005	0.9326	0.9360
0.06	0.1628	44	8.3752	0.9310	0.0005	0.9320	0.9355
0.06	0.1665	46	8.8013	0.9299	0.0005	0.9309	0.9350
0.06	0.1736	50	9.6536	0.9244	0.0005	0.9254	0.9341
0.1	0.2241	30	5.3922	0.9151	0.0005	0.9161	0.9370
0.1	0.2385	34	6.2444	0.9280	0.0005	0.9290	0.9370
0.1	0.2454	36	6.6706	0.9310	0.0006	0.9322	0.9370
0.1	0.2522	38	7.0967	0.9333	0.0006	0.9345	0.9369
0.1	0.2587	40	7.5229	0.9339	0.0005	0.9349	0.9364
0.1	0.2651	42	7.9490	0.9328	0.0005	0.9338	0.9360
0.1	0.2714	44	8.3752	0.9322	0.0005	0.9332	0.9355
0.1	0.2775	46	8.8013	0.9300	0.0005	0.9310	0.9350
0.1	0.2893	50	9.6536	0.9247	0.0004	0.9255	0.9341
0.14	0.3137	30	5.3922	0.9173	0.0005	0.9183	0.9370
0.14	0.3339	34	6.2444	0.9306	0.0005	0.9316	0.9370
0.14	0.3436	36	6.6706	0.9316	0.0005	0.9326	0.9370
0.14	0.3530	38	7.0967	0.9337	0.0005	0.9347	0.9369
0.14	0.3622	40	7.5229	0.9331	0.0005	0.9341	0.9364
0.14	0.3712	42	7.9490	0.9329	0.0005	0.9339	0.9360
0.14	0.3799	44	8.3752	0.9316	0.0005	0.9326	0.9355
0.14	0.3884	46	8.8013	0.9301	0.0005	0.9311	0.9350
0.14	0.4050	50	9.6536	0.9236	0.0006	0.9248	0.9341
0.18	0.4033	30	5.3922	0.9186	0.0005	0.9196	0.9370
0.18	0.4294	34	6.2444	0.9291	0.0005	0.9301	0.9370
0.18	0.4418	36	6.6706	0.9325	0.0005	0.9335	0.9370
0.18	**0.4539**	**38**	**7.0967**	**0.9343**	**0.0006**	**0.9355**	**0.9369**
0.18	0.4657	40	7.5229	0.9339	0.0005	0.9349	0.9364
0.18	0.4772	42	7.9490	0.9334	0.0005	0.9344	0.9360
0.18	0.4884	44	8.3752	0.9306	0.0005	0.9316	0.9355
0.18	0.4994	46	8.8013	0.9282	0.0005	0.9292	0.9350
0.18	0.5207	50	9.6536	0.9219	0.0005	0.9229	0.9341

(continued)

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.22	0.4929	30	5.3922	0.9199	0.0006	0.9211	0.9370
0.22	0.5248	34	6.2444	0.9286	0.0005	0.9296	0.9370
0.22	0.5400	36	6.6706	0.9318	0.0006	0.9330	0.9370
0.22	0.5548	38	7.0967	0.9328	0.0005	0.9338	0.9369
0.22	0.5692	40	7.5229	0.9326	0.0005	0.9336	0.9364
0.22	0.5833	42	7.9490	0.9323	0.0005	0.9333	0.9360
0.22	0.5970	44	8.3752	0.9302	0.0005	0.9312	0.9355
0.22	0.6104	46	8.8013	0.9264	0.0005	0.9274	0.9350
0.22	0.6364	50	9.6536	0.9202	0.0005	0.9212	0.9341
0.26	0.5826	30	5.3922	0.9184	0.0005	0.9194	0.9370
0.26	0.6202	34	6.2444	0.9291	0.0005	0.9301	0.9370
0.26	0.6382	36	6.6706	0.9310	0.0005	0.9320	0.9370
0.26	0.6557	38	7.0967	0.9331	0.0005	0.9341	0.9370
0.26	0.6727	40	7.5229	0.9317	0.0006	0.9329	0.9364
0.26	0.6893	42	7.9490	0.9298	0.0006	0.9310	0.9360
0.26	0.7055	44	8.3752	0.9278	0.0005	0.9288	0.9355
0.26	0.7214	46	8.8013	0.9245	0.0005	0.9255	0.9350
0.26	0.7521	50	9.6536	0.9168	0.0005	0.9178	0.9341

Table 6-49. 197 kg Pellets, 5.00% Enriched, Modified Foam Composition

Fuel/Water Mixture Height, cm	Diameter, cm	W/F Ratio	k_{eff}	σ	$k_{eff}+2\sigma$	USL
30	0.18	5.3922	0.9174	0.0005	0.9184	0.9370
34	0.18	6.2444	0.9298	0.0006	0.9310	0.9370
36	0.18	6.6706	0.9312	0.0005	0.9322	0.9370
38	0.18	7.0967	0.9332	0.0004	0.9340	0.9369
40	0.18	7.5229	0.9337	0.0005	0.9347	0.9364
42	**0.18**	**7.9490**	**0.9342**	**0.0005**	**0.9352**	**0.9360**
44	0.18	8.3752	0.9315	0.0005	0.9325	0.9355
46	0.18	8.8013	0.9282	0.0006	0.9294	0.9350
50	0.18	9.6536	0.9214	0.0005	0.9224	0.9341

Table 6-50. 197 kg Pellets, 5.00% Enriched, Water in Charred Foam

Water Fraction in Charred Foam[3]	Diameter, cm	Fuel/Water Mixture Height, cm	W/F Ratio	k_{eff}	σ	$k_{eff}+2\sigma$	USL
0.0	**0.18**	**38**	**7.0967**	**0.9343**	**0.0006**	**0.9355**	**0.9369**
0.1	0.18	38	7.0967	0.9328	0.0005	0.9338	0.9369
0.2	0.18	38	7.0967	0.9313	0.0005	0.9323	0.9369
0.3	0.18	38	7.0967	0.9328	0.0005	0.9338	0.9369
0.4	0.18	38	7.0967	0.9310	0.0006	0.9322	0.9369
0.5	0.18	38	7.0967	0.9304	0.0006	0.9316	0.9369
0.6	0.18	38	7.0967	0.9291	0.0006	0.9303	0.9369
0.7	0.18	38	7.0967	0.9287	0.0005	0.9297	0.9369
0.8	0.18	38	7.0967	0.9278	0.0005	0.9288	0.9369
0.9	0.18	38	7.0967	0.9282	0.0005	0.9292	0.9369
1.0	0.18	38	7.0967	0.9277	0.0005	0.9287	0.9369

Table 6-51. 197 kg Pellets, 5.00% Enriched, Water in All Foam

Water Fraction in Foam[4]	Diameter, cm	Fuel/Water Mixture Height, cm	W/F Ratio	k_{eff}	σ	$k_{eff}+2\sigma$	USL
0.0	**0.18**	**38**	**7.0967**	**0.9343**	**0.0006**	**0.9355**	**0.9369**
0.1	0.18	38	7.0967	0.9296	0.0005	0.9306	0.9369
0.2	0.18	38	7.0967	0.9260	0.0005	0.9270	0.9369
0.3	0.18	38	7.0967	0.9255	0.0006	0.9267	0.9369
0.4	0.18	38	7.0967	0.9245	0.0005	0.9255	0.9369
0.5	0.18	38	7.0967	0.9242	0.0005	0.9252	0.9369
0.6	0.18	38	7.0967	0.9239	0.0005	0.9249	0.9369
0.7	0.18	38	7.0967	0.9231	0.0005	0.9241	0.9369
0.8	0.18	38	7.0967	0.9235	0.0005	0.9245	0.9369
0.9	0.18	38	7.0967	0.9229	0.0005	0.9239	0.9369
1.0	0.18	38	7.0967	0.9230	0.0005	0.9240	0.9369

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[3] The “water fraction in charred foam” is the density of water in the foam divided by the nominal density of water. Note that the carbon density in the foam is constant, i.e., water does not replace carbon.

[4] The “water fraction in foam” is the density of water in the foam divided by the nominal density of water. Note that the carbon density in the foam is constant, i.e., water does not replace carbon.

Table 6-52. 197 kg Pellets, 5.00% Enriched, Modified Aluminum Disk

Fuel/Water Mixture Height, cm	Diameter, cm	W/F Ratio	k_{eff}	σ	$k_{eff}+2\sigma$	USL
30	0.18	5.3922	0.9171	0.0005	0.9181	0.9370
34	0.18	6.2444	0.9289	0.0005	0.9299	0.9370
36	0.18	6.6706	0.9314	0.0005	0.9324	0.9370
38	**0.18**	**7.0967**	**0.9334**	**0.0005**	**0.9344**	**0.9369**
40	0.18	7.5229	0.9333	0.0005	0.9343	0.9364
42	0.18	7.9490	0.9326	0.0005	0.9336	0.9360
44	0.18	8.3752	0.9311	0.0005	0.9321	0.9355
46	0.18	8.8013	0.9285	0.0005	0.9295	0.9350
50	0.18	9.6536	0.9216	0.0005	0.9226	0.9341

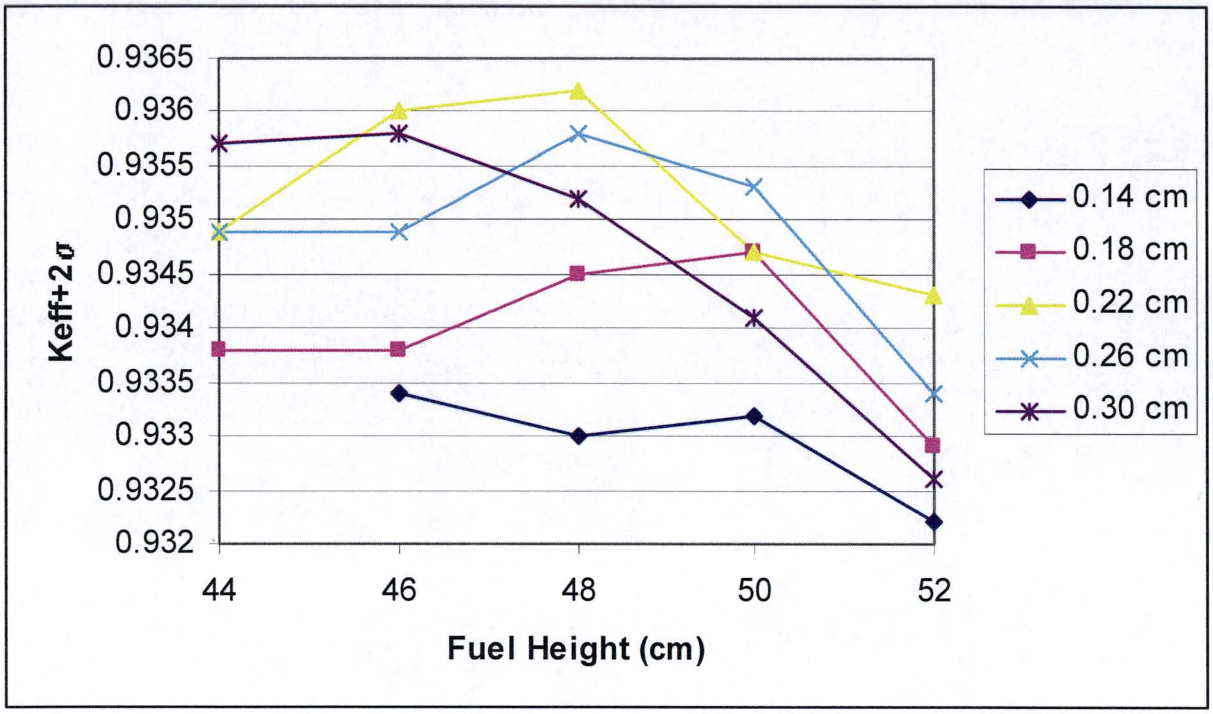

Figure 6-28. HAC, 6x6x6 Array, 4.05 wt.% Heterogeneous Material

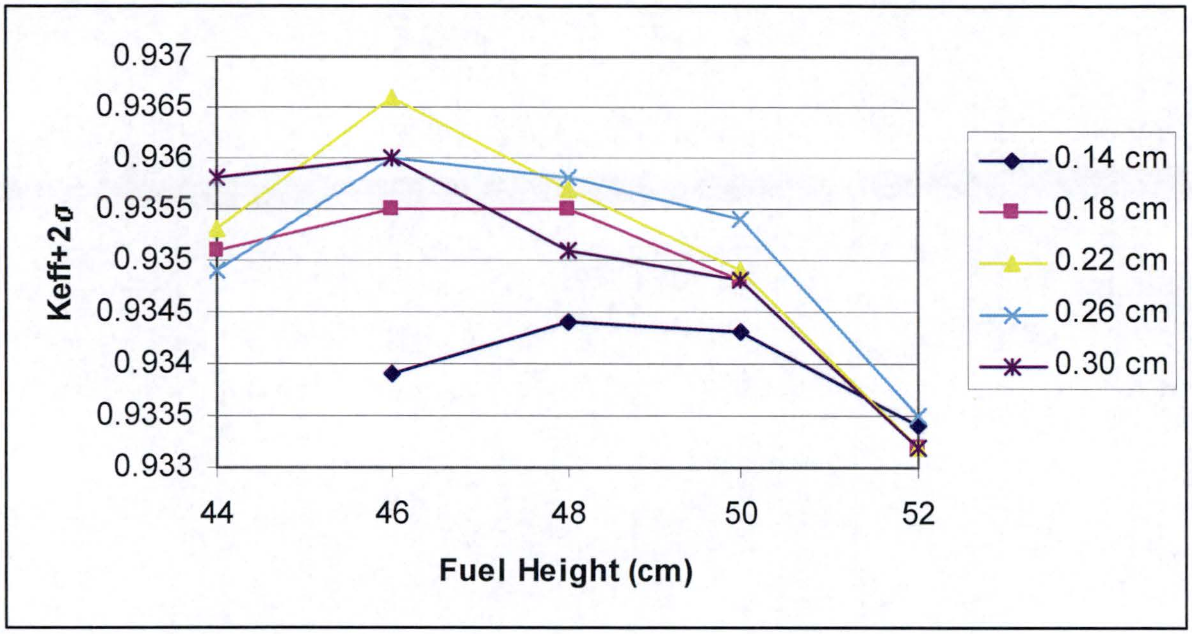

Figure 6-29. HAC, 6x6x6 Array, 4.10 wt.% Heterogeneous Material

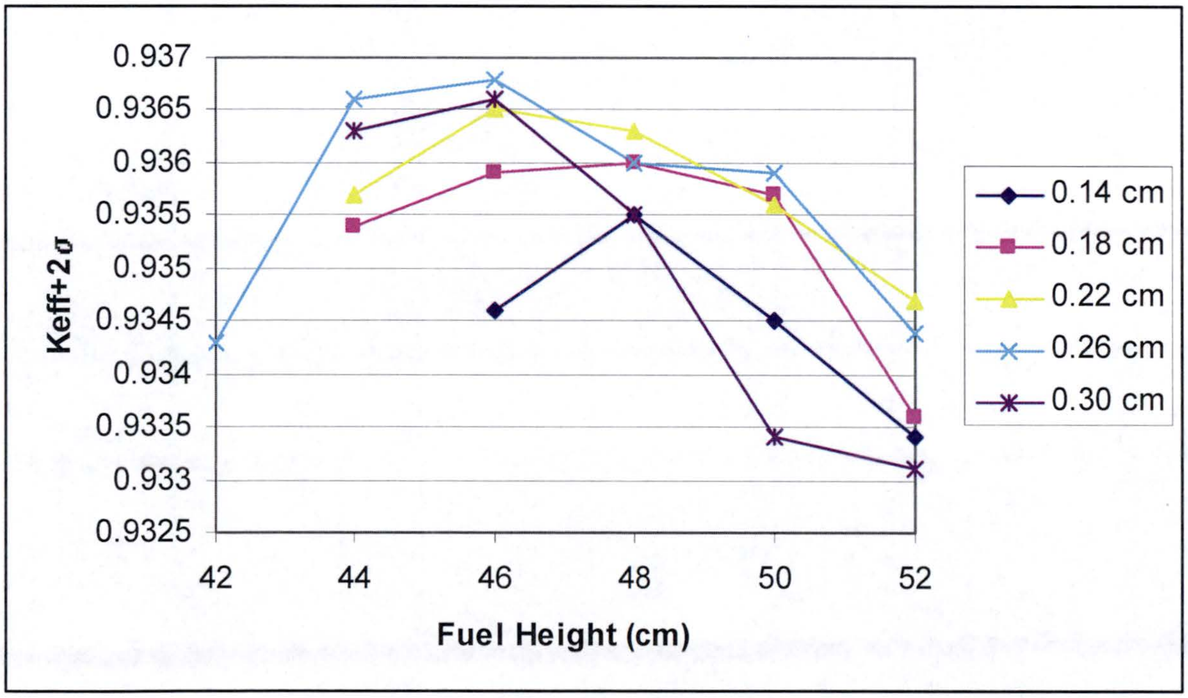

Figure 6-30. HAC, 6x6x6 Array, 4.15 wt.% Heterogeneous Material

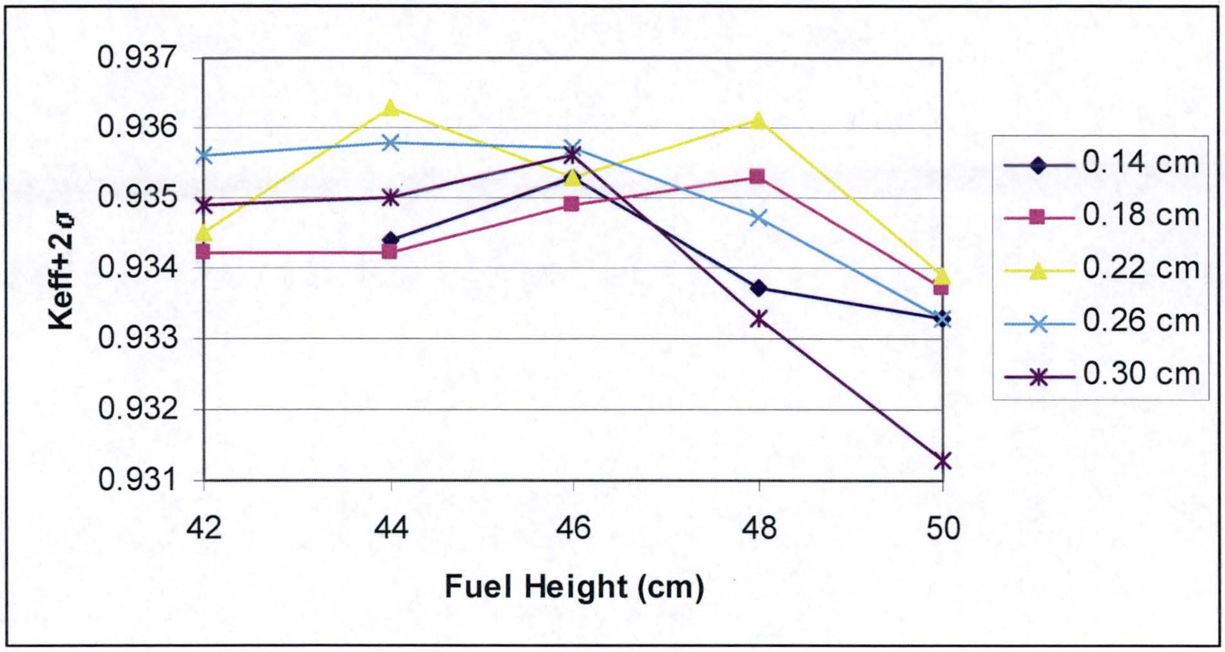

Figure 6-31. HAC, 6x6x6 Array, 4.25 wt.% Heterogeneous Material

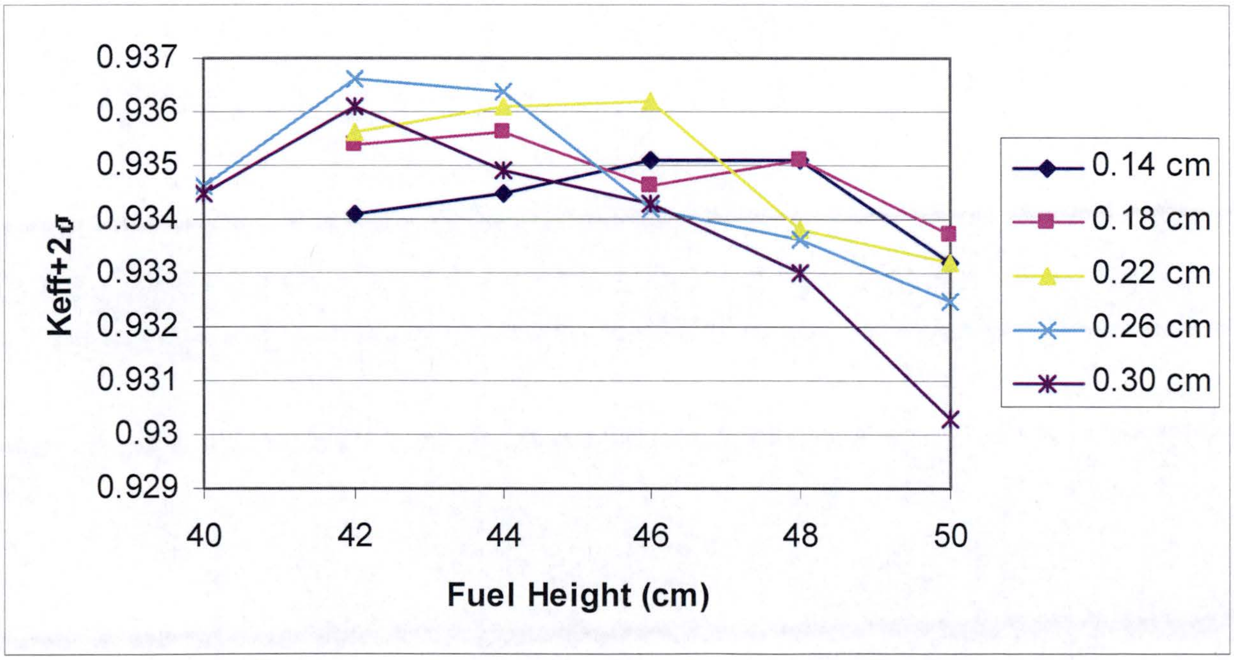

Figure 6-32. HAC, 6x6x6 Array, 4.35 wt.% Heterogeneous Material

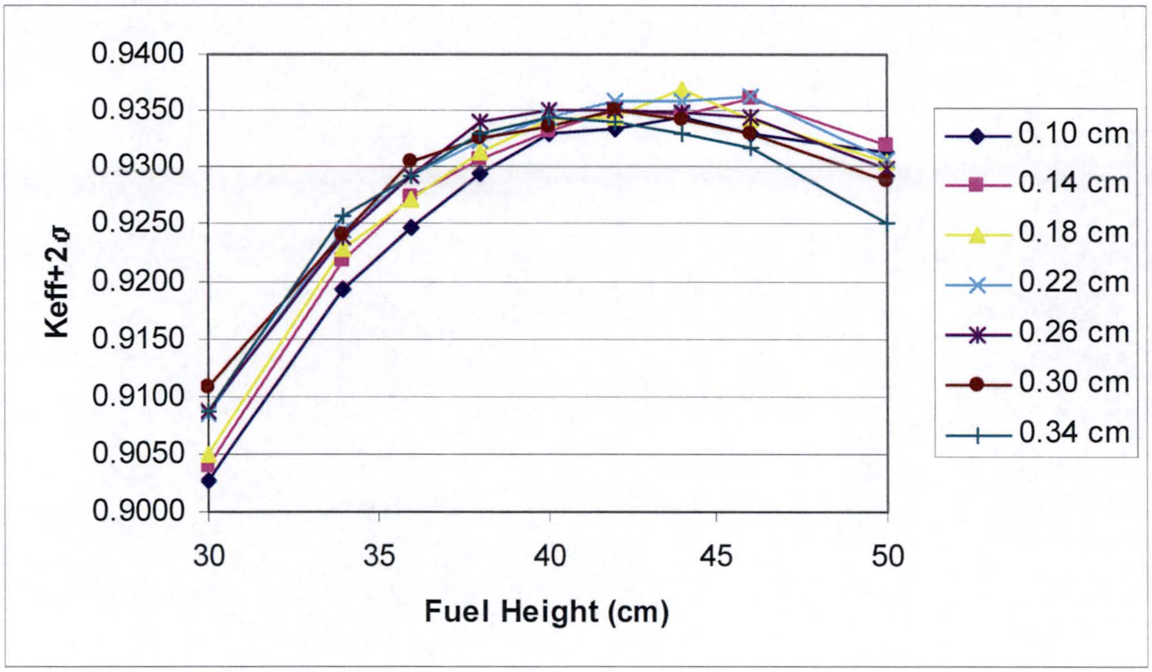

Figure 6-33. HAC, 6x6x6 Array, 4.45 wt.% Heterogeneous Material

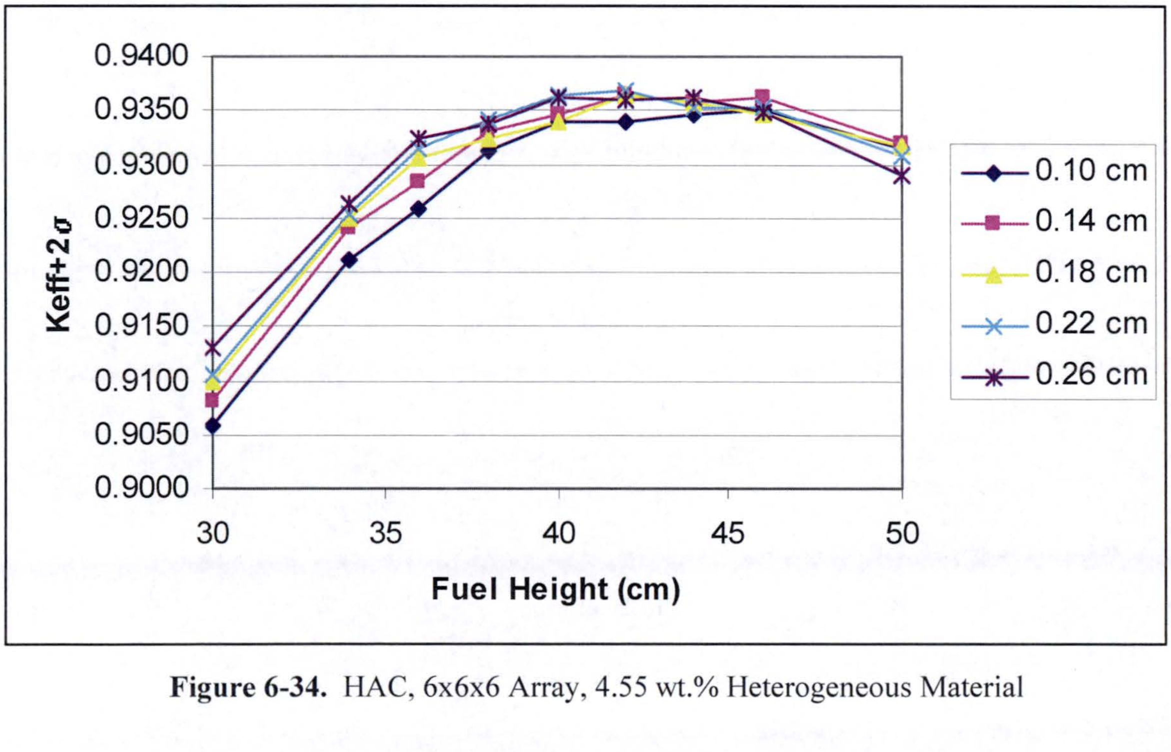

Figure 6-34. HAC, 6x6x6 Array, 4.55 wt.% Heterogeneous Material

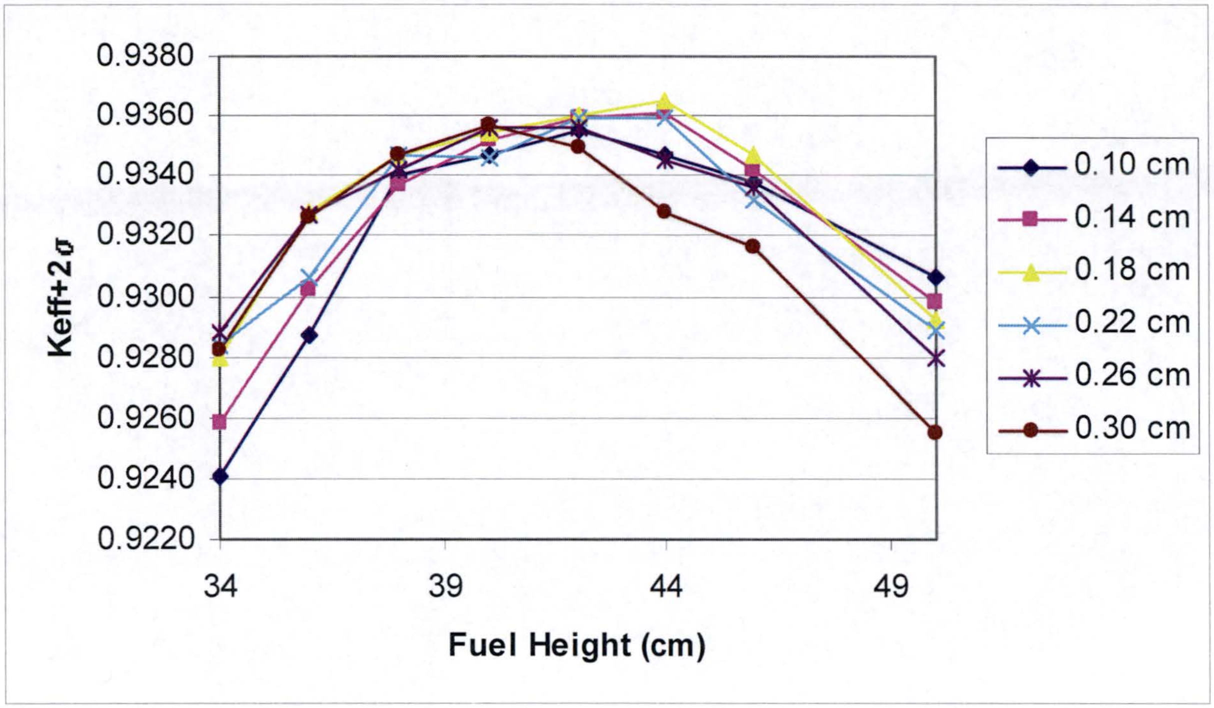

Figure 6-35. HAC, 6x6x6 Array, 4.65 wt.% Heterogeneous Material

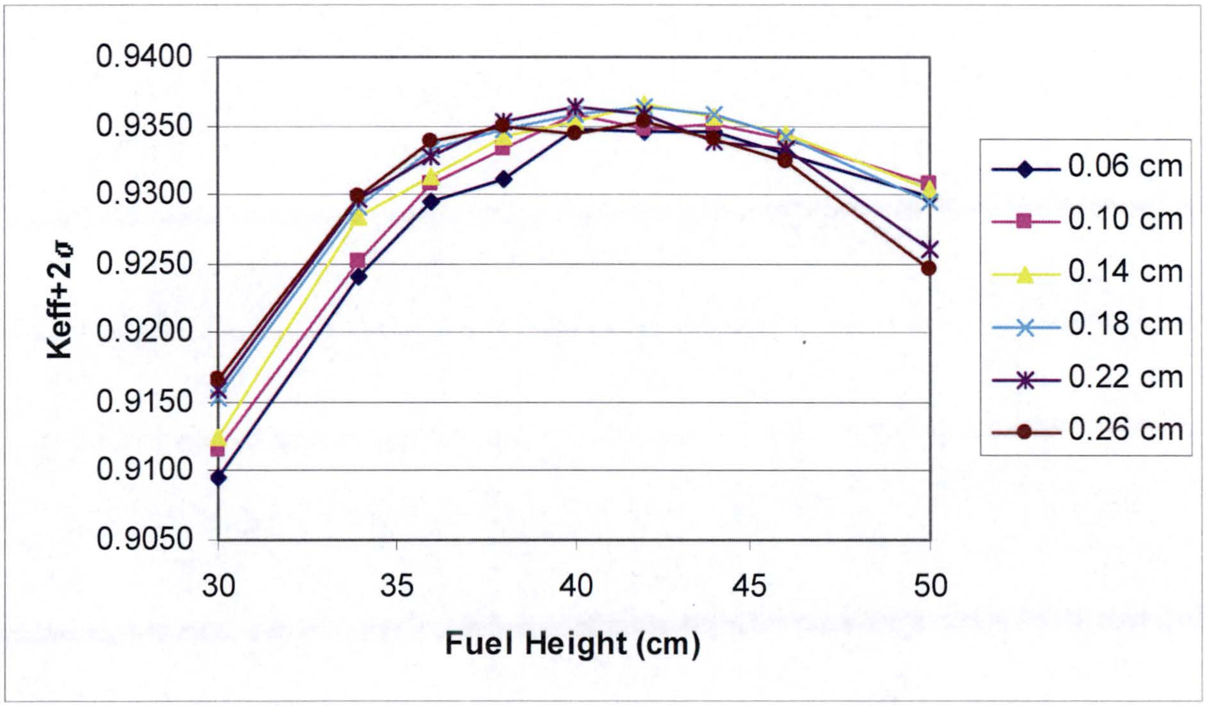

Figure 6-36. HAC, 6x6x6 Array, 4.75 wt.% Heterogeneous Material

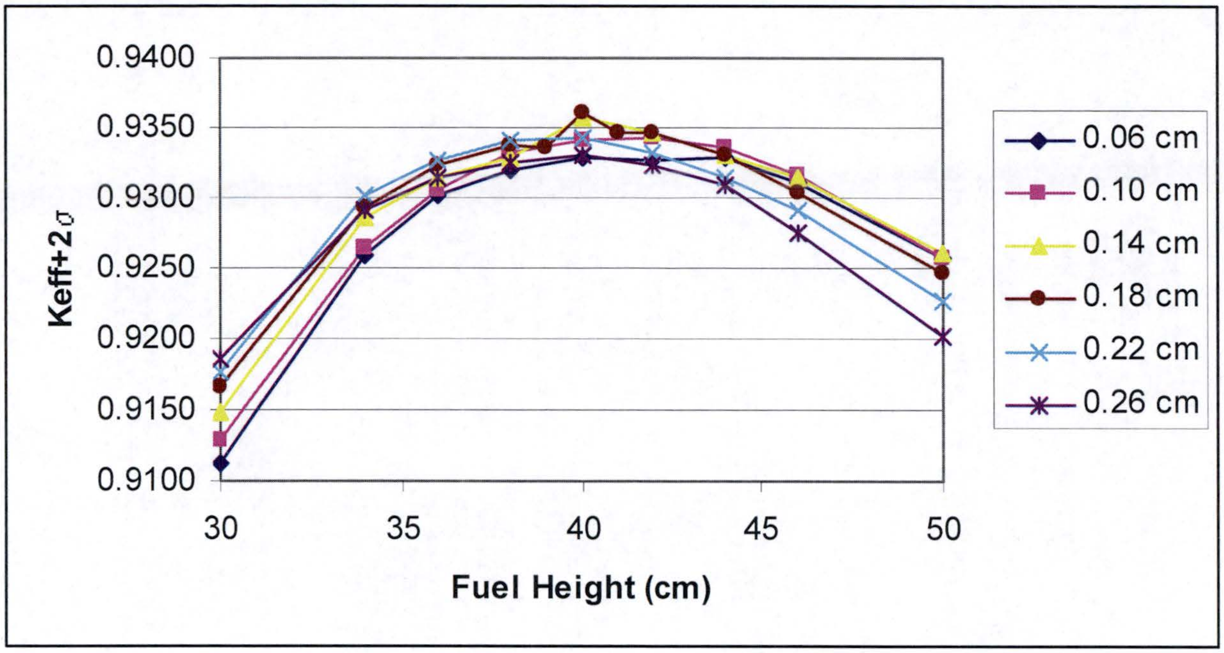

Figure 6-37. HAC, 6x6x6 Array, 4.85 wt.% Heterogeneous Material

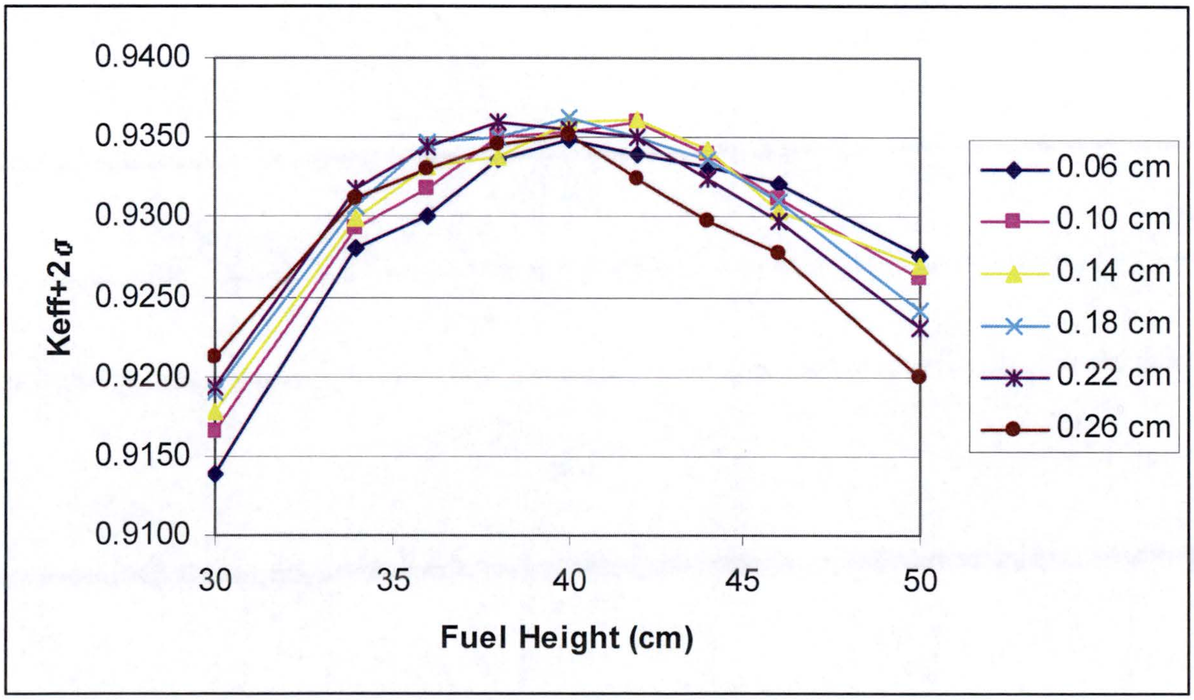

Figure 6-38. HAC, 6x6x6 Array, 4.95 wt.% Heterogeneous Material

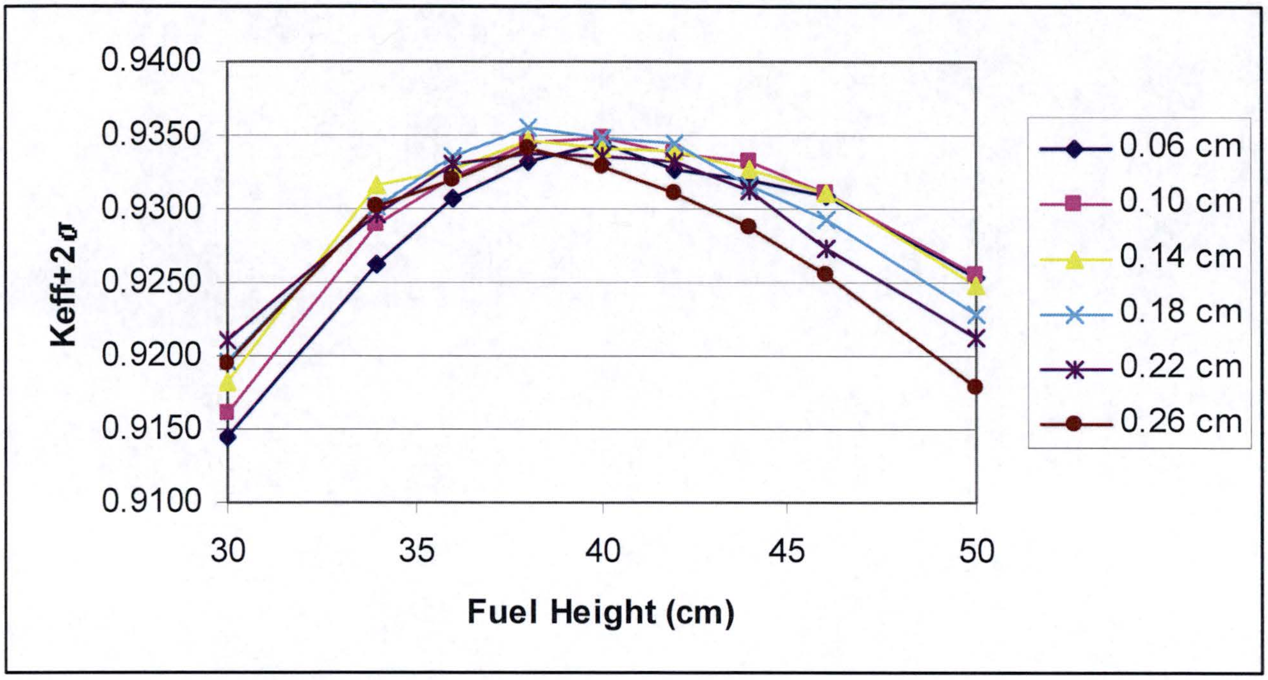

Figure 6-39. HAC, 6x6x6 Array, 5.00 wt.% Heterogeneous Material

Table 6-53. NOC, 8x9x8 Array, 300 kg UO_2, 4.05% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.34	0.5715	40	2.5978	0.8498	0.0005	0.8508	0.9370
0.34	0.5996	44	2.9603	0.8720	0.0005	0.8730	0.9370
0.34	0.6265	48	3.3229	0.8892	0.0004	0.8900	0.9370
0.34	0.6522	52	3.6854	0.9004	0.0005	0.9014	0.9370
0.34	0.6770	56	4.0479	0.9072	0.0005	0.9082	0.9370
0.34	0.7009	60	4.4104	0.9131	0.0005	0.9141	0.9370
0.34	0.7096	61.5	4.5463	0.9137	0.0006	0.9149	0.9370
0.38	0.6388	40	2.5978	0.8530	0.0005	0.8540	0.9370
0.38	0.6702	44	2.9603	0.8735	0.0005	0.8745	0.9370
0.38	0.7002	48	3.3229	0.8891	0.0005	0.8901	0.9370
0.38	0.7290	52	3.6854	0.9005	0.0005	0.9015	0.9370
0.38	0.7566	56	4.0479	0.9087	0.0005	0.9097	0.9370
0.38	0.7833	60	4.4104	0.9141	0.0005	0.9151	0.9370
0.38	0.7931	61.5	4.5463	0.9144	0.0004	0.9152	0.9370
0.42	0.7060	40	2.5978	0.8544	0.0005	0.8554	0.9370
0.42	0.7407	44	2.9603	0.8753	0.0005	0.8763	0.9370
0.42	0.7739	48	3.3229	0.8901	0.0005	0.8911	0.9370
0.42	0.8057	52	3.6854	0.9008	0.0006	0.9020	0.9370
0.42	0.8363	56	4.0479	0.9079	0.0005	0.9089	0.9370
0.42	0.8658	60	4.4104	0.9123	0.0006	0.9135	0.9370
0.42	0.8766	61.5	4.5463	0.9147	0.0005	0.9157	0.9370
0.46	0.7733	40	2.5978	0.8547	0.0005	0.8557	0.9370
0.46	0.8113	44	2.9603	0.8759	0.0004	0.8767	0.9370
0.46	0.8476	48	3.3229	0.8917	0.0005	0.8927	0.9370
0.46	0.8824	52	3.6854	0.9012	0.0005	0.9022	0.9370
0.46	0.9159	56	4.0479	0.9091	0.0005	0.9101	0.9370
0.46	0.9482	60	4.4104	0.9141	0.0005	0.9151	0.9370
0.46	**0.9601**	**61.5**	**4.5463**	**0.9151**	**0.0005**	**0.9161**	**0.9370**
0.5	0.8405	40	2.5978	0.8561	0.0005	0.8571	0.9370
0.5	0.8818	44	2.9603	0.8759	0.0006	0.8771	0.9370
0.5	0.9213	48	3.3229	0.8916	0.0005	0.8926	0.9370
0.5	0.9591	52	3.6854	0.9016	0.0006	0.9028	0.9370
0.5	0.9956	56	4.0479	0.9087	0.0005	0.9097	0.9370
0.5	1.0307	60	4.4104	0.9124	0.0005	0.9134	0.9370
0.5	1.0436	61.5	4.5463	0.915	0.0004	0.9158	0.9370

Table 6-54. NOC, 8x9x8 Array, 293 kg UO_2, 4.10% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.18	0.3062	40	2.6838	0.8454	0.0005	0.8464	0.9370
0.18	0.3212	44	3.0550	0.8668	0.0005	0.8678	0.9370
0.18	0.3356	48	3.4261	0.884	0.0005	0.8850	0.9370
0.18	0.3494	52	3.7973	0.8956	0.0005	0.8966	0.9370
0.18	0.3627	56	4.1685	0.9036	0.0005	0.9046	0.9370
0.18	0.3755	60	4.5396	0.9103	0.0005	0.9113	0.9370
0.18	0.3801	61.5	4.6788	0.912	0.0006	0.9132	0.9370
0.22	0.3742	40	2.6838	0.8486	0.0005	0.8496	0.9370
0.22	0.3926	44	3.0550	0.8701	0.0005	0.8711	0.9370
0.22	0.4102	48	3.4261	0.8864	0.0005	0.8874	0.9370
0.22	0.4270	52	3.7973	0.8982	0.0006	0.8994	0.9370
0.22	0.4432	56	4.1685	0.9062	0.0005	0.9072	0.9370
0.22	0.4589	60	4.5396	0.9123	0.0005	0.9133	0.9370
0.22	0.4646	61.5	4.6788	0.9131	0.0005	0.9141	0.9370
0.26	0.4422	40	2.6838	0.8508	0.0004	0.8516	0.9370
0.26	0.4640	44	3.0550	0.8725	0.0005	0.8735	0.9370
0.26	0.4848	48	3.4261	0.8872	0.0005	0.8882	0.9370
0.26	0.5047	52	3.7973	0.8991	0.0006	0.9003	0.9370
0.26	0.5238	56	4.1685	0.9074	0.0005	0.9084	0.9370
0.26	0.5423	60	4.5396	0.9122	0.0005	0.9132	0.9370
0.26	0.5491	61.5	4.6788	0.9136	0.0006	0.9148	0.9370
0.3	0.5103	40	2.6838	0.8524	0.0005	0.8534	0.9370
0.3	0.5354	44	3.0550	0.8743	0.0005	0.8753	0.9370
0.3	0.5593	48	3.4261	0.8901	0.0004	0.8909	0.9370
0.3	0.5823	52	3.7973	0.9009	0.0005	0.9019	0.9370
0.3	0.6044	56	4.1685	0.9086	0.0005	0.9096	0.9370
0.3	0.6258	60	4.5396	0.9139	0.0005	0.9149	0.9370
0.3	**0.6336**	**61.5**	**4.6788**	**0.9160**	**0.0005**	**0.9170**	**0.9370**
0.34	0.5783	40	2.6838	0.8544	0.0005	0.8554	0.9370
0.34	0.6068	44	3.0550	0.8755	0.0005	0.8765	0.9370
0.34	0.6339	48	3.4261	0.8912	0.0005	0.8922	0.9370
0.34	0.6600	52	3.7973	0.9013	0.0005	0.9023	0.9370
0.34	0.6850	56	4.1685	0.9098	0.0005	0.9108	0.9370
0.34	0.7092	60	4.5396	0.9131	0.0005	0.9141	0.9370
0.34	0.7180	61.5	4.6788	0.9151	0.0005	0.9161	0.9370

Table 6-55. NOC, 8x9x8 Array, 287 kg UO_2, 4.15% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.2406	40	2.7608	0.8474	0.0006	0.8486	0.9370
0.14	0.2524	44	3.1397	0.8684	0.0006	0.8696	0.9370
0.14	0.2637	48	3.5187	0.8852	0.0005	0.8862	0.9370
0.14	0.2746	52	3.8976	0.8954	0.0005	0.8964	0.9370
0.14	0.2850	56	4.2765	0.9051	0.0005	0.9061	0.9370
0.14	0.2951	60	4.6554	0.9108	0.0005	0.9118	0.9370
0.14	0.2987	61.5	4.7975	0.9121	0.0005	0.9131	0.9370
0.18	0.3094	40	2.7608	0.8488	0.0005	0.8498	0.9370
0.18	0.3246	44	3.1397	0.8705	0.0005	0.8715	0.9370
0.18	0.3391	48	3.5187	0.8863	0.0006	0.8875	0.9370
0.18	0.3530	52	3.8976	0.8987	0.0006	0.8999	0.9370
0.18	0.3664	56	4.2765	0.9065	0.0005	0.9075	0.9370
0.18	0.3794	60	4.6554	0.9120	0.0005	0.9130	0.9370
0.18	0.3841	61.5	4.7975	0.9138	0.0005	0.9148	0.9370
0.22	0.3781	40	2.7608	0.8525	0.0005	0.8535	0.9370
0.22	0.3967	44	3.1397	0.8744	0.0005	0.8754	0.9370
0.22	0.4145	48	3.5187	0.8892	0.0005	0.8902	0.9370
0.22	0.4315	52	3.8976	0.9011	0.0004	0.9019	0.9370
0.22	0.4479	56	4.2765	0.9089	0.0005	0.9099	0.9370
0.22	0.4637	60	4.6554	0.9130	0.0006	0.9142	0.9370
0.22	0.4694	61.5	4.7975	0.9154	0.0005	0.9164	0.9370
0.26	0.4468	40	2.7608	0.8541	0.0005	0.8551	0.9370
0.26	0.4688	44	3.1397	0.8754	0.0005	0.8764	0.9370
0.26	0.4898	48	3.5187	0.8914	0.0005	0.8924	0.9370
0.26	0.5099	52	3.8976	0.9021	0.0005	0.9031	0.9370
0.26	0.5293	56	4.2765	0.9095	0.0005	0.9105	0.9370
0.26	0.5480	60	4.6554	0.9147	0.0005	0.9157	0.9370
0.26	**0.5548**	**61.5**	**4.7975**	**0.9163**	**0.0005**	**0.9173**	**0.9370**
0.3	0.5156	40	2.7608	0.8552	0.0005	0.8562	0.9370
0.3	0.5409	44	3.1397	0.8776	0.0005	0.8786	0.9370
0.3	0.5652	48	3.5187	0.8925	0.0005	0.8935	0.9370
0.3	0.5884	52	3.8976	0.9042	0.0005	0.9052	0.9370
0.3	0.6107	56	4.2765	0.9105	0.0005	0.9115	0.9370
0.3	0.6323	60	4.6554	0.9160	0.0005	0.9170	0.9370
0.3	0.6402	61.5	4.7975	0.9160	0.0005	0.9170	0.9370

Table 6-56. NOC, 8x9x8 Array, 271 kg UO_2, 4.25% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.18	0.3184	40	2.9829	0.8578	0.0005	0.8588	0.9370
0.18	0.3340	44	3.3841	0.8773	0.0005	0.8783	0.9370
0.18	0.3490	48	3.7854	0.8938	0.0006	0.8950	0.9370
0.18	0.3633	52	4.1867	0.9027	0.0005	0.9037	0.9370
0.18	0.3771	56	4.5880	0.9101	0.0004	0.9109	0.9370
0.18	0.3904	60	4.9893	0.9156	0.0005	0.9166	0.9370
0.18	0.3953	61.5	5.1398	0.9147	0.0005	0.9157	0.9370
0.22	0.3891	40	2.9829	0.8611	0.0005	0.8621	0.9370
0.22	0.4082	44	3.3841	0.8807	0.0005	0.8817	0.9370
0.22	0.4265	48	3.7854	0.8946	0.0005	0.8956	0.9370
0.22	0.4440	52	4.1867	0.9047	0.0006	0.9059	0.9370
0.22	0.4609	56	4.5880	0.9120	0.0005	0.9130	0.9370
0.22	0.4772	60	4.9893	0.9160	0.0005	0.9170	0.9370
0.22	0.4831	61.5	5.1398	0.9166	0.0005	0.9176	0.9370
0.26	0.4598	40	2.9829	0.8624	0.0005	0.8634	0.9370
0.26	0.4825	44	3.3841	0.8823	0.0005	0.8833	0.9370
0.26	0.5041	48	3.7854	0.8968	0.0005	0.8978	0.9370
0.26	0.5248	52	4.1867	0.9067	0.0005	0.9077	0.9370
0.26	0.5447	56	4.5880	0.9131	0.0005	0.9141	0.9370
0.26	0.5639	60	4.9893	0.9165	0.0005	0.9175	0.9370
0.26	0.5709	61.5	5.1398	0.9169	0.0005	0.9179	0.9370
0.3	0.5306	40	2.9829	0.8649	0.0005	0.8659	0.9370
0.3	0.5567	44	3.3841	0.8837	0.0006	0.8849	0.9370
0.3	0.5816	48	3.7854	0.8975	0.0006	0.8987	0.9370
0.3	0.6055	52	4.1867	0.9075	0.0005	0.9085	0.9370
0.3	0.6285	56	4.5880	0.9137	0.0005	0.9147	0.9370
0.3	0.6507	60	4.9893	0.9163	0.0005	0.9173	0.9370
0.3	**0.6588**	**61.5**	**5.1398**	**0.9194**	**0.0005**	**0.9204**	**0.9370**
0.34	0.6013	40	2.9829	0.8657	0.0006	0.8669	0.9370
0.34	0.6309	44	3.3841	0.8850	0.0006	0.8862	0.9370
0.34	0.6592	48	3.7854	0.8983	0.0005	0.8993	0.9370
0.34	0.6862	52	4.1867	0.9071	0.0005	0.9081	0.9370
0.34	0.7123	56	4.5880	0.9134	0.0005	0.9144	0.9370
0.34	0.7374	60	4.9893	0.9171	0.0004	0.9179	0.9370
0.34	0.7466	61.5	5.1398	0.9178	0.0005	0.9188	0.9370

Table 6-57. NOC, 8x9x8 Array, 259 kg UO_2, 4.35% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.2533	40	3.1674	0.8624	0.0005	0.8634	0.9370
0.14	0.2657	44	3.5873	0.8813	0.0006	0.8825	0.9370
0.14	0.2776	48	4.0072	0.8952	0.0005	0.8962	0.9370
0.14	0.2890	52	4.4271	0.9055	0.0006	0.9067	0.9370
0.14	0.3000	56	4.8469	0.9115	0.0005	0.9125	0.9370
0.14	0.3106	60	5.2668	0.9154	0.0005	0.9164	0.9370
0.14	0.3145	61.5	5.4243	0.9161	0.0005	0.9171	0.9370
0.18	0.3256	40	3.1674	0.8647	0.0005	0.8657	0.9370
0.18	0.3417	44	3.5873	0.8836	0.0006	0.8848	0.9370
0.18	0.3570	48	4.0072	0.8971	0.0005	0.8981	0.9370
0.18	0.3716	52	4.4271	0.9068	0.0005	0.9078	0.9370
0.18	0.3857	56	4.8469	0.9132	0.0005	0.9142	0.9370
0.18	0.3993	60	5.2668	0.9174	0.0005	0.9184	0.9370
0.18	0.4043	61.5	5.4243	0.9165	0.0005	0.9175	0.9370
0.22	0.3980	40	3.1674	0.8670	0.0005	0.8680	0.9370
0.22	0.4176	44	3.5873	0.8857	0.0005	0.8867	0.9370
0.22	0.4363	48	4.0072	0.9000	0.0005	0.9010	0.9370
0.22	0.4542	52	4.4271	0.9085	0.0005	0.9095	0.9370
0.22	0.4714	56	4.8469	0.9154	0.0005	0.9164	0.9370
0.22	0.4881	60	5.2668	0.9193	0.0006	0.9205	0.9370
0.22	**0.4942**	**61.5**	**5.4243**	**0.9198**	**0.0005**	**0.9208**	**0.9370**
0.26	0.4704	40	3.1674	0.8682	0.0005	0.8692	0.9370
0.26	0.4935	44	3.5873	0.8876	0.0006	0.8888	0.9370
0.26	0.5156	48	4.0072	0.9011	0.0005	0.9021	0.9370
0.26	0.5368	52	4.4271	0.9094	0.0005	0.9104	0.9370
0.26	0.5572	56	4.8469	0.9153	0.0005	0.9163	0.9370
0.26	0.5768	60	5.2668	0.9187	0.0005	0.9197	0.9370
0.26	0.5840	61.5	5.4243	0.9189	0.0005	0.9199	0.9370
0.3	0.5427	40	3.1674	0.8692	0.0005	0.8702	0.9370
0.3	0.5694	44	3.5873	0.8890	0.0005	0.8900	0.9370
0.3	0.5949	48	4.0072	0.9016	0.0006	0.9028	0.9370
0.3	0.6194	52	4.4271	0.9107	0.0005	0.9117	0.9370
0.3	0.6429	56	4.8469	0.9156	0.0006	0.9168	0.9370
0.3	0.6656	60	5.2668	0.9189	0.0005	0.9199	0.9370
0.3	0.6739	61.5	5.4243	0.9194	0.0005	0.9204	0.9370

Table 6-58. NOC, 8x9x8 Array, 247 kg UO_2, 4.45% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.2594	40	3.3699	0.8684	0.0005	0.8694	0.9370
0.14	0.2721	44	3.8101	0.8873	0.0005	0.8883	0.9370
0.14	0.2843	48	4.2504	0.8995	0.0005	0.9005	0.9370
0.14	0.2960	52	4.6907	0.9086	0.0006	0.9098	0.9370
0.14	0.3072	56	5.1310	0.9137	0.0006	0.9149	0.9370
0.14	0.3181	60	5.5713	0.9173	0.0005	0.9183	0.9370
0.14	0.3220	61.5	5.7364	0.9201	0.0006	0.9213	0.9370
0.18	0.3335	40	3.3699	0.8711	0.0005	0.8721	0.9370
0.18	0.3499	44	3.8101	0.8905	0.0005	0.8915	0.9370
0.18	0.3655	48	4.2504	0.9011	0.0006	0.9023	0.9370
0.18	0.3805	52	4.6907	0.9106	0.0006	0.9118	0.9370
0.18	0.3950	56	5.1310	0.9157	0.0005	0.9167	0.9370
0.18	0.4089	60	5.5713	0.9189	0.0005	0.9199	0.9370
0.18	0.4140	61.5	5.7364	0.9189	0.0005	0.9199	0.9370
0.22	0.4076	40	3.3699	0.8744	0.0005	0.8754	0.9370
0.22	0.4276	44	3.8101	0.8910	0.0005	0.8920	0.9370
0.22	0.4468	48	4.2504	0.9034	0.0005	0.9044	0.9370
0.22	0.4651	52	4.6907	0.9116	0.0005	0.9126	0.9370
0.22	0.4828	56	5.1310	0.9176	0.0005	0.9186	0.9370
0.22	0.4998	60	5.5713	0.9196	0.0005	0.9206	0.9370
0.22	**0.5060**	**61.5**	**5.7364**	**0.9210**	**0.0005**	**0.9220**	**0.9370**
0.26	0.4817	40	3.3699	0.8755	0.0005	0.8765	0.9370
0.26	0.5054	44	3.8101	0.8925	0.0005	0.8935	0.9370
0.26	0.5280	48	4.2504	0.9042	0.0006	0.9054	0.9370
0.26	0.5497	52	4.6907	0.9130	0.0005	0.9140	0.9370
0.26	0.5705	56	5.1310	0.9185	0.0005	0.9195	0.9370
0.26	0.5907	60	5.5713	0.9197	0.0005	0.9207	0.9370
0.26	0.5980	61.5	5.7364	0.9209	0.0005	0.9219	0.9370
0.3	0.5558	40	3.3699	0.8783	0.0005	0.8793	0.9370
0.3	0.5831	44	3.8101	0.8924	0.0005	0.8934	0.9370
0.3	0.6092	48	4.2504	0.9050	0.0006	0.9062	0.9370
0.3	0.6342	52	4.6907	0.9138	0.0005	0.9148	0.9370
0.3	0.6583	56	5.1310	0.9177	0.0005	0.9187	0.9370
0.3	0.6815	60	5.5713	0.9207	0.0006	0.9219	0.9370
0.3	0.6900	61.5	5.7364	0.9200	0.0005	0.9210	0.9370

Table 6-59. NOC, 8x9x8 Array, 238 kg UO_2, 4.55% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.18	0.3397	40	3.5351	0.8762	0.0005	0.8772	0.9370
0.18	0.3564	44	3.9920	0.8940	0.0005	0.8950	0.9370
0.18	0.3724	48	4.4490	0.9052	0.0005	0.9062	0.9370
0.18	0.3877	52	4.9059	0.9131	0.0006	0.9143	0.9370
0.18	0.4024	56	5.3628	0.9175	0.0005	0.9185	0.9370
0.18	0.4166	60	5.8198	0.9216	0.0005	0.9226	0.9370
0.18	0.4218	61.5	5.9911	0.9217	0.0005	0.9227	0.9370
0.22	0.4152	40	3.5351	0.8788	0.0005	0.8798	0.9370
0.22	0.4356	44	3.9920	0.8967	0.0006	0.8979	0.9370
0.22	0.4551	48	4.4490	0.9080	0.0006	0.9092	0.9370
0.22	0.4738	52	4.9059	0.9136	0.0006	0.9148	0.9370
0.22	0.4918	56	5.3628	0.9194	0.0005	0.9204	0.9370
0.22	0.5092	60	5.8198	0.9223	0.0005	0.9233	0.9370
0.22	0.5155	61.5	5.9911	0.9222	0.0006	0.9234	0.9370
0.26	0.4907	40	3.5351	0.8814	0.0006	0.8826	0.9370
0.26	0.5148	44	3.9920	0.8972	0.0005	0.8982	0.9370
0.26	0.5379	48	4.4490	0.9079	0.0005	0.9089	0.9370
0.26	0.5600	52	4.9059	0.9155	0.0005	0.9165	0.9370
0.26	0.5812	56	5.3628	0.9193	0.0005	0.9203	0.9370
0.26	0.6017	60	5.8198	0.9224	0.0005	0.9234	0.9370
0.26	0.6092	61.5	5.9911	0.9222	0.0006	0.9234	0.9370
0.3	0.5662	40	3.5351	0.8808	0.0005	0.8818	0.9370
0.3	0.5940	44	3.9920	0.8974	0.0005	0.8984	0.9370
0.3	0.6206	48	4.4490	0.9096	0.0005	0.9106	0.9370
0.3	0.6461	52	4.9059	0.9165	0.0004	0.9173	0.9370
0.3	0.6706	56	5.3628	0.9197	0.0005	0.9207	0.9370
0.3	**0.6943**	**60**	**5.8198**	**0.9231**	**0.0005**	**0.9241**	**0.9370**
0.3	0.7030	61.5	5.9911	0.9215	0.0005	0.9225	0.9370
0.34	0.6417	40	3.5351	0.8833	0.0005	0.8843	0.9370
0.34	0.6732	44	3.9920	0.8993	0.0005	0.9003	0.9370
0.34	0.7034	48	4.4490	0.9101	0.0006	0.9113	0.9370
0.34	0.7323	52	4.9059	0.9171	0.0005	0.9181	0.9370
0.34	0.7601	56	5.3628	0.9204	0.0006	0.9216	0.9370
0.34	0.7869	60	5.8198	0.9217	0.0005	0.9227	0.9370
0.34	0.7967	61.5	5.9911	0.9209	0.0005	0.9219	0.9370

Table 6-60. NOC, 8x9x8 Array, 228 kg UO_2, 4.65% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.18	0.3471	40	3.7340	0.8814	0.0005	0.8824	0.9370
0.18	0.3641	44	4.2110	0.8982	0.0005	0.8992	0.9370
0.18	0.3804	48	4.6880	0.9099	0.0005	0.9109	0.9370
0.18	0.3961	52	5.1649	0.9148	0.0005	0.9158	0.9370
0.18	0.4111	56	5.6419	0.9203	0.0005	0.9213	0.9370
0.18	0.4256	60	6.1189	0.9211	0.0005	0.9221	0.9370
0.18	0.4309	61.5	6.2978	0.9237	0.0005	0.9247	0.9370
0.22	0.4242	40	3.7340	0.8837	0.0005	0.8847	0.9370
0.22	0.4451	44	4.2110	0.8996	0.0005	0.9006	0.9370
0.22	0.4650	48	4.6880	0.9105	0.0005	0.9115	0.9370
0.22	0.4841	52	5.1649	0.9170	0.0005	0.9180	0.9370
0.22	0.5025	56	5.6419	0.9209	0.0005	0.9219	0.9370
0.22	0.5202	60	6.1189	0.9236	0.0005	0.9246	0.9370
0.22	0.5267	61.5	6.2978	0.9226	0.0006	0.9238	0.9370
0.26	0.5013	40	3.7340	0.8861	0.0005	0.8871	0.9370
0.26	0.5260	44	4.2110	0.9013	0.0005	0.9023	0.9370
0.26	0.5495	48	4.6880	0.9123	0.0005	0.9133	0.9370
0.26	0.5721	52	5.1649	0.9179	0.0005	0.9189	0.9370
0.26	0.5938	56	5.6419	0.9214	0.0006	0.9226	0.9370
0.26	0.6148	60	6.1189	0.9232	0.0005	0.9242	0.9370
0.26	0.6225	61.5	6.2978	0.9222	0.0005	0.9232	0.9370
0.3	0.5785	40	3.7340	0.8878	0.0005	0.8888	0.9370
0.3	0.6069	44	4.2110	0.9022	0.0005	0.9032	0.9370
0.3	0.6341	48	4.6880	0.9115	0.0005	0.9125	0.9370
0.3	0.6601	52	5.1649	0.9197	0.0005	0.9207	0.9370
0.3	0.6852	56	5.6419	0.9214	0.0005	0.9224	0.9370
0.3	**0.7094**	**60**	**6.1189**	**0.9239**	**0.0005**	**0.9249**	**0.9370**
0.3	0.7182	61.5	6.2978	0.9219	0.0005	0.9229	0.9370
0.34	0.6556	40	3.7340	0.8869	0.0005	0.8879	0.9370
0.34	0.6878	44	4.2110	0.9039	0.0005	0.9049	0.9370
0.34	0.7186	48	4.6880	0.9122	0.0005	0.9132	0.9370
0.34	0.7481	52	5.1649	0.9179	0.0005	0.9189	0.9370
0.34	0.7766	56	5.6419	0.9215	0.0005	0.9225	0.9370
0.34	0.8040	60	6.1189	0.9211	0.0005	0.9221	0.9370
0.34	0.8140	61.5	6.2978	0.9214	0.0006	0.9226	0.9370

Table 6-61. NOC, 8x9x8 Array, 219 kg UO_2, 4.75% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.18	0.3541	40	3.9286	0.8860	0.0005	0.8870	0.9370
0.18	0.3716	44	4.4251	0.9012	0.0005	0.9022	0.9370
0.18	0.3882	48	4.9217	0.9126	0.0005	0.9136	0.9370
0.18	0.4041	52	5.4183	0.9182	0.0005	0.9192	0.9370
0.18	0.4195	56	5.9149	0.9218	0.0005	0.9228	0.9370
0.18	0.4343	60	6.4115	0.9226	0.0005	0.9236	0.9370
0.18	0.4397	61.5	6.5977	0.9228	0.0005	0.9238	0.9370
0.22	0.4328	40	3.9286	0.8889	0.0005	0.8899	0.9370
0.22	0.4541	44	4.4251	0.9041	0.0005	0.9051	0.9370
0.22	0.4745	48	4.9217	0.9126	0.0005	0.9136	0.9370
0.22	0.4939	52	5.4183	0.9182	0.0005	0.9192	0.9370
0.22	0.5127	56	5.9149	0.9226	0.0005	0.9236	0.9370
0.22	0.5308	60	6.4115	0.9237	0.0005	0.9247	0.9370
0.22	0.5374	61.5	6.5977	0.9239	0.0005	0.9249	0.9370
0.26	0.5115	40	3.9286	0.8897	0.0005	0.8907	0.9370
0.26	0.5367	44	4.4251	0.9042	0.0005	0.9052	0.9370
0.26	0.5607	48	4.9217	0.9146	0.0005	0.9156	0.9370
0.26	0.5838	52	5.4183	0.9194	0.0005	0.9204	0.9370
0.26	0.6059	56	5.9149	0.9232	0.0005	0.9242	0.9370
0.26	0.6273	60	6.4115	0.9227	0.0005	0.9237	0.9370
0.26	0.6351	61.5	6.5977	0.9236	0.0005	0.9246	0.9370
0.3	0.5902	40	3.9286	0.8916	0.0005	0.8926	0.9370
0.3	0.6193	44	4.4251	0.9055	0.0005	0.9065	0.9370
0.3	0.6470	48	4.9217	0.9143	0.0005	0.9153	0.9370
0.3	0.6736	52	5.4183	0.9198	0.0005	0.9208	0.9370
0.3	0.6991	56	5.9149	0.9234	0.0005	0.9244	0.9370
0.3	**0.7238**	**60**	**6.4115**	**0.9238**	**0.0006**	**0.9250**	**0.9370**
0.3	**0.7328**	**61.5**	**6.5977**	**0.9240**	**0.0005**	**0.9250**	**0.9370**
0.34	0.6689	40	3.9286	0.8919	0.0006	0.8931	0.9370
0.34	0.7018	44	4.4251	0.9058	0.0005	0.9068	0.9370
0.34	0.7332	48	4.9217	0.9147	0.0005	0.9157	0.9370
0.34	0.7634	52	5.4183	0.9202	0.0006	0.9214	0.9370
0.34	0.7923	56	5.9149	0.9214	0.0005	0.9224	0.9370
0.34	0.8203	60	6.4115	0.9215	0.0005	0.9225	0.9370
0.34	0.8305	61.5	6.5977	0.9208	0.0005	0.9218	0.9370

Table 6-62. NOC, 8x9x8 Array, 208 kg UO_2, 4.85% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.2826	40	4.1892	0.8880	0.0005	0.8890	0.9370
0.14	0.2965	44	4.7120	0.9021	0.0005	0.9031	0.9370
0.14	0.3098	48	5.2349	0.9133	0.0005	0.9143	0.9370
0.14	0.3225	52	5.7577	0.9187	0.0005	0.9197	0.9370
0.14	0.3348	56	6.2806	0.9213	0.0005	0.9223	0.9370
0.14	0.3466	60	6.8034	0.9218	0.0006	0.9230	0.9370
0.14	0.3509	61.5	6.9995	0.9210	0.0005	0.9220	0.9370
0.18	0.3634	40	4.1892	0.8911	0.0005	0.8921	0.9370
0.18	0.3813	44	4.7120	0.9056	0.0006	0.9068	0.9370
0.18	0.3983	48	5.2349	0.9130	0.0005	0.9140	0.9370
0.18	0.4147	52	5.7577	0.9193	0.0005	0.9203	0.9370
0.18	0.4304	56	6.2806	0.9209	0.0006	0.9221	0.9370
0.18	0.4456	60	6.8034	0.9233	0.0005	0.9243	0.9370
0.18	0.4512	61.5	6.9995	0.9226	0.0005	0.9236	0.9370
0.22	0.4441	40	4.1892	0.8934	0.0005	0.8944	0.9370
0.22	0.4660	44	4.7120	0.9066	0.0005	0.9076	0.9370
0.22	0.4868	48	5.2349	0.9160	0.0005	0.9170	0.9370
0.22	0.5068	52	5.7577	0.9202	0.0005	0.9212	0.9370
0.22	0.5261	56	6.2806	0.9222	0.0005	0.9232	0.9370
0.22	0.5446	60	6.8034	0.9224	0.0005	0.9234	0.9370
0.22	0.5514	61.5	6.9995	0.9220	0.0005	0.9230	0.9370
0.26	0.5249	40	4.1892	0.8947	0.0005	0.8957	0.9370
0.26	0.5507	44	4.7120	0.9071	0.0006	0.9083	0.9370
0.26	0.5754	48	5.2349	0.9155	0.0005	0.9165	0.9370
0.26	0.5990	52	5.7577	0.9193	0.0005	0.9203	0.9370
0.26	**0.6217**	**56**	**6.2806**	**0.9236**	**0.0005**	**0.9246**	**0.9370**
0.26	**0.6437**	**60**	**6.8034**	**0.9236**	**0.0005**	**0.9246**	**0.9370**
0.26	0.6517	61.5	6.9995	0.9225	0.0005	0.9235	0.9370
0.3	0.6056	40	4.1892	0.8952	0.0005	0.8962	0.9370
0.3	0.6354	44	4.7120	0.9081	0.0005	0.9091	0.9370
0.3	0.6639	48	5.2349	0.9156	0.0005	0.9166	0.9370
0.3	0.6911	52	5.7577	0.9209	0.0005	0.9219	0.9370
0.3	0.7174	56	6.2806	0.9213	0.0005	0.9223	0.9370
0.3	0.7427	60	6.8034	0.9215	0.0005	0.9225	0.9370
0.3	0.7520	61.5	6.9995	0.9209	0.0005	0.9219	0.9370

Table 6-63. NOC, 8x9x8 Array, 202 kg UO_2, 4.95% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.2868	40	4.3433	0.8916	0.0005	0.8926	0.9370
0.14	0.3009	44	4.8817	0.9066	0.0005	0.9076	0.9370
0.14	0.3144	48	5.4201	0.9162	0.0005	0.9172	0.9370
0.14	0.3273	52	5.9584	0.9214	0.0005	0.9224	0.9370
0.14	0.3397	56	6.4968	0.9233	0.0005	0.9243	0.9370
0.14	0.3517	60	7.0352	0.9236	0.0006	0.9248	0.9370
0.14	0.3561	61.5	7.2371	0.9240	0.0005	0.9250	0.9368
0.18	0.3687	40	4.3433	0.8944	0.0005	0.8954	0.9370
0.18	0.3869	44	4.8817	0.9077	0.0005	0.9087	0.9370
0.18	0.4042	48	5.4201	0.9168	0.0005	0.9178	0.9370
0.18	0.4208	52	5.9584	0.9212	0.0005	0.9222	0.9370
0.18	**0.4368**	**56**	**6.4968**	**0.9250**	**0.0006**	**0.9262**	**0.9370**
0.18	0.4522	60	7.0352	0.9247	0.0005	0.9257	0.9370
0.18	0.4578	61.5	7.2371	0.9241	0.0006	0.9253	0.9368
0.22	0.4507	40	4.3433	0.8968	0.0006	0.8980	0.9370
0.22	0.4728	44	4.8817	0.9084	0.0005	0.9094	0.9370
0.22	0.4940	48	5.4201	0.9176	0.0006	0.9188	0.9370
0.22	0.5143	52	5.9584	0.9223	0.0005	0.9233	0.9370
0.22	0.5338	56	6.4968	0.9242	0.0005	0.9252	0.9370
0.22	0.5527	60	7.0352	0.9234	0.0005	0.9244	0.9370
0.22	0.5596	61.5	7.2371	0.9232	0.0005	0.9242	0.9368
0.26	0.5326	40	4.3433	0.8977	0.0006	0.8989	0.9370
0.26	0.5588	44	4.8817	0.9108	0.0005	0.9118	0.9370
0.26	0.5838	48	5.4201	0.9185	0.0006	0.9197	0.9370
0.26	0.6078	52	5.9584	0.9212	0.0005	0.9222	0.9370
0.26	0.6309	56	6.4968	0.9236	0.0005	0.9246	0.9370
0.26	0.6532	60	7.0352	0.9235	0.0005	0.9245	0.9370
0.26	0.6613	61.5	7.2371	0.9227	0.0005	0.9237	0.9368
0.3	0.6146	40	4.3433	0.8987	0.0005	0.8997	0.9370
0.3	0.6448	44	4.8817	0.9109	0.0006	0.9121	0.9370
0.3	0.6737	48	5.4201	0.9185	0.0005	0.9195	0.9370
0.3	0.7013	52	5.9584	0.9214	0.0004	0.9222	0.9370
0.3	0.7280	56	6.4968	0.9229	0.0006	0.9241	0.9370
0.3	0.7536	60	7.0352	0.9230	0.0005	0.9240	0.9370
0.3	0.7630	61.5	7.2371	0.9224	0.0005	0.9234	0.9368

Table 6-64. NOC, 8x9x8 Array, 197 kg UO_2, 5.00% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.2904	40	4.4790	0.8945	0.0006	0.8957	0.9370
0.14	0.3047	44	5.0310	0.9072	0.0005	0.9082	0.9370
0.14	0.3183	48	5.5830	0.9153	0.0005	0.9163	0.9370
0.14	0.3314	52	6.1351	0.9210	0.0005	0.9220	0.9370
0.14	0.3440	56	6.6871	0.9229	0.0005	0.9239	0.9370
0.14	0.3561	60	7.2391	0.9234	0.0005	0.9244	0.9368
0.14	0.3606	61.5	7.4461	0.9241	0.0005	0.9251	0.9365
0.18	0.3734	40	4.4790	0.8960	0.0005	0.8970	0.9370
0.18	0.3918	44	5.0310	0.9088	0.0005	0.9098	0.9370
0.18	0.4093	48	5.5830	0.9173	0.0005	0.9183	0.9370
0.18	0.4261	52	6.1351	0.9233	0.0004	0.9241	0.9370
0.18	**0.4423**	**56**	**6.6871**	**0.9253**	**0.0005**	**0.9263**	**0.9370**
0.18	0.4579	60	7.2391	0.9232	0.0005	0.9242	0.9368
0.18	0.4636	61.5	7.4461	0.9234	0.0004	0.9242	0.9365
0.22	0.4564	40	4.4790	0.8980	0.0005	0.8990	0.9370
0.22	0.4788	44	5.0310	0.9105	0.0005	0.9115	0.9370
0.22	0.5002	48	5.5830	0.9173	0.0006	0.9185	0.9370
0.22	0.5208	52	6.1351	0.9222	0.0005	0.9232	0.9370
0.22	0.5406	56	6.6871	0.9231	0.0005	0.9241	0.9370
0.22	0.5596	60	7.2391	0.9239	0.0005	0.9249	0.9368
0.22	0.5666	61.5	7.4461	0.9233	0.0005	0.9243	0.9365
0.26	0.5393	40	4.4790	0.8989	0.0005	0.8999	0.9370
0.26	0.5659	44	5.0310	0.9107	0.0005	0.9117	0.9370
0.26	0.5912	48	5.5830	0.9198	0.0005	0.9208	0.9370
0.26	0.6155	52	6.1351	0.9229	0.0005	0.9239	0.9370
0.26	0.6389	56	6.6871	0.9234	0.0006	0.9246	0.9370
0.26	0.6614	60	7.2391	0.9226	0.0005	0.9236	0.9368
0.26	0.6696	61.5	7.4461	0.9217	0.0005	0.9227	0.9365
0.3	0.6223	40	4.4790	0.8997	0.0005	0.9007	0.9370
0.3	0.6529	44	5.0310	0.9105	0.0005	0.9115	0.9370
0.3	0.6821	48	5.5830	0.9187	0.0005	0.9197	0.9370
0.3	0.7102	52	6.1351	0.9219	0.0005	0.9229	0.9370
0.3	0.7371	56	6.6871	0.9221	0.0006	0.9233	0.9370
0.3	0.7631	60	7.2391	0.9222	0.0005	0.9232	0.9368
0.3	0.7727	61.5	7.4461	0.9206	0.0005	0.9216	0.9365

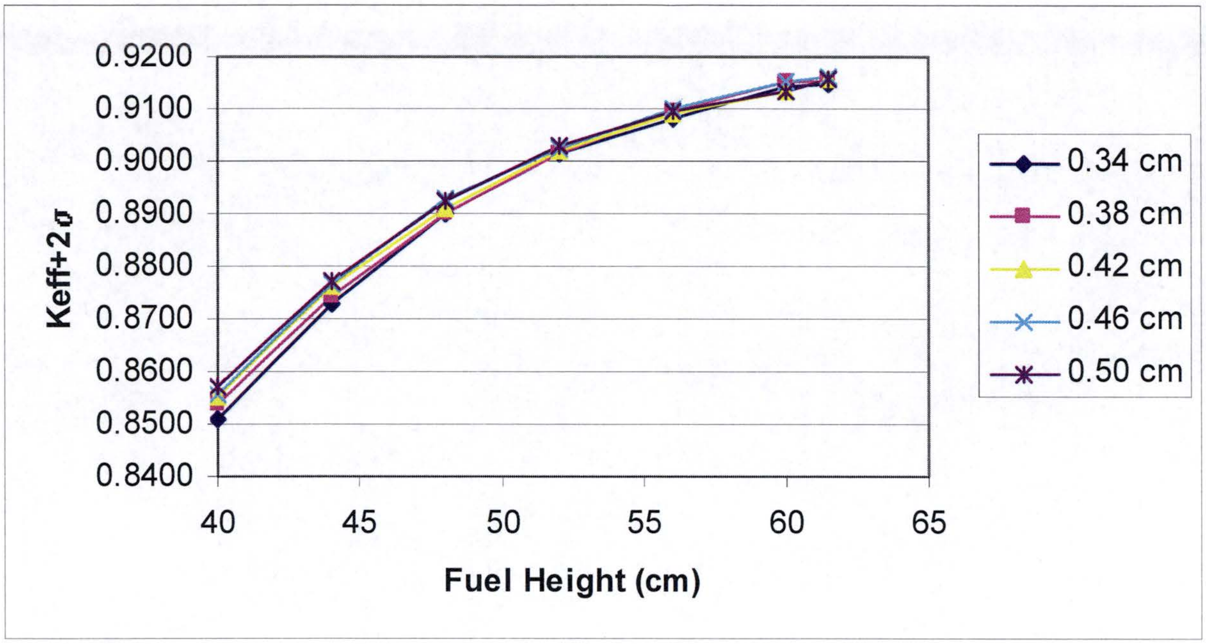

Figure 6-40. NOC, 8x9x8 Array, 4.05 wt.% Heterogeneous Material

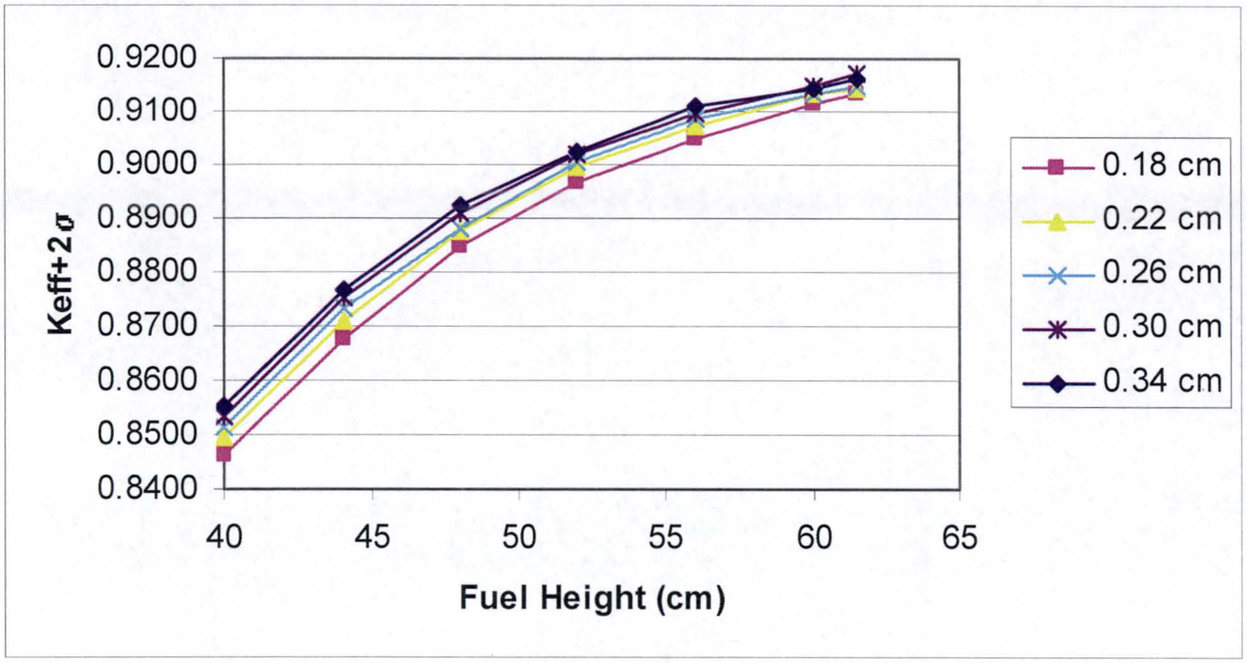

Figure 6-41. NOC, 8x9x8 Array, 4.10 wt.% Heterogeneous Material

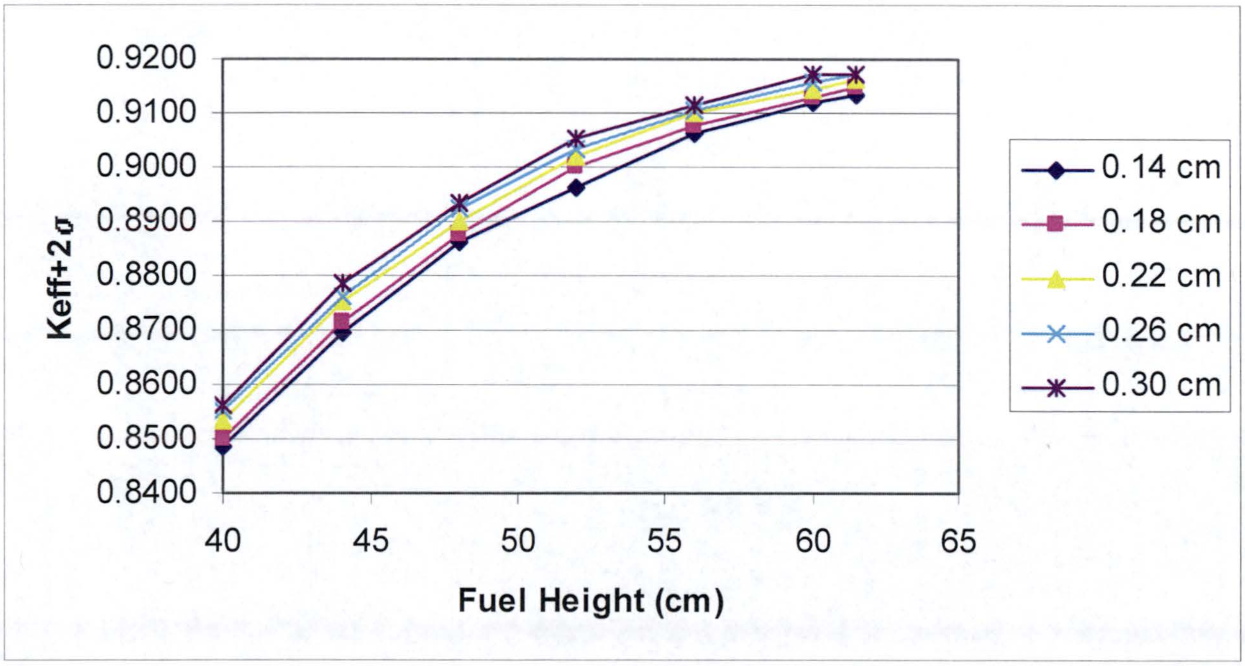

Figure 6-42. NOC, 8x9x8 Array, 4.15 wt.% Heterogeneous Material

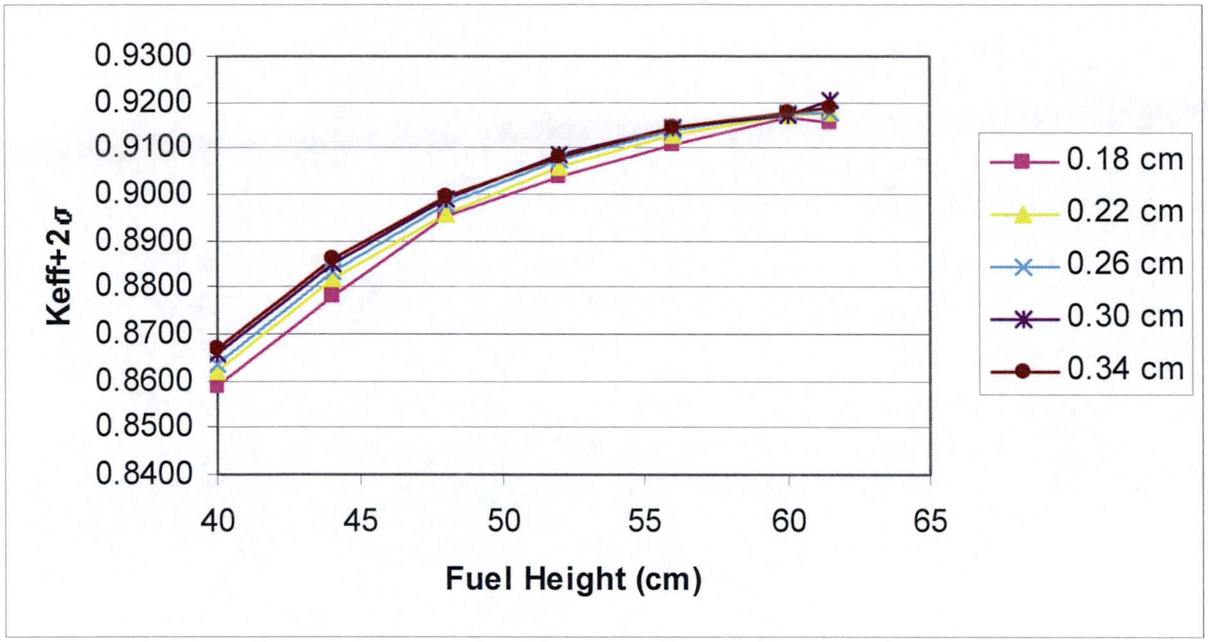

Figure 6-43. NOC, 8x9x8 Array, 4.25 wt.% Heterogeneous Material

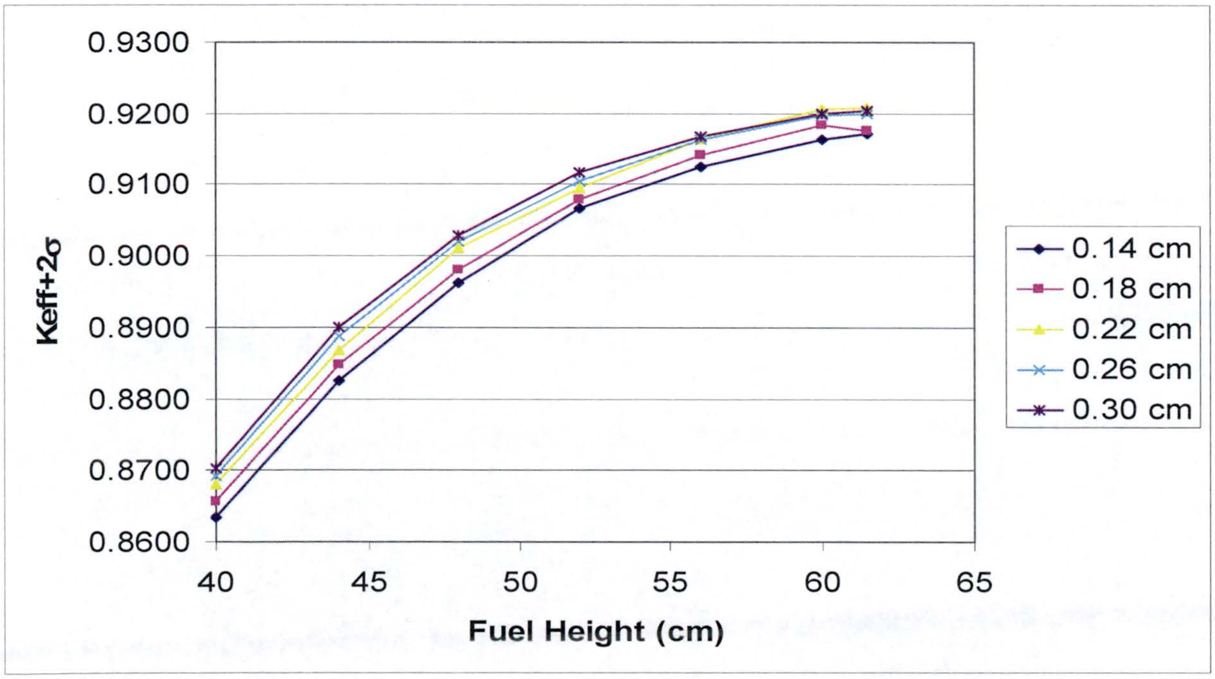

Figure 6-44. NOC, 8x9x8 Array, 4.35 wt.% Heterogeneous Material

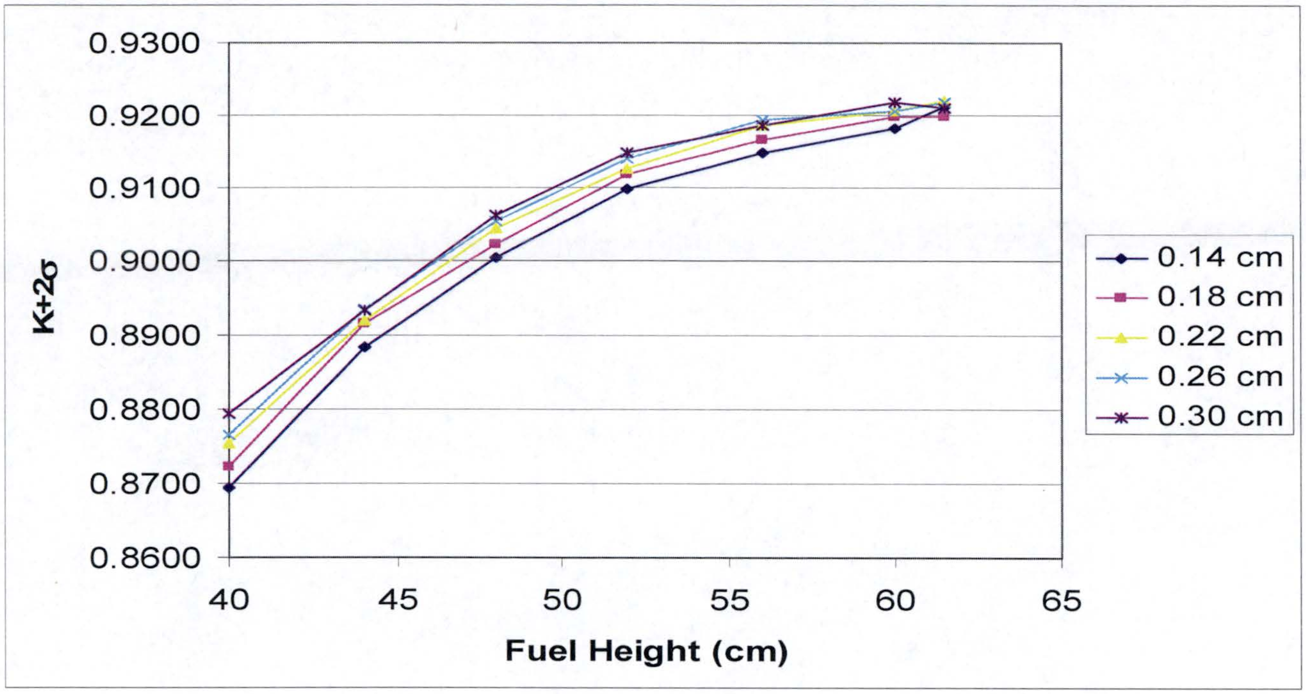

Figure 6-45. NOC, 8x9x8 Array, 4.45 wt.% Heterogeneous Material

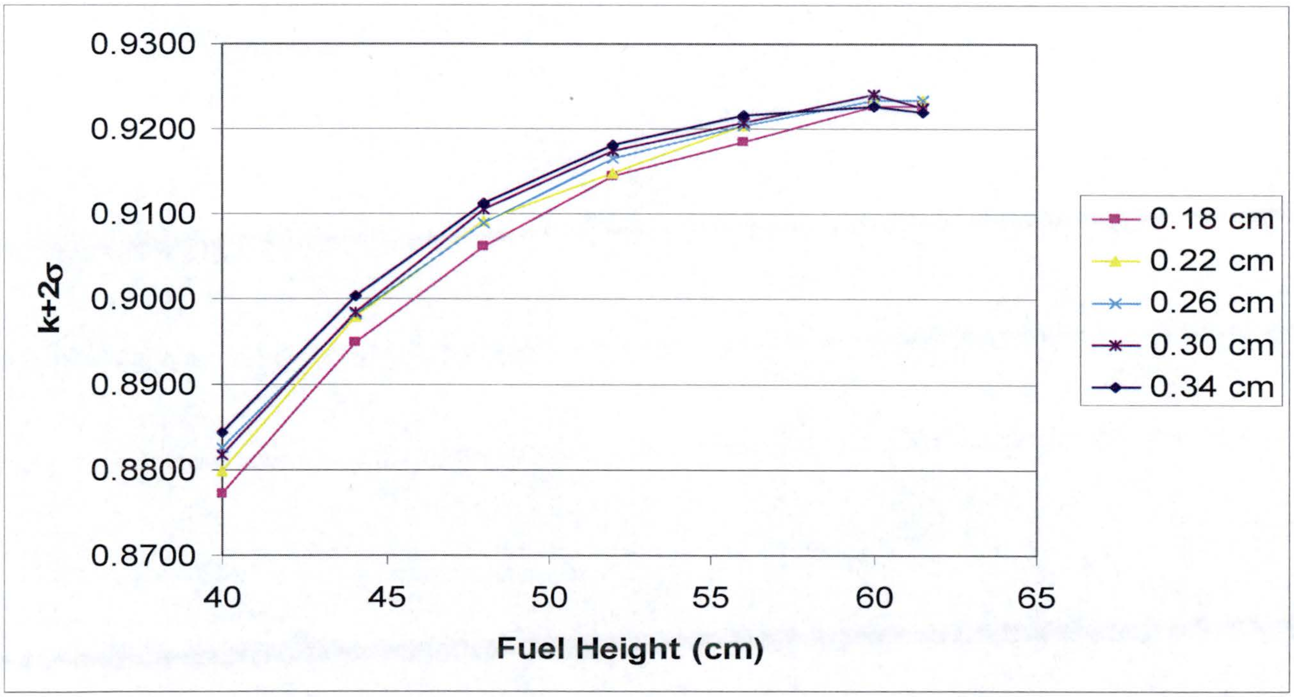

Figure 6-46. NOC, 8x9x8 Array, 4.55 wt.% Heterogeneous Material

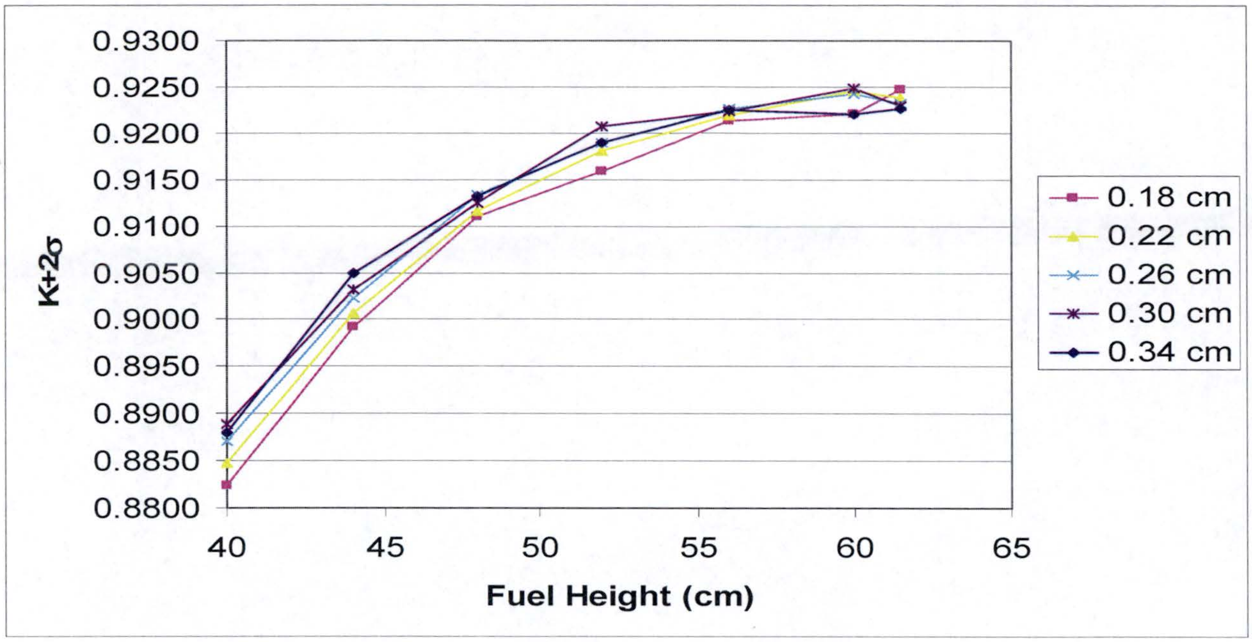

Figure 6-47. NOC, 8x9x8 Array, 4.65 wt.% Heterogeneous Material

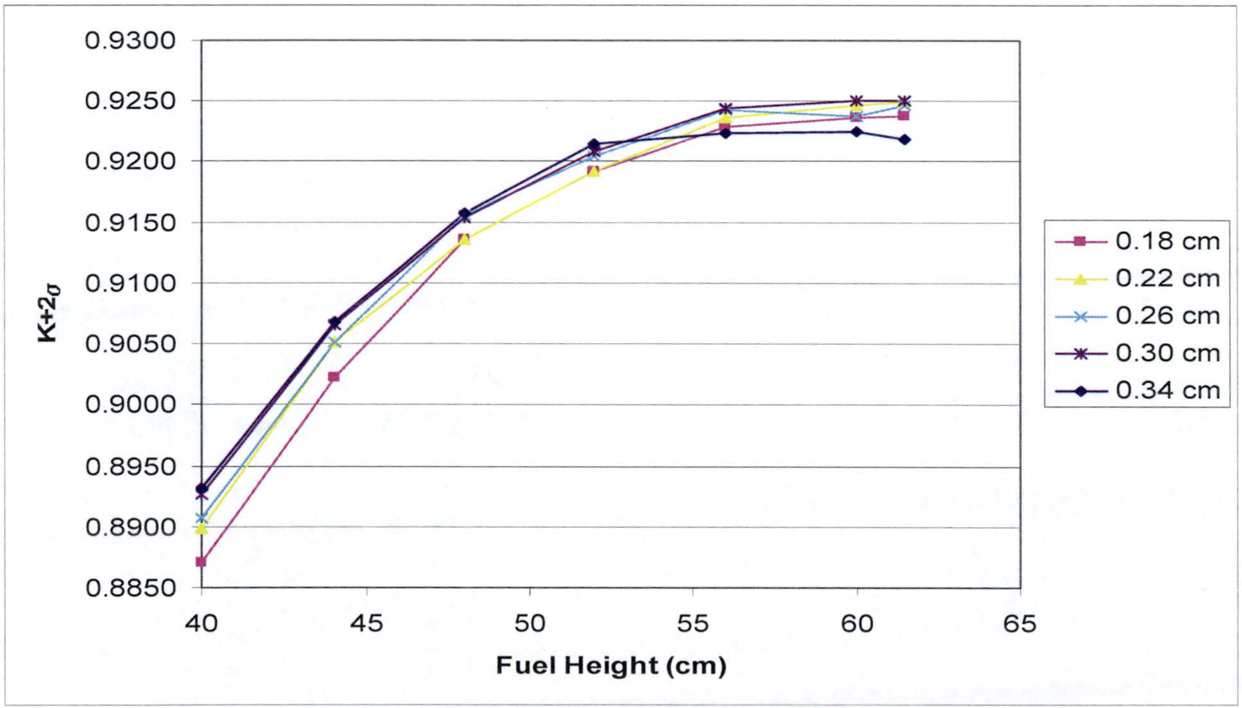

Figure 6-48. NOC, 8x9x8 Array, 4.75 wt.% Heterogeneous Material

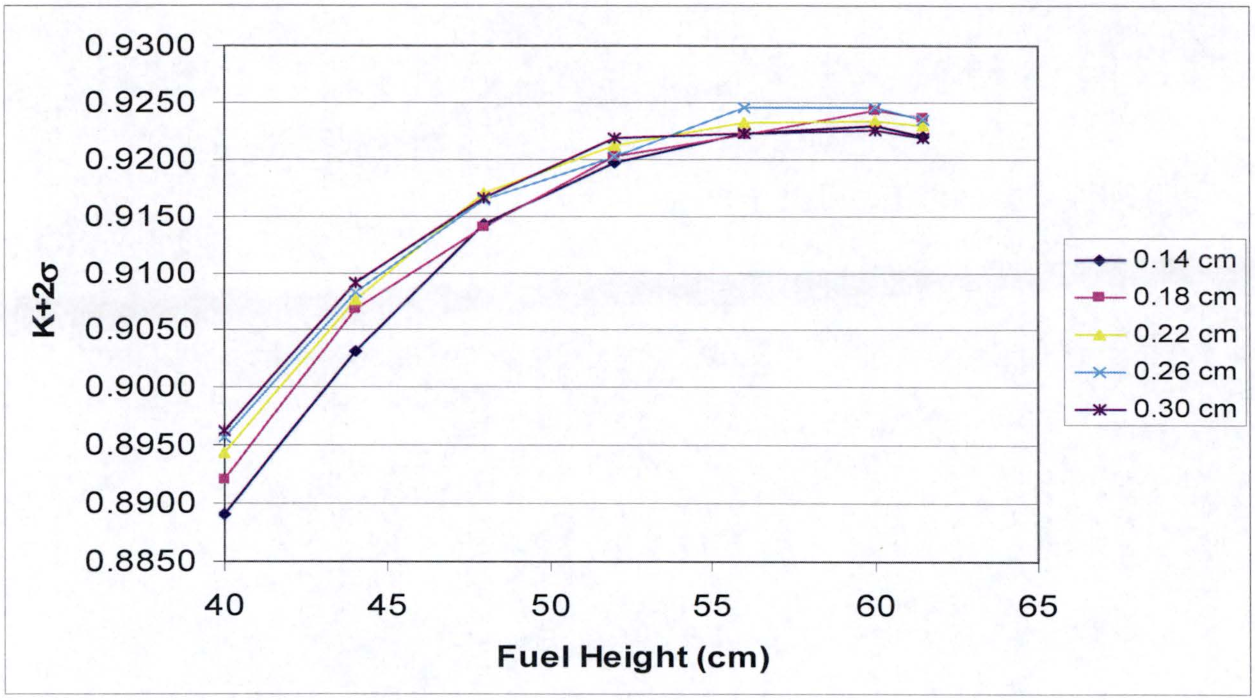

Figure 6-49. NOC, 8x9x8 Array, 4.85 wt.% Heterogeneous Material

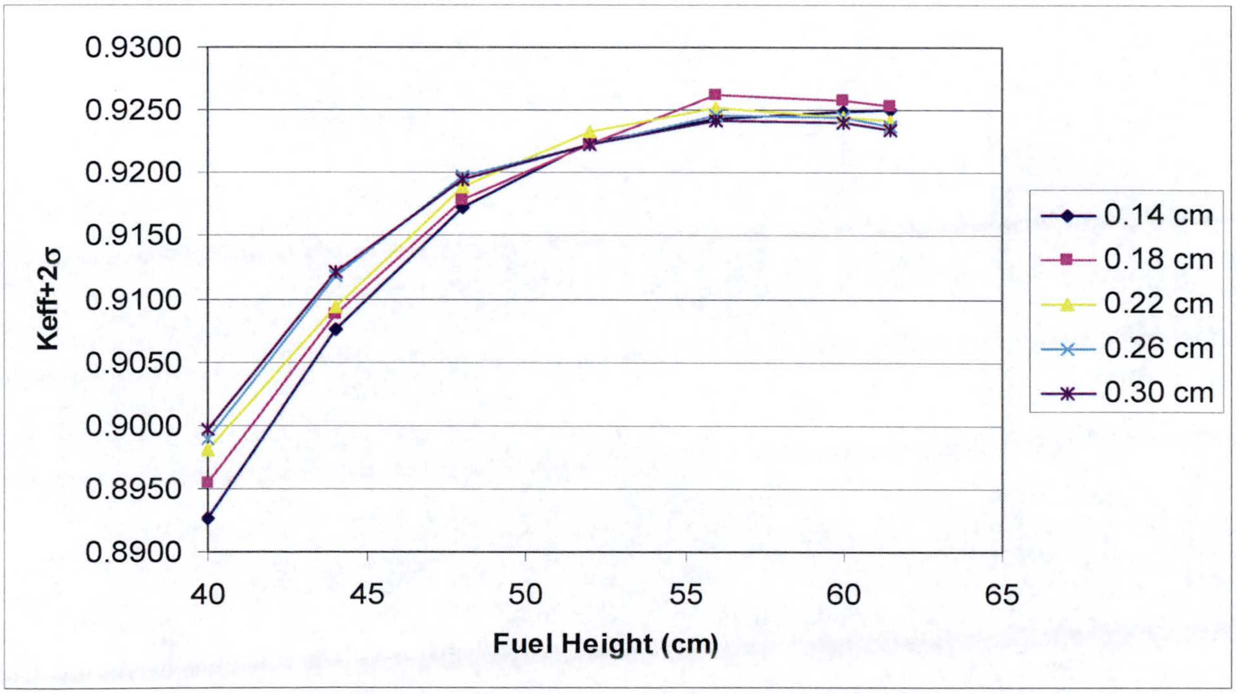

Figure 6-50. NOC, 8x9x8 Array, 4.95 wt.% Heterogeneous Material

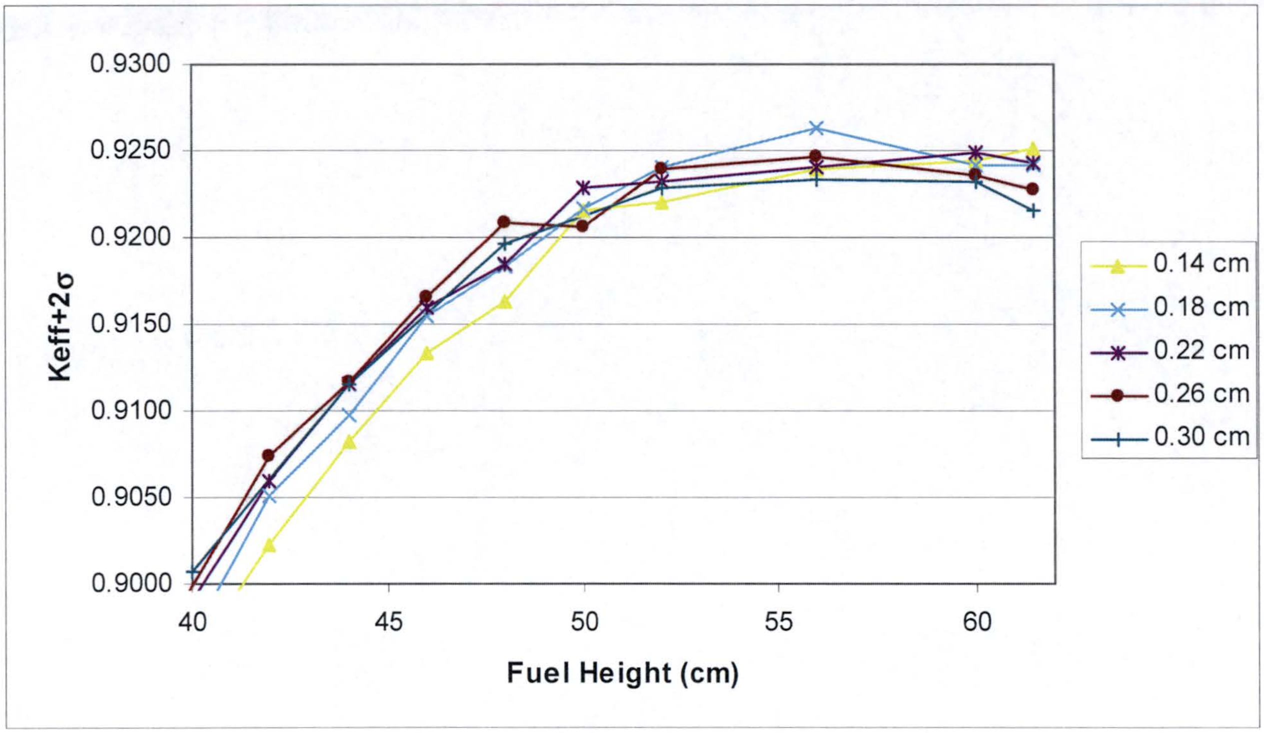

Figure 6-51. NOC, 8x9x8 Array, 5.00 wt.% Heterogeneous Material

Table 6-65. NOC, Single Package, 300 kg UO_2, 4.05% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	Keff	σ	keff+2σ	USL
0.22	0.3698	40	2.5978	0.8300	0.0005	0.8310	0.9370
0.22	0.3880	44	2.9603	0.8520	0.0005	0.8530	0.9370
0.22	0.4054	48	3.3229	0.8681	0.0005	0.8691	0.9370
0.22	0.4220	52	3.6854	0.8804	0.0005	0.8814	0.9370
0.22	0.4380	56	4.0479	0.8880	0.0005	0.8890	0.9370
0.22	0.4535	60	4.4104	0.8941	0.0005	0.8951	0.9370
0.22	0.4592	61.5	4.5463	0.8954	0.0005	0.8964	0.9370
0.26	0.4371	40	2.5978	0.8320	0.0006	0.8332	0.9370
0.26	0.4585	44	2.9603	0.8535	0.0005	0.8545	0.9370
0.26	0.4791	48	3.3229	0.8698	0.0005	0.8708	0.9370
0.26	0.4988	52	3.6854	0.8811	0.0005	0.8821	0.9370
0.26	0.5177	56	4.0479	0.8899	0.0005	0.8909	0.9370
0.26	0.5360	60	4.4104	0.8955	0.0005	0.8965	0.9370
0.26	0.5427	61.5	4.5463	0.8955	0.0005	0.8965	0.9370
0.3	0.5043	40	2.5978	0.8335	0.0005	0.8345	0.9370
0.3	0.5291	44	2.9603	0.8555	0.0005	0.8565	0.9370
0.3	0.5528	48	3.3229	0.8712	0.0005	0.8722	0.9370
0.3	0.5755	52	3.6854	0.8827	0.0005	0.8837	0.9370
0.3	0.5973	56	4.0479	0.8910	0.0005	0.8920	0.9370
0.3	0.6184	60	4.4104	0.8967	0.0006	0.8979	0.9370
0.3	0.6261	61.5	4.5463	0.8964	0.0005	0.8974	0.9370
0.34	0.5715	40	2.5978	0.8361	0.0005	0.8371	0.9370
0.34	0.5996	44	2.9603	0.8578	0.0005	0.8588	0.9370
0.34	0.6265	48	3.3229	0.8730	0.0005	0.8740	0.9370
0.34	0.6522	52	3.6854	0.8843	0.0005	0.8853	0.9370
0.34	0.6770	56	4.0479	0.8923	0.0005	0.8933	0.9370
0.34	0.7009	60	4.4104	0.8959	0.0005	0.8969	0.9370
0.34	**0.7096**	**61.5**	**4.5463**	**0.8978**	**0.0006**	**0.8990**	**0.9370**
0.38	0.6388	40	2.5978	0.8377	0.0005	0.8387	0.9370
0.38	0.6702	44	2.9603	0.8596	0.0005	0.8606	0.9370
0.38	0.7002	48	3.3229	0.8740	0.0005	0.8750	0.9370
0.38	0.7290	52	3.6854	0.8846	0.0005	0.8856	0.9370
0.38	0.7566	56	4.0479	0.8923	0.0006	0.8935	0.9370
0.38	0.7833	60	4.4104	0.8956	0.0005	0.8966	0.9370
0.38	0.7931	61.5	4.5463	0.8974	0.0005	0.8984	0.9370

Table 6-66. NOC, Single Package, 293 kg UO_2, 4.10% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	Keff	σ	keff+2σ	USL
0.22	0.3742	40	2.6838	0.8340	0.0005	0.8350	0.9370
0.22	0.3926	44	3.0550	0.8555	0.0005	0.8565	0.9370
0.22	0.4102	48	3.4261	0.8707	0.0005	0.8717	0.9370
0.22	0.4270	52	3.7973	0.8818	0.0005	0.8828	0.9370
0.22	0.4432	56	4.1685	0.8896	0.0005	0.8906	0.9370
0.22	0.4589	60	4.5396	0.8952	0.0005	0.8962	0.9370
0.22	0.4646	61.5	4.6788	0.8966	0.0005	0.8976	0.9370
0.26	0.4422	40	2.6838	0.8367	0.0006	0.8379	0.9370
0.26	0.4640	44	3.0550	0.8576	0.0005	0.8586	0.9370
0.26	0.4848	48	3.4261	0.8733	0.0005	0.8743	0.9370
0.26	0.5047	52	3.7973	0.8843	0.0005	0.8853	0.9370
0.26	0.5238	56	4.1685	0.8918	0.0005	0.8928	0.9370
0.26	0.5423	60	4.5396	0.8961	0.0005	0.8971	0.9370
0.26	0.5491	61.5	4.6788	0.8981	0.0005	0.8991	0.9370
0.3	0.5103	40	2.6838	0.8382	0.0005	0.8392	0.9370
0.3	0.5354	44	3.0550	0.8584	0.0005	0.8594	0.9370
0.3	0.5593	48	3.4261	0.8744	0.0005	0.8754	0.9370
0.3	0.5823	52	3.7973	0.8868	0.0006	0.8880	0.9370
0.3	0.6044	56	4.1685	0.8930	0.0005	0.8940	0.9370
0.3	0.6258	60	4.5396	0.8973	0.0005	0.8983	0.9370
0.3	0.6336	61.5	4.6788	0.8990	0.0005	0.9000	0.9370
0.34	0.5783	40	2.6838	0.8405	0.0005	0.8415	0.9370
0.34	0.6068	44	3.0550	0.8610	0.0005	0.8620	0.9370
0.34	0.6339	48	3.4261	0.8766	0.0005	0.8776	0.9370
0.34	0.6600	52	3.7973	0.8862	0.0006	0.8874	0.9370
0.34	0.6850	56	4.1685	0.8928	0.0005	0.8938	0.9370
0.34	0.7092	60	4.5396	0.8981	0.0005	0.8991	0.9370
0.34	**0.7180**	**61.5**	**4.6788**	**0.8999**	**0.0005**	**0.9009**	**0.9370**
0.38	0.6464	40	2.6838	0.8416	0.0005	0.8426	0.9370
0.38	0.6781	44	3.0550	0.8625	0.0005	0.8635	0.9370
0.38	0.7085	48	3.4261	0.8767	0.0006	0.8779	0.9370
0.38	0.7376	52	3.7973	0.8864	0.0006	0.8876	0.9370
0.38	0.7656	56	4.1685	0.8943	0.0006	0.8955	0.9370
0.38	0.7926	60	4.5396	0.8987	0.0005	0.8997	0.9370
0.38	0.8025	61.5	4.6788	0.8979	0.0005	0.8989	0.9370

Table 6-67. NOC, Single Package, 287 kg UO_2, 4.15% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.18	0.3094	40	2.7608	0.8363	0.0005	0.8373	0.9370
0.18	0.3246	44	3.1397	0.8566	0.0005	0.8576	0.9370
0.18	0.3391	48	3.5187	0.8712	0.0005	0.8722	0.9370
0.18	0.3530	52	3.8976	0.8834	0.0005	0.8844	0.9370
0.18	0.3664	56	4.2765	0.8907	0.0005	0.8917	0.9370
0.18	0.3794	60	4.6554	0.8957	0.0005	0.8967	0.9370
0.18	0.3841	61.5	4.7975	0.8977	0.0006	0.8989	0.9370
0.22	0.3781	40	2.7608	0.8385	0.0005	0.8395	0.9370
0.22	0.3967	44	3.1397	0.8592	0.0005	0.8602	0.9370
0.22	0.4145	48	3.5187	0.8747	0.0006	0.8759	0.9370
0.22	0.4315	52	3.8976	0.8849	0.0005	0.8859	0.9370
0.22	0.4479	56	4.2765	0.8923	0.0005	0.8933	0.9370
0.22	0.4637	60	4.6554	0.8971	0.0006	0.8983	0.9370
0.22	0.4694	61.5	4.7975	0.8984	0.0005	0.8994	0.9370
0.26	0.4468	40	2.7608	0.8395	0.0005	0.8405	0.9370
0.26	0.4688	44	3.1397	0.8598	0.0006	0.8610	0.9370
0.26	0.4898	48	3.5187	0.8757	0.0005	0.8767	0.9370
0.26	0.5099	52	3.8976	0.8871	0.0006	0.8883	0.9370
0.26	0.5293	56	4.2765	0.8939	0.0005	0.8949	0.9370
0.26	0.5480	60	4.6554	0.8991	0.0005	0.9001	0.9370
0.26	0.5548	61.5	4.7975	0.8992	0.0005	0.9002	0.9370
0.3	0.5156	40	2.7608	0.8412	0.0004	0.8420	0.9370
0.3	0.5409	44	3.1397	0.8617	0.0006	0.8629	0.9370
0.3	0.5652	48	3.5187	0.8777	0.0005	0.8787	0.9370
0.3	0.5884	52	3.8976	0.8872	0.0006	0.8884	0.9370
0.3	0.6107	56	4.2765	0.8951	0.0005	0.8961	0.9370
0.3	0.6323	60	4.6554	0.8992	0.0006	0.9004	0.9370
0.3	**0.6402**	**61.5**	**4.7975**	**0.9005**	**0.0005**	**0.9015**	**0.9370**
0.34	0.5843	40	2.7608	0.8436	0.0005	0.8446	0.9370
0.34	0.6131	44	3.1397	0.8631	0.0005	0.8641	0.9370
0.34	0.6405	48	3.5187	0.8778	0.0005	0.8788	0.9370
0.34	0.6668	52	3.8976	0.8883	0.0005	0.8893	0.9370
0.34	0.6921	56	4.2765	0.8960	0.0005	0.8970	0.9370
0.34	0.7166	60	4.6554	0.8998	0.0005	0.9008	0.9370
0.34	0.7255	61.5	4.7975	0.8996	0.0005	0.9006	0.9370

Table 6-68. NOC, Single Package, 271 kg UO_2, 4.25% Enriched Heterogeneous Material

Diameter, cm	Pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.22	0.3891	40	2.9829	0.8455	0.0006	0.8467	0.9370
0.22	0.4082	44	3.3841	0.8653	0.0005	0.8663	0.9370
0.22	0.4265	48	3.7854	0.8789	0.0005	0.8799	0.9370
0.22	0.4440	52	4.1867	0.8888	0.0005	0.8898	0.9370
0.22	0.4609	56	4.5880	0.8959	0.0005	0.8969	0.9370
0.22	0.4772	60	4.9893	0.8992	0.0004	0.9000	0.9370
0.22	0.4831	61.5	5.1398	0.9004	0.0005	0.9014	0.9370
0.26	0.4598	40	2.9829	0.8476	0.0005	0.8486	0.9370
0.26	0.4825	44	3.3841	0.8668	0.0005	0.8678	0.9370
0.26	0.5041	48	3.7854	0.8805	0.0005	0.8815	0.9370
0.26	0.5248	52	4.1867	0.8909	0.0005	0.8919	0.9370
0.26	0.5447	56	4.5880	0.8961	0.0005	0.8971	0.9370
0.26	0.5639	60	4.9893	0.9002	0.0006	0.9014	0.9370
0.26	0.5709	61.5	5.1398	0.9008	0.0005	0.9018	0.9370
0.3	0.5306	40	2.9829	0.8496	0.0005	0.8506	0.9370
0.3	0.5567	44	3.3841	0.8682	0.0005	0.8692	0.9370
0.3	0.5816	48	3.7854	0.8834	0.0006	0.8846	0.9370
0.3	0.6055	52	4.1867	0.8907	0.0005	0.8917	0.9370
0.3	0.6285	56	4.5880	0.8969	0.0006	0.8981	0.9370
0.3	0.6507	60	4.9893	0.9013	0.0006	0.9025	0.9370
0.3	**0.6588**	**61.5**	**5.1398**	**0.9018**	**0.0005**	**0.9028**	**0.9370**
0.34	0.6013	40	2.9829	0.8512	0.0005	0.8522	0.9370
0.34	0.6309	44	3.3841	0.8698	0.0005	0.8708	0.9370
0.34	0.6592	48	3.7854	0.8829	0.0005	0.8839	0.9370
0.34	0.6862	52	4.1867	0.8928	0.0005	0.8938	0.9370
0.34	0.7123	56	4.5880	0.8981	0.0005	0.8991	0.9370
0.34	0.7374	60	4.9893	0.9009	0.0005	0.9019	0.9370
0.34	**0.7466**	**61.5**	**5.1398**	**0.9018**	**0.0005**	**0.9028**	**0.9370**
0.38	0.6721	40	2.9829	0.8532	0.0005	0.8542	0.9370
0.38	0.7051	44	3.3841	0.8721	0.0005	0.8731	0.9370
0.38	0.7367	48	3.7854	0.8840	0.0005	0.8850	0.9370
0.38	0.7670	52	4.1867	0.8925	0.0006	0.8937	0.9370
0.38	0.7961	56	4.5880	0.8979	0.0005	0.8989	0.9370
0.38	0.8242	60	4.9893	0.9010	0.0005	0.9020	0.9370
0.38	0.8345	61.5	5.1398	0.9012	0.0005	0.9022	0.9370

Table 6-69. NOC, Single Package, 259 kg UO_2, 4.35% Enriched Heterogeneous Material

Diameter, cm	Pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.18	0.3256	40	3.1674	0.8502	0.0005	0.8512	0.9370
0.18	0.3417	44	3.5873	0.8679	0.0005	0.8689	0.9370
0.18	0.3570	48	4.0072	0.8830	0.0005	0.8840	0.9370
0.18	0.3716	52	4.4271	0.8908	0.0005	0.8918	0.9370
0.18	0.3857	56	4.8469	0.8963	0.0005	0.8973	0.9370
0.18	0.3993	60	5.2668	0.9015	0.0005	0.9025	0.9370
0.18	0.4043	61.5	5.4243	0.9029	0.0005	0.9039	0.9370
0.22	0.3980	40	3.1674	0.8520	0.0005	0.8530	0.9370
0.22	0.4176	44	3.5873	0.8715	0.0006	0.8727	0.9370
0.22	0.4363	48	4.0072	0.8834	0.0005	0.8844	0.9370
0.22	0.4542	52	4.4271	0.8928	0.0005	0.8938	0.9370
0.22	0.4714	56	4.8469	0.8988	0.0005	0.8998	0.9370
0.22	0.4881	60	5.2668	0.9011	0.0005	0.9021	0.9370
0.22	0.4942	61.5	5.4243	0.9026	0.0005	0.9036	0.9370
0.26	0.4704	40	3.1674	0.8542	0.0005	0.8552	0.9370
0.26	0.4935	44	3.5873	0.8732	0.0006	0.8744	0.9370
0.26	0.5156	48	4.0072	0.8855	0.0005	0.8865	0.9370
0.26	0.5368	52	4.4271	0.8939	0.0005	0.8949	0.9370
0.26	0.5572	56	4.8469	0.8996	0.0005	0.9006	0.9370
0.26	0.5768	60	5.2668	0.9020	0.0005	0.9030	0.9370
0.26	0.5840	61.5	5.4243	0.9027	0.0005	0.9037	0.9370
0.3	0.5427	40	3.1674	0.8555	0.0005	0.8565	0.9370
0.3	0.5694	44	3.5873	0.8742	0.0005	0.8752	0.9370
0.3	0.5949	48	4.0072	0.8865	0.0005	0.8875	0.9370
0.3	0.6194	52	4.4271	0.8946	0.0005	0.8956	0.9370
0.3	0.6429	56	4.8469	0.8998	0.0005	0.9008	0.9370
0.3	0.6656	60	5.2668	0.9030	0.0005	0.9040	0.9370
0.3	**0.6739**	**61.5**	**5.4243**	**0.9031**	**0.0005**	**0.9041**	**0.9370**
0.34	0.6151	40	3.1674	0.8573	0.0005	0.8583	0.9370
0.34	0.6454	44	3.5873	0.8748	0.0005	0.8758	0.9370
0.34	0.6742	48	4.0072	0.8876	0.0005	0.8886	0.9370
0.34	0.7019	52	4.4271	0.8967	0.0006	0.8979	0.9370
0.34	0.7286	56	4.8469	0.9007	0.0006	0.9019	0.9370
0.34	0.7543	60	5.2668	0.9025	0.0005	0.9035	0.9370
0.34	0.7637	61.5	5.4243	0.9028	0.0005	0.9038	0.9370

Table 6-70. NOC, Single Package, 247 kg UO_2, 4.45% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.22	0.4076	40	3.3699	0.8583	0.0005	0.8593	0.9370
0.22	0.4276	44	3.8101	0.8757	0.0005	0.8767	0.9370
0.22	0.4468	48	4.2504	0.8881	0.0005	0.8891	0.9370
0.22	0.4651	52	4.6907	0.8964	0.0006	0.8976	0.9370
0.22	0.4828	56	5.1310	0.9008	0.0006	0.9020	0.9370
0.22	0.4998	60	5.5713	0.9028	0.0005	0.9038	0.9370
0.22	0.5060	61.5	5.7364	0.9035	0.0004	0.9043	0.9370
0.26	0.4817	40	3.3699	0.8608	0.0005	0.8618	0.9370
0.26	0.5054	44	3.8101	0.8781	0.0005	0.8791	0.9370
0.26	0.5280	48	4.2504	0.8901	0.0005	0.8911	0.9370
0.26	0.5497	52	4.6907	0.8959	0.0005	0.8969	0.9370
0.26	0.5705	56	5.1310	0.9014	0.0005	0.9024	0.9370
0.26	0.5907	60	5.5713	0.904	0.0006	0.9052	0.9370
0.26	0.5980	61.5	5.7364	0.9039	0.0005	0.9049	0.9370
0.3	0.5558	40	3.3699	0.862	0.0005	0.8630	0.9370
0.3	0.5831	44	3.8101	0.8792	0.0006	0.8804	0.9370
0.3	0.6092	48	4.2504	0.8918	0.0005	0.8928	0.9370
0.3	0.6342	52	4.6907	0.8972	0.0005	0.8982	0.9370
0.3	0.6583	56	5.1310	0.9027	0.0005	0.9037	0.9370
0.3	0.6815	60	5.5713	0.904	0.0004	0.9048	0.9370
0.3	**0.6900**	**61.5**	**5.7364**	**0.9043**	**0.0005**	**0.9053**	**0.9370**
0.34	0.6299	40	3.3699	0.8641	0.0005	0.8651	0.9370
0.34	0.6608	44	3.8101	0.8803	0.0005	0.8813	0.9370
0.34	0.6904	48	4.2504	0.8916	0.0005	0.8926	0.9370
0.34	0.7188	52	4.6907	0.8976	0.0005	0.8986	0.9370
0.34	0.7461	56	5.1310	0.9021	0.0005	0.9031	0.9370
0.34	**0.7724**	**60**	**5.5713**	**0.9043**	**0.0005**	**0.9053**	**0.9370**
0.34	0.7821	61.5	5.7364	0.9032	0.0005	0.9042	0.9370
0.38	0.7040	40	3.3699	0.8642	0.0005	0.8652	0.9370
0.38	0.7386	44	3.8101	0.8809	0.0005	0.8819	0.9370
0.38	0.7717	48	4.2504	0.8922	0.0005	0.8932	0.9370
0.38	0.8034	52	4.6907	0.8981	0.0005	0.8991	0.9370
0.38	0.8339	56	5.1310	0.9022	0.0005	0.9032	0.9370
0.38	0.8633	60	5.5713	0.9022	0.0005	0.9032	0.9370
0.38	0.8741	61.5	5.7364	0.9039	0.0006	0.9051	0.9370

Table 6-71. NOC, Single Package, 238 kg UO_2, 4.55% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.18	0.3397	40	3.5351	0.8623	0.0005	0.8633	0.9370
0.18	0.3564	44	3.9920	0.8789	0.0005	0.8799	0.9370
0.18	0.3724	48	4.4490	0.8911	0.0005	0.8921	0.9370
0.18	0.3877	52	4.9059	0.8975	0.0005	0.8985	0.9370
0.18	0.4024	56	5.3628	0.9021	0.0006	0.9033	0.9370
0.18	0.4166	60	5.8198	0.9051	0.0005	0.9061	0.9370
0.18	0.4218	61.5	5.9911	0.9054	0.0005	0.9064	0.9370
0.22	0.4152	40	3.5351	0.8637	0.0005	0.8647	0.9370
0.22	0.4356	44	3.9920	0.8805	0.0005	0.8815	0.9370
0.22	0.4551	48	4.4490	0.8921	0.0005	0.8931	0.9370
0.22	0.4738	52	4.9059	0.9001	0.0005	0.9011	0.9370
0.22	0.4918	56	5.3628	0.9031	0.0005	0.9041	0.9370
0.22	0.5092	60	5.8198	0.9056	0.0005	0.9066	0.9370
0.22	0.5155	61.5	5.9911	0.9066	0.0005	0.9076	0.9370
0.26	0.4907	40	3.5351	0.8652	0.0005	0.8662	0.9370
0.26	0.5148	44	3.9920	0.8836	0.0006	0.8848	0.9370
0.26	0.5379	48	4.4490	0.8927	0.0005	0.8937	0.9370
0.26	0.5600	52	4.9059	0.9000	0.0004	0.9008	0.9370
0.26	0.5812	56	5.3628	0.9048	0.0006	0.9060	0.9370
0.26	**0.6017**	**60**	**5.8198**	**0.9067**	**0.0006**	**0.9079**	**0.9370**
0.26	0.6092	61.5	5.9911	0.9059	0.0005	0.9069	0.9370
0.3	0.5662	40	3.5351	0.8674	0.0005	0.8684	0.9370
0.3	0.5940	44	3.9920	0.8837	0.0006	0.8849	0.9370
0.3	0.6206	48	4.4490	0.8936	0.0005	0.8946	0.9370
0.3	0.6461	52	4.9059	0.9012	0.0006	0.9024	0.9370
0.3	0.6706	56	5.3628	0.9046	0.0006	0.9058	0.9370
0.3	0.6943	60	5.8198	0.9056	0.0005	0.9066	0.9370
0.3	0.7030	61.5	5.9911	0.9047	0.0005	0.9057	0.9370
0.34	0.6417	40	3.5351	0.8682	0.0006	0.8694	0.9370
0.34	0.6732	44	3.9920	0.8838	0.0005	0.8848	0.9370
0.34	0.7034	48	4.4490	0.8943	0.0005	0.8953	0.9370
0.34	0.7323	52	4.9059	0.9014	0.0005	0.9024	0.9370
0.34	0.7601	56	5.3628	0.9043	0.0005	0.9053	0.9370
0.34	0.7869	60	5.8198	0.9047	0.0005	0.9057	0.9370
0.34	0.7967	61.5	5.9911	0.9047	0.0005	0.9057	0.9370

Table 6-72. NOC, Single Package, 228 kg UO$_2$, 4.65% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.18	0.3471	40	3.7340	0.8661	0.0005	0.8671	0.9370
0.18	0.3641	44	4.2110	0.8835	0.0005	0.8845	0.9370
0.18	0.3804	48	4.6880	0.8942	0.0005	0.8952	0.9370
0.18	0.3961	52	5.1649	0.9006	0.0005	0.9016	0.9370
0.18	0.4111	56	5.6419	0.9050	0.0005	0.9060	0.9370
0.18	0.4256	60	6.1189	0.9062	0.0005	0.9072	0.9370
0.18	0.4309	61.5	6.2978	0.9063	0.0005	0.9073	0.9370
0.22	0.4242	40	3.7340	0.8685	0.0005	0.8695	0.9370
0.22	0.4451	44	4.2110	0.8858	0.0005	0.8868	0.9370
0.22	0.4650	48	4.6880	0.8946	0.0005	0.8956	0.9370
0.22	0.4841	52	5.1649	0.9021	0.0005	0.9031	0.9370
0.22	0.5025	56	5.6419	0.9045	0.0005	0.9055	0.9370
0.22	0.5202	60	6.1189	0.9070	0.0005	0.9080	0.9370
0.22	**0.5267**	**61.5**	**6.2978**	**0.9079**	**0.0005**	**0.9089**	**0.9370**
0.26	0.5013	40	3.7340	0.8701	0.0005	0.8711	0.9370
0.26	0.5260	44	4.2110	0.8853	0.0005	0.8863	0.9370
0.26	0.5495	48	4.6880	0.8961	0.0005	0.8971	0.9370
0.26	0.5721	52	5.1649	0.9024	0.0006	0.9036	0.9370
0.26	0.5938	56	5.6419	0.9053	0.0005	0.9063	0.9370
0.26	0.6148	60	6.1189	0.9059	0.0005	0.9069	0.9370
0.26	0.6225	61.5	6.2978	0.9065	0.0005	0.9075	0.9370
0.3	0.5785	40	3.7340	0.8709	0.0005	0.8719	0.9370
0.3	0.6069	44	4.2110	0.8879	0.0006	0.8891	0.9370
0.3	0.6341	48	4.6880	0.8969	0.0005	0.8979	0.9370
0.3	0.6601	52	5.1649	0.9025	0.0005	0.9035	0.9370
0.3	0.6852	56	5.6419	0.9053	0.0006	0.9065	0.9370
0.3	0.7094	60	6.1189	0.9065	0.0006	0.9077	0.9370
0.3	0.7182	61.5	6.2978	0.9065	0.0005	0.9075	0.9370
0.34	0.6556	40	3.7340	0.8732	0.0005	0.8742	0.9370
0.34	0.6878	44	4.2110	0.8878	0.0005	0.8888	0.9370
0.34	0.7186	48	4.6880	0.8971	0.0005	0.8981	0.9370
0.34	0.7481	52	5.1649	0.9023	0.0005	0.9033	0.9370
0.34	0.7766	56	5.6419	0.9059	0.0005	0.9069	0.9370
0.34	0.8040	60	6.1189	0.9056	0.0005	0.9066	0.9370
0.34	0.8140	61.5	6.2978	0.9050	0.0005	0.9060	0.9370

Table 6-73. NOC, Single Package, 219 kg UO_2, 4.75% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.18	0.3541	40	3.9286	0.8708	0.0005	0.8718	0.9370
0.18	0.3716	44	4.4251	0.8870	0.0006	0.8882	0.9370
0.18	0.3882	48	4.9217	0.8970	0.0005	0.8980	0.9370
0.18	0.4041	52	5.4183	0.9024	0.0005	0.9034	0.9370
0.18	0.4195	56	5.9149	0.9052	0.0005	0.9062	0.9370
0.18	0.4343	60	6.4115	0.9081	0.0005	0.9091	0.9370
0.18	0.4397	61.5	6.5977	0.9078	0.0005	0.9088	0.9370
0.22	0.4328	40	3.9286	0.8736	0.0005	0.8746	0.9370
0.22	0.4541	44	4.4251	0.8881	0.0005	0.8891	0.9370
0.22	0.4745	48	4.9217	0.8981	0.0005	0.8991	0.9370
0.22	0.4939	52	5.4183	0.9048	0.0005	0.9058	0.9370
0.22	0.5127	56	5.9149	0.9067	0.0005	0.9077	0.9370
0.22	0.5308	60	6.4115	0.9074	0.0005	0.9084	0.9370
0.22	0.5374	61.5	6.5977	0.9077	0.0005	0.9087	0.9370
0.26	0.5115	40	3.9286	0.8756	0.0006	0.8768	0.9370
0.26	0.5367	44	4.4251	0.8899	0.0005	0.8909	0.9370
0.26	0.5607	48	4.9217	0.8989	0.0005	0.8999	0.9370
0.26	0.5838	52	5.4183	0.9045	0.0005	0.9055	0.9370
0.26	0.6059	56	5.9149	0.9078	0.0005	0.9088	0.9370
0.26	**0.6273**	**60**	**6.4115**	**0.9085**	**0.0005**	**0.9095**	**0.9370**
0.26	0.6351	61.5	6.5977	0.9071	0.0005	0.9081	0.9370
0.3	0.5902	40	3.9286	0.8755	0.0006	0.8767	0.9370
0.3	0.6193	44	4.4251	0.8898	0.0005	0.8908	0.9370
0.3	0.6470	48	4.9217	0.8996	0.0005	0.9006	0.9370
0.3	0.6736	52	5.4183	0.9042	0.0006	0.9054	0.9370
0.3	0.6991	56	5.9149	0.9064	0.0005	0.9074	0.9370
0.3	0.7238	60	6.4115	0.9070	0.0006	0.9082	0.9370
0.3	0.7328	61.5	6.5977	0.9065	0.0005	0.9075	0.9370
0.34	0.6689	40	3.9286	0.8777	0.0005	0.8787	0.9370
0.34	0.7018	44	4.4251	0.8911	0.0005	0.8921	0.9370
0.34	0.7332	48	4.9217	0.8986	0.0005	0.8996	0.9370
0.34	0.7634	52	5.4183	0.9038	0.0006	0.9050	0.9370
0.34	0.7923	56	5.9149	0.9061	0.0005	0.9071	0.9370
0.34	0.8203	60	6.4115	0.9063	0.0005	0.9073	0.9370
0.34	0.8305	61.5	6.5977	0.9059	0.0005	0.9069	0.9370

Table 6-74. NOC, Single Package, 208 kg UO_2, 4.85% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.2826	40	4.1892	0.8732	0.0005	0.8742	0.9370
0.14	0.2965	44	4.7120	0.8874	0.0005	0.8884	0.9370
0.14	0.3098	48	5.2349	0.8972	0.0005	0.8982	0.9370
0.14	0.3225	52	5.7577	0.9035	0.0005	0.9045	0.9370
0.14	0.3348	56	6.2806	0.9052	0.0005	0.9062	0.9370
0.14	0.3466	60	6.8034	0.9061	0.0005	0.9071	0.9370
0.14	0.3509	61.5	6.9995	0.9056	0.0005	0.9066	0.9370
0.18	0.3634	40	4.1892	0.8751	0.0005	0.8761	0.9370
0.18	0.3813	44	4.7120	0.8888	0.0006	0.8900	0.9370
0.18	0.3983	48	5.2349	0.8992	0.0005	0.9002	0.9370
0.18	0.4147	52	5.7577	0.9052	0.0005	0.9062	0.9370
0.18	0.4304	56	6.2806	0.9059	0.0006	0.9071	0.9370
0.18	0.4456	60	6.8034	0.9072	0.0004	0.9080	0.9370
0.18	0.4512	61.5	6.9995	0.9067	0.0004	0.9075	0.9370
0.22	0.4441	40	4.1892	0.8769	0.0005	0.8779	0.9370
0.22	0.4660	44	4.7120	0.8911	0.0006	0.8923	0.9370
0.22	0.4868	48	5.2349	0.9000	0.0005	0.9010	0.9370
0.22	0.5068	52	5.7577	0.9049	0.0005	0.9059	0.9370
0.22	0.5261	56	6.2806	0.9061	0.0005	0.9071	0.9370
0.22	0.5446	60	6.8034	0.9058	0.0005	0.9068	0.9370
0.22	0.5514	61.5	6.9995	0.9073	0.0005	0.9083	0.9370
0.26	0.5249	40	4.1892	0.8781	0.0005	0.8791	0.9370
0.26	0.5507	44	4.7120	0.8916	0.0005	0.8926	0.9370
0.26	0.5754	48	5.2349	0.9002	0.0006	0.9014	0.9370
0.26	0.5990	52	5.7577	0.9040	0.0005	0.9050	0.9370
0.26	**0.6217**	**56**	**6.2806**	**0.9080**	**0.0006**	**0.9092**	**0.9370**
0.26	0.6437	60	6.8034	0.9063	0.0005	0.9073	0.9370
0.26	0.6517	61.5	6.9995	0.9057	0.0005	0.9067	0.9370
0.3	0.6056	40	4.1892	0.8788	0.0006	0.8800	0.9370
0.3	0.6354	44	4.7120	0.8923	0.0005	0.8933	0.9370
0.3	0.6639	48	5.2349	0.9011	0.0006	0.9023	0.9370
0.3	0.6911	52	5.7577	0.9042	0.0006	0.9054	0.9370
0.3	0.7174	56	6.2806	0.9067	0.0006	0.9079	0.9370
0.3	0.7427	60	6.8034	0.9051	0.0005	0.9061	0.9370
0.3	0.7520	61.5	6.9995	0.9041	0.0004	0.9049	0.9370

Table 6-75. NOC, Single Package, 202 kg UO_2, 4.95% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.2868	40	4.3433	0.8773	0.0005	0.8783	0.9370
0.14	0.3009	44	4.8817	0.8918	0.0005	0.8928	0.9370
0.14	0.3144	48	5.4201	0.9005	0.0006	0.9017	0.9370
0.14	0.3273	52	5.9584	0.9056	0.0005	0.9066	0.9370
0.14	0.3397	56	6.4968	0.9081	0.0005	0.9091	0.9370
0.14	0.3517	60	7.0352	0.9086	0.0005	0.9096	0.9370
0.14	0.3561	61.5	7.2371	0.9080	0.0005	0.9090	0.9368
0.18	0.3687	40	4.3433	0.8788	0.0005	0.8798	0.9370
0.18	0.3869	44	4.8817	0.8934	0.0006	0.8946	0.9370
0.18	0.4042	48	5.4201	0.9016	0.0006	0.9028	0.9370
0.18	0.4208	52	5.9584	0.9069	0.0005	0.9079	0.9370
0.18	0.4368	56	6.4968	0.9078	0.0005	0.9088	0.9370
0.18	**0.4522**	**60**	**7.0352**	**0.9098**	**0.0006**	**0.9110**	**0.9370**
0.18	0.4578	61.5	7.2371	0.9082	0.0005	0.9092	0.9368
0.22	0.4507	40	4.3433	0.8815	0.0005	0.8825	0.9370
0.22	0.4728	44	4.8817	0.8947	0.0005	0.8957	0.9370
0.22	0.4940	48	5.4201	0.9020	0.0005	0.9030	0.9370
0.22	0.5143	52	5.9584	0.9067	0.0005	0.9077	0.9370
0.22	0.5338	56	6.4968	0.9082	0.0006	0.9094	0.9370
0.22	0.5527	60	7.0352	0.9077	0.0005	0.9087	0.9370
0.22	0.5596	61.5	7.2371	0.9071	0.0005	0.9081	0.9368
0.26	0.5326	40	4.3433	0.8820	0.0006	0.8832	0.9370
0.26	0.5588	44	4.8817	0.8965	0.0006	0.8977	0.9370
0.26	0.5838	48	5.4201	0.9030	0.0005	0.9040	0.9370
0.26	0.6078	52	5.9584	0.9065	0.0005	0.9075	0.9370
0.26	0.6309	56	6.4968	0.9077	0.0005	0.9087	0.9370
0.26	0.6532	60	7.0352	0.9074	0.0004	0.9082	0.9370
0.26	0.6613	61.5	7.2371	0.9068	0.0005	0.9078	0.9368
0.3	0.6146	40	4.3433	0.8840	0.0005	0.8850	0.9370
0.3	0.6448	44	4.8817	0.8953	0.0005	0.8963	0.9370
0.3	0.6737	48	5.4201	0.9037	0.0005	0.9047	0.9370
0.3	0.7013	52	5.9584	0.9070	0.0005	0.9080	0.9370
0.3	0.7280	56	6.4968	0.9079	0.0005	0.9089	0.9370
0.3	0.7536	60	7.0352	0.9079	0.0006	0.9091	0.9370
0.3	0.7630	61.5	7.2371	0.9057	0.0006	0.9069	0.9368

Table 6-76. NOC, Single Package, 197 kg UO_2, 5.00% Enriched Heterogeneous Material

Diameter, cm	pitch, cm	Stack height, cm	W/F Ratio	keff	σ	keff+2σ	USL
0.14	0.2904	40	4.4790	0.8791	0.0005	0.8801	0.9370
0.14	0.3047	44	5.0310	0.8927	0.0005	0.8937	0.9370
0.14	0.3183	48	5.5830	0.9005	0.0005	0.9015	0.9370
0.14	0.3314	52	6.1351	0.9064	0.0005	0.9074	0.9370
0.14	0.3440	56	6.6871	0.9077	0.0006	0.9089	0.9370
0.14	0.3561	60	7.2391	0.9077	0.0005	0.9087	0.9368
0.14	0.3606	61.5	7.4461	0.9074	0.0005	0.9084	0.9365
0.18	0.3734	40	4.4790	0.8813	0.0005	0.8823	0.9370
0.18	0.3918	44	5.0310	0.8935	0.0005	0.8945	0.9370
0.18	0.4093	48	5.5830	0.9026	0.0005	0.9036	0.9370
0.18	0.4261	52	6.1351	0.9064	0.0005	0.9074	0.9370
0.18	0.4423	56	6.6871	0.9074	0.0006	0.9086	0.9370
0.18	0.4579	60	7.2391	0.9075	0.0005	0.9085	0.9368
0.18	0.4636	61.5	7.4461	0.9073	0.0005	0.9083	0.9365
0.22	0.4564	40	4.4790	0.8826	0.0005	0.8836	0.9370
0.22	0.4788	44	5.0310	0.8957	0.0006	0.8969	0.9370
0.22	0.5002	48	5.5830	0.9034	0.0005	0.9044	0.9370
0.22	0.5208	52	6.1351	0.9072	0.0005	0.9082	0.9370
0.22	0.5406	56	6.6871	0.9079	0.0005	0.9089	0.9370
0.22	0.5596	60	7.2391	0.9078	0.0005	0.9088	0.9368
0.22	0.5666	61.5	7.4461	0.9067	0.0005	0.9077	0.9365
0.26	0.5393	40	4.4790	0.8838	0.0005	0.8848	0.9370
0.26	0.5659	44	5.0310	0.8951	0.0005	0.8961	0.9370
0.26	0.5912	48	5.5830	0.9040	0.0005	0.9050	0.9370
0.26	**0.6155**	**52**	**6.1351**	**0.9080**	**0.0006**	**0.9092**	**0.9370**
0.26	0.6389	56	6.6871	0.9077	0.0005	0.9087	0.9370
0.26	0.6614	60	7.2391	0.9066	0.0005	0.9076	0.9368
0.26	0.6696	61.5	7.4461	0.9061	0.0005	0.9071	0.9365
0.3	0.6223	40	4.4790	0.8852	0.0005	0.8862	0.9370
0.3	0.6529	44	5.0310	0.8970	0.0005	0.8980	0.9370
0.3	0.6821	48	5.5830	0.9039	0.0006	0.9051	0.9370
0.3	0.7102	52	6.1351	0.9076	0.0006	0.9088	0.9370
0.3	0.7371	56	6.6871	0.9071	0.0005	0.9081	0.9370
0.3	0.7631	60	7.2391	0.9056	0.0005	0.9066	0.9368
0.3	0.7727	61.5	7.4461	0.9055	0.0005	0.9065	0.9365

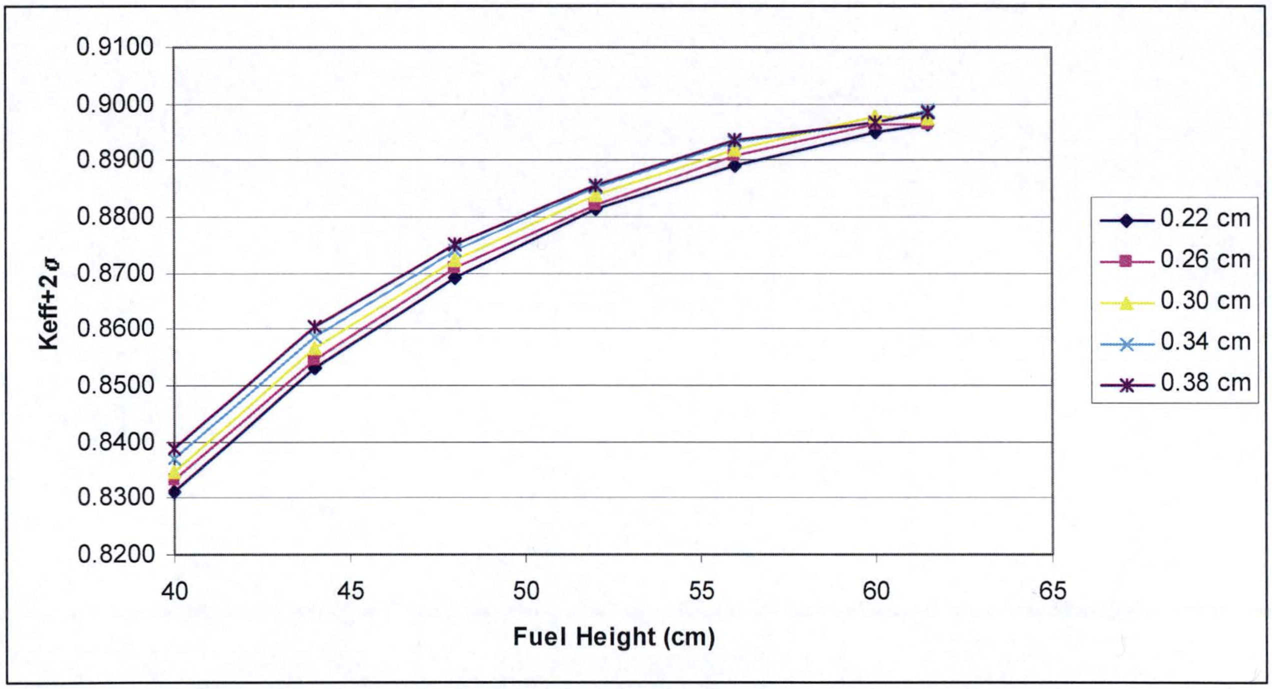

Figure 6-52. NOC, Single Package, 4.05 wt.% Heterogeneous Material

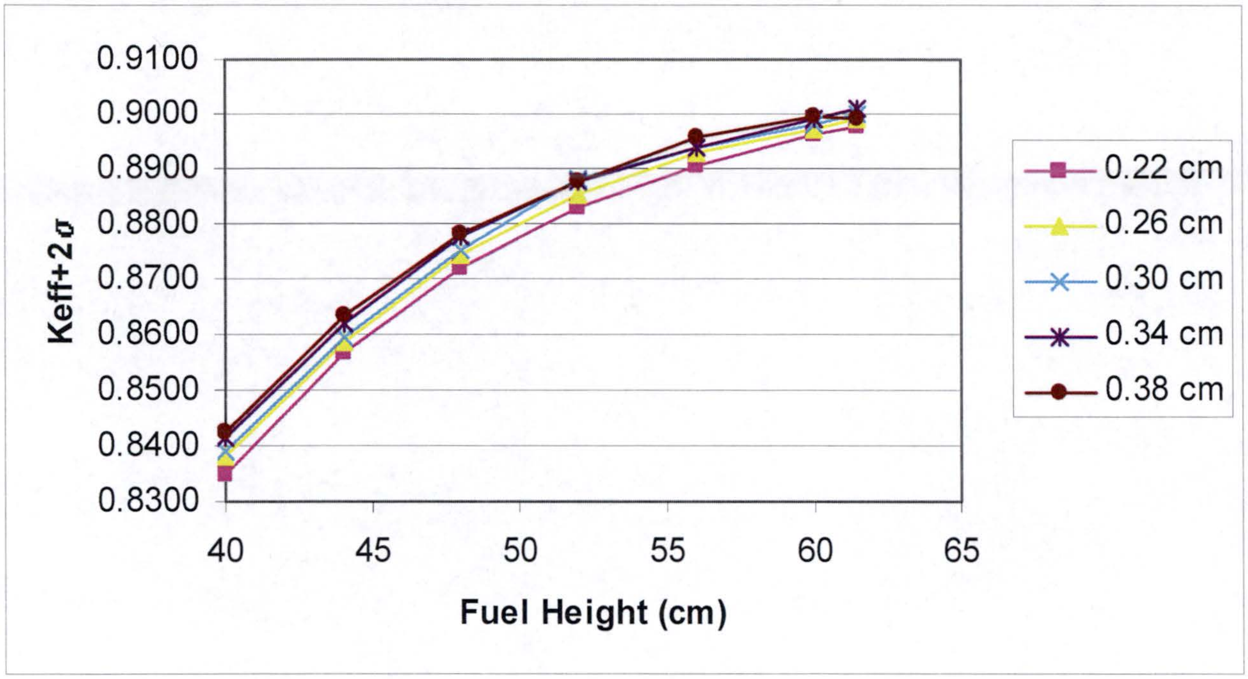

Figure 6-53. NOC, Single Package, 4.10 wt.% Heterogeneous Material

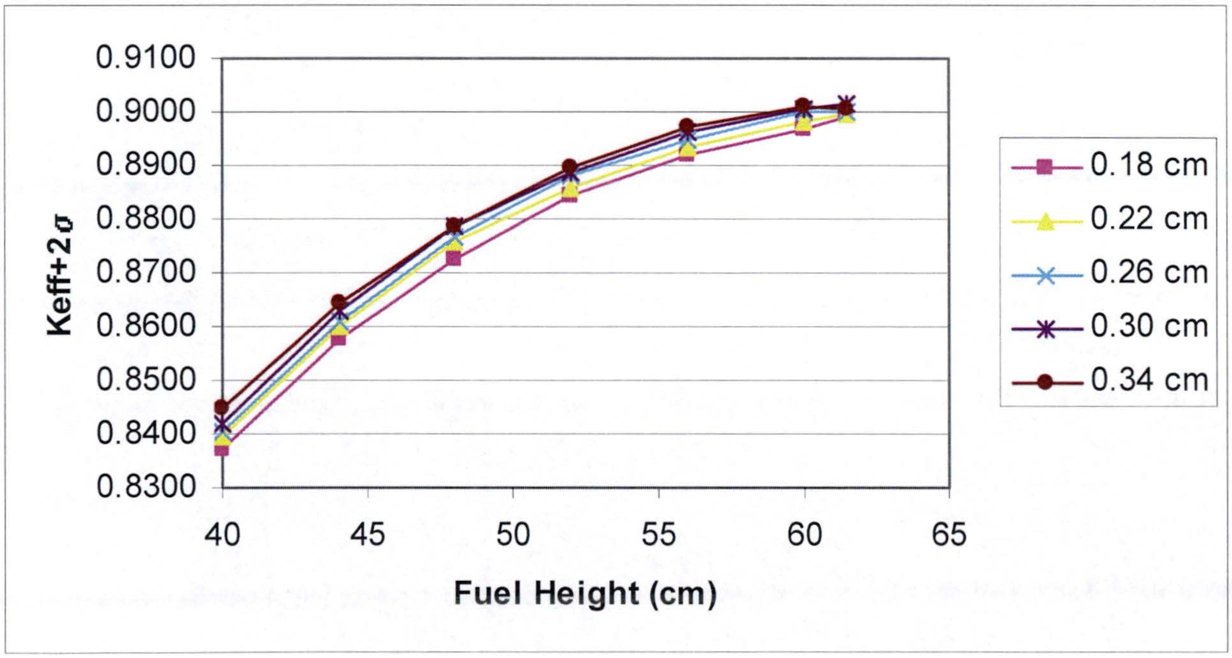

Figure 6-54. NOC, Single Package, 4.15 wt.% Heterogeneous Material

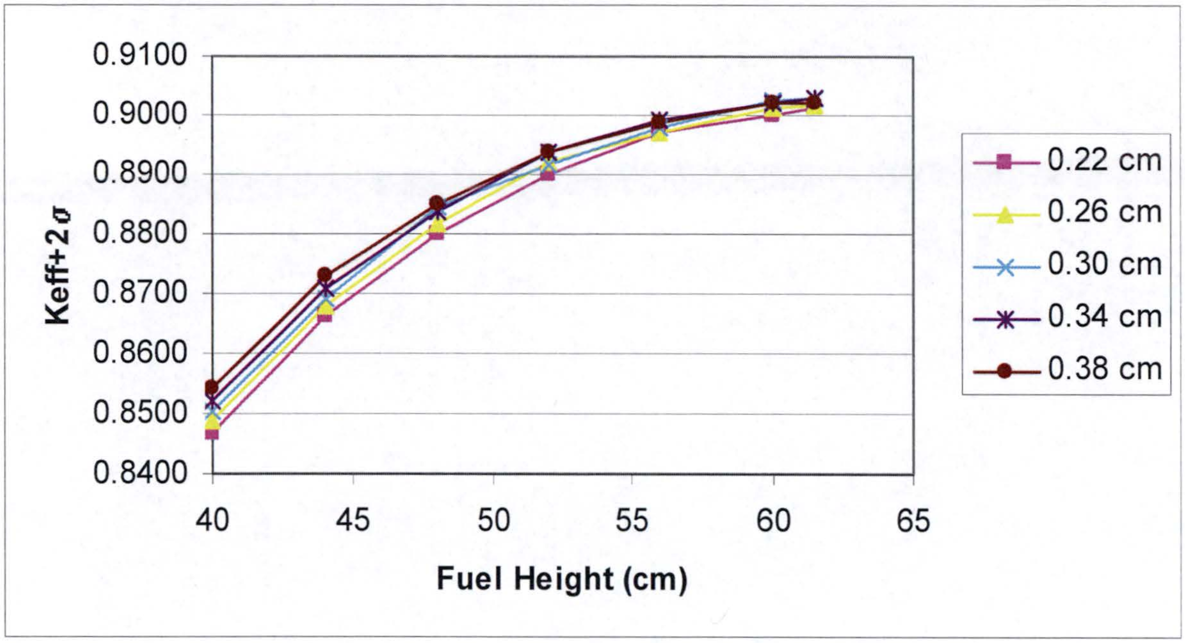

Figure 6-55. NOC, Single Package, 4.25 wt.% Heterogeneous Material

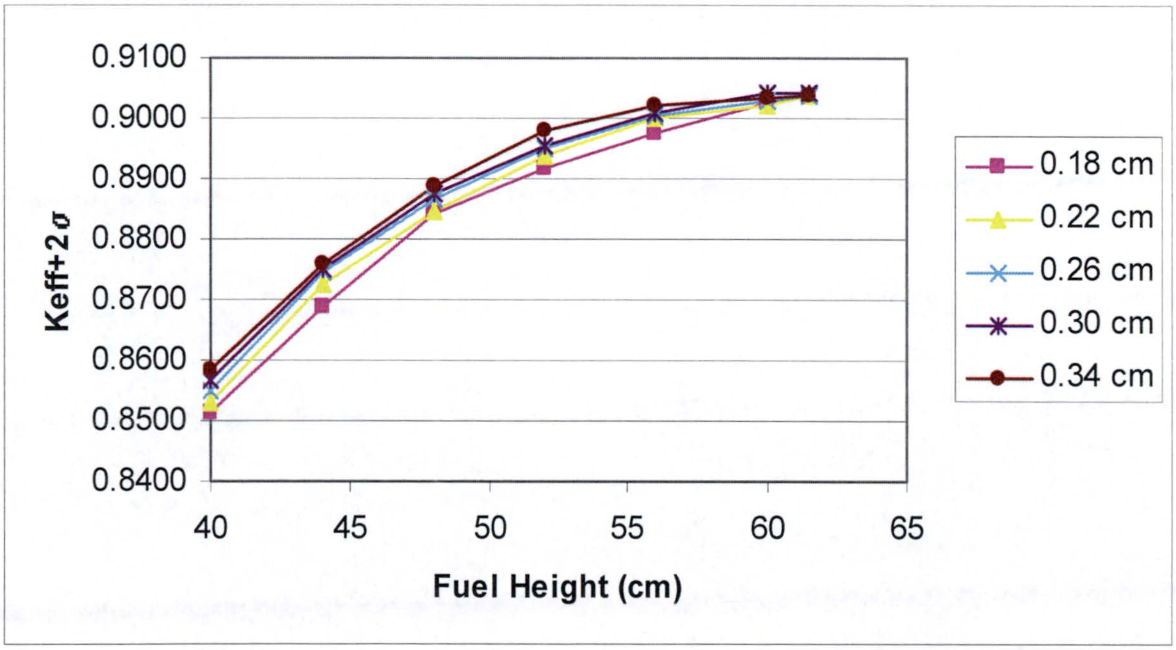

Figure 6-56. NOC, Single Package, 4.35 wt.% Heterogeneous Material

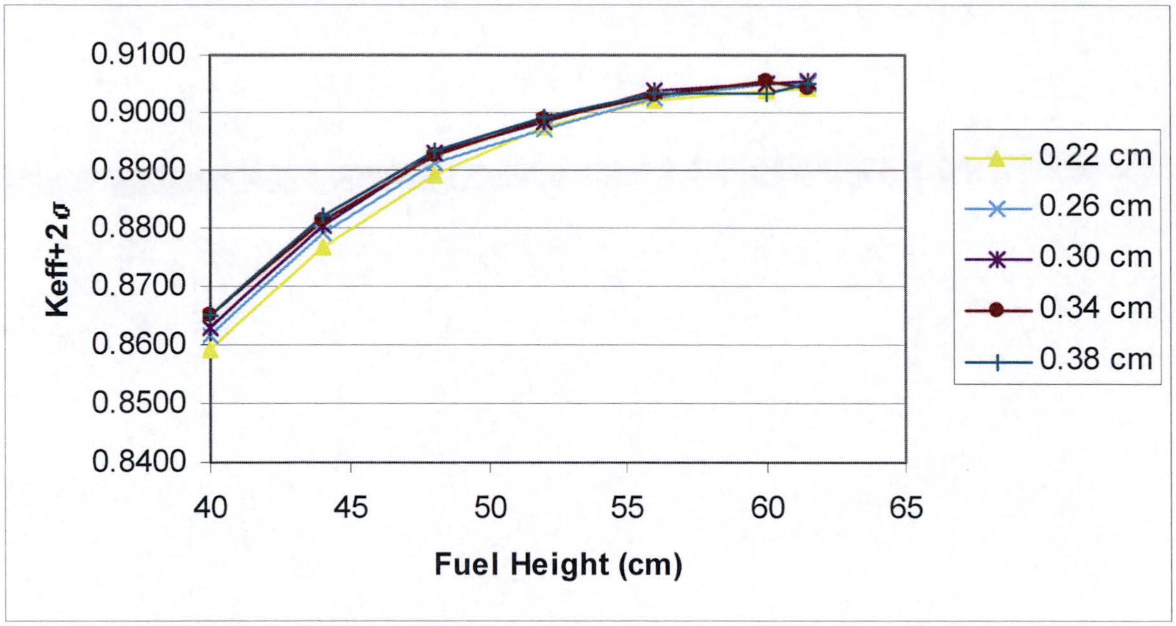

Figure 6-57. NOC, Single Package, 4.45 wt.% Heterogeneous Material

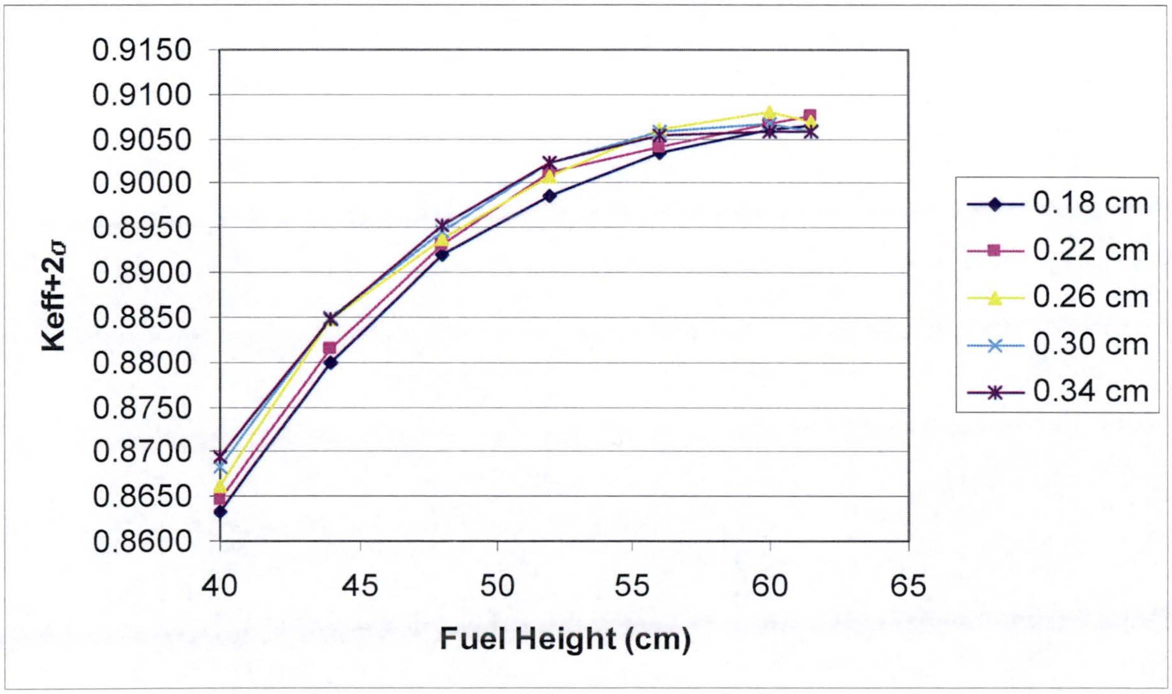

Figure 6-58. NOC, Single Package, 4.55 wt.% Heterogeneous Material

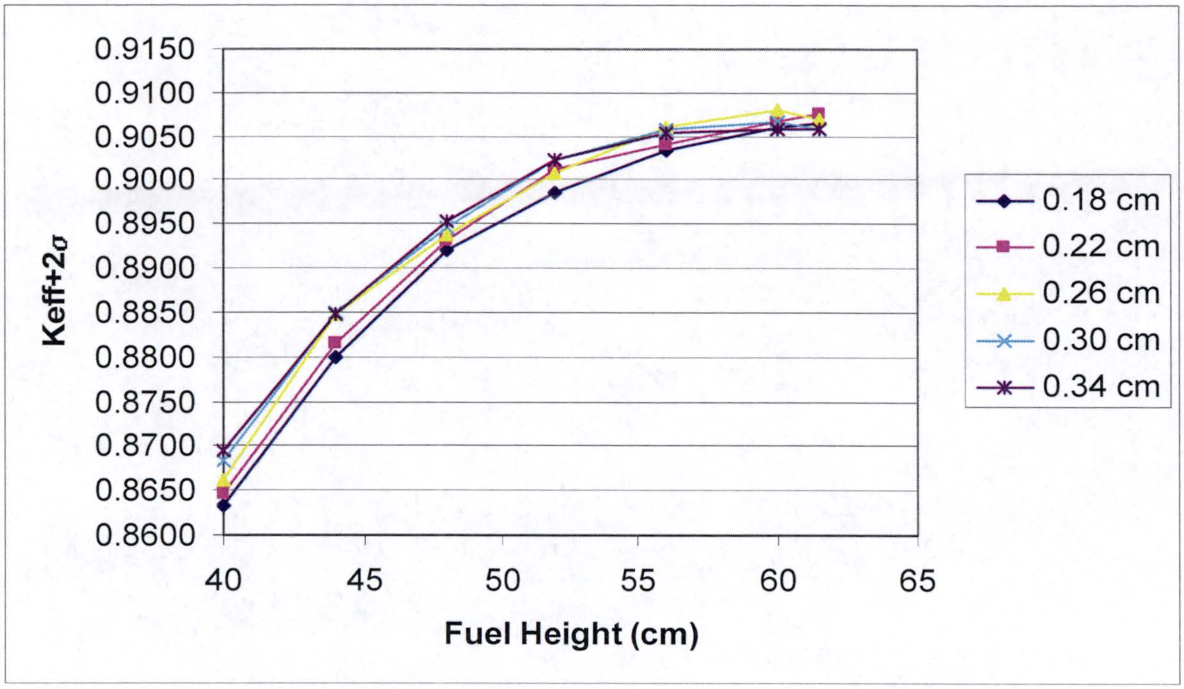

Figure 6-59. NOC, Single Package, 4.65 wt.% Heterogeneous Material

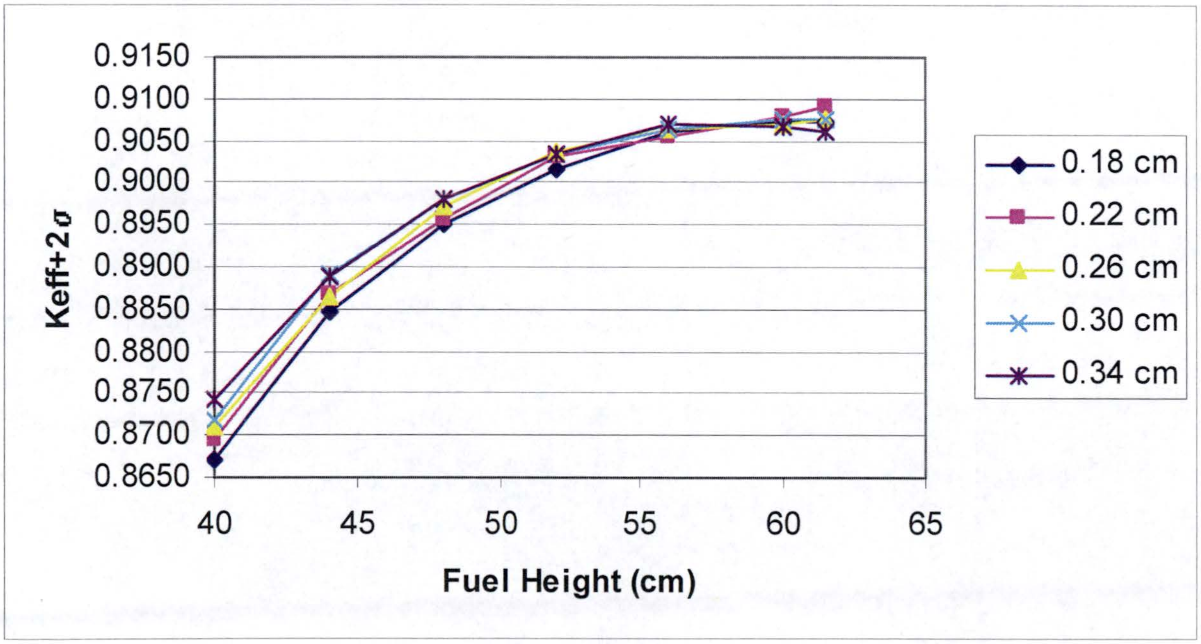

Figure 6-60. NOC, Single Package, 4.75 wt.% Heterogeneous Material

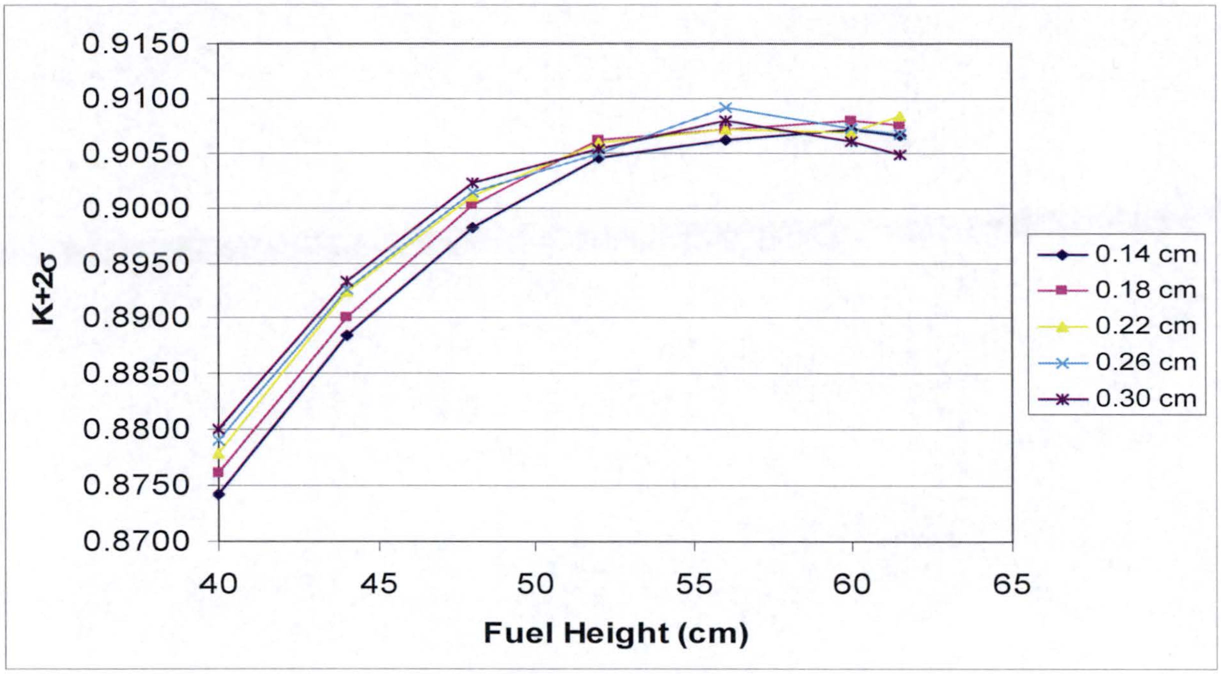

Figure 6-61. NOC, Single Package, 4.85 wt.% Heterogeneous Material

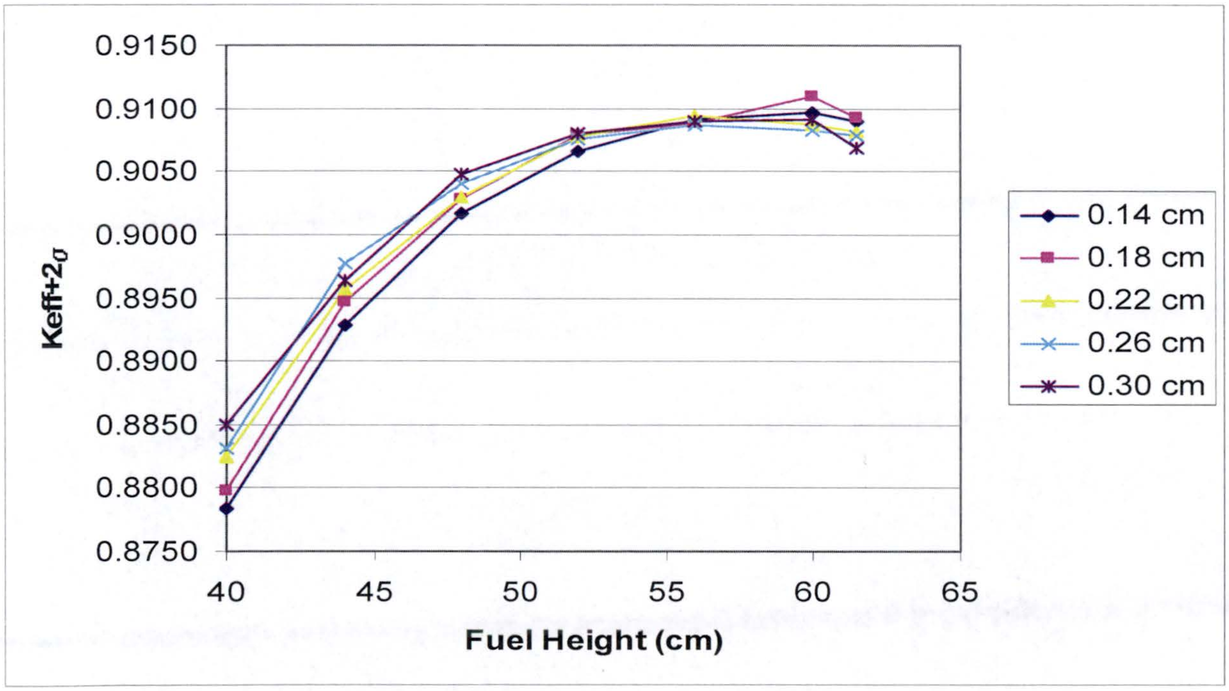

Figure 6-62. NOC, Single Package, 4.95 wt.% Heterogeneous Material

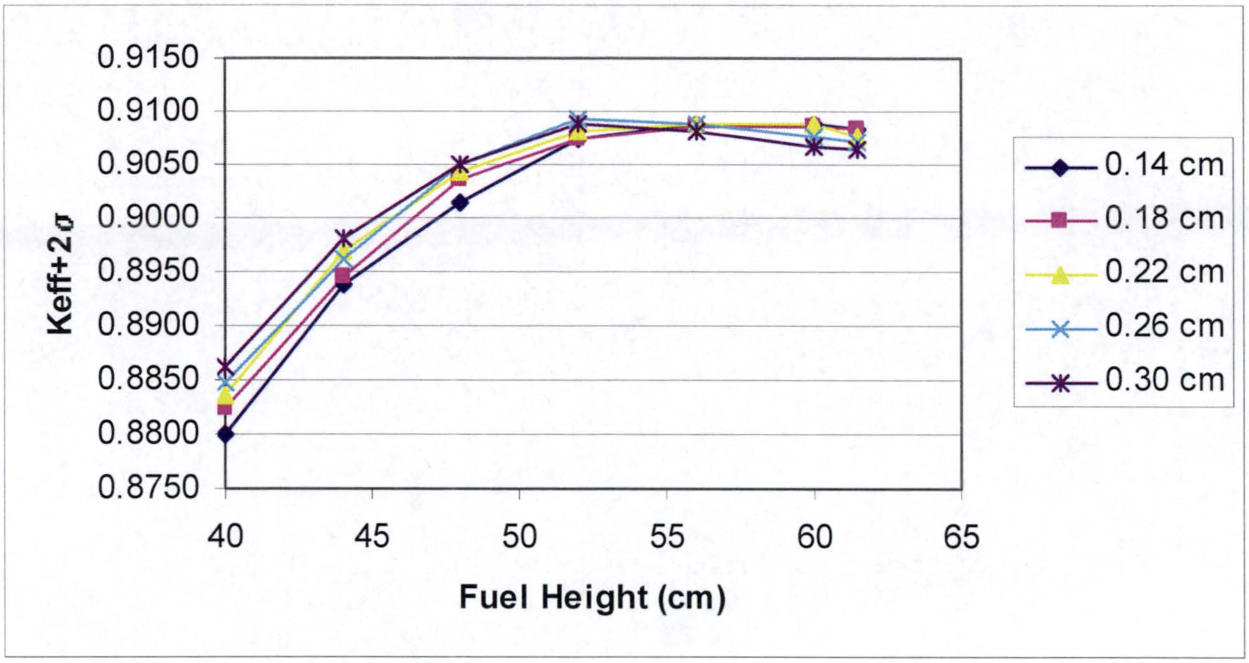

Figure 6-63. NOC, Single Package, 5.00 wt.% Heterogeneous Material

6.4.3 Criticality Safety Index

The number of packages that remain below the USL determines the CSI for criticality control. The number of packages to be transported at one time is set at 108. For normal conditions of transport, an array size of 8×9×8 (5N=540) was shown to remain subcritical. Under hypothetical accident conditions, an array size of 6×6×6 (2N=216) was also shown to remain subcritical. Thus, CSI=50/108=0.5.

6.5 Critical Benchmark Experiments

The results of this benchmark are used in the analysis of the TNF-XI containers. Two types of analysis is performed. One involves a payload of optimally moderated uranium oxide powder, and the other involves pellets or scraps of uranium oxide fuel. The input files for all benchmarks are taken from References [8] and [9]. The number of sampling histories is increased in all input files to reduce the statistical deviation associated with the Monte Carlo method. For the powder benchmark, cases that use the "multiregion" unit cell data are modified to "infinite homogeneous." The rod benchmark cases are modified to run the CSAS2X sequence and the fuel region is represented by a "mixture 500." This method generates cell-weighted cross sections in the XSDRNPM code to be used in the KENO calculation. These methods are selected to be consistent with the technique used to analyze the contents of the two packages.

An upper subcritical limit (USL) is determined as a function of several experimental variables. The values are then applied using Method 1 "confidence band with administrative margin", described in Section 4.1.1 of Reference [3]. The administrative margin is 0.05, and the confidence level $1-\gamma_1$ is 0.95. Excel spreadsheet functions and the ORNL program USLSTATS version1.3.7 are used to do the statistical analysis of the data.

6.5.1 Critical Experiment Characteristics

6.5.1.1 Description of Powder Cases

Critical experiments chosen to represent a UO_2 powder and water mixture include those that feature low enriched, homogeneous, and well-moderated systems without dissolved boron such as UF_2 solutions, and Uranium-paraffin mixtures. A total of 18 experiments were found to be sufficient for this benchmark, and are listed in Table 6-77.

Three independent variables were used in the analysis, enrichment, Hydrogen to fissile material ratio (H/X), and the average energy of the fission-causing neutron (AEF). Figures 6-64, 6-65, and 6-66 show the plots of each independent variable as a function of the k_{eff} value calculated in KENOVa. The USL value calculated from USLSTATS is also shown.

6.5.1.2 Description of Pellet Cases

Experiments chosen for the pellet scenario feature low enriched simple arrays with steel and/or water reflector walls in water without soluble boron. A total of 27 cases were used for the benchmark and are listed in Table 6-78. In addition to enrichment, H/X, and AEF, the volume ratio of water to fuel was also used as an independent variable. Figures 6-67 through 6-70 show the plots of each independent variable as a function of the k_{eff} value calculated in KENOVa. The USL value calculated from USLSTATS is also shown.

An additional set of experiments is chosen to account for the borated material in the packages. The most appropriate representative experiments available contain borated separator plates made of either borated stainless steel, borated aluminum (Boral), or a hydro-boron hybrid polymer (Boroflex). The independent variable used for the statistical analysis is B-10 areal density. A total of 17 cases, listed in Table 6-79, are used in the benchmark. Figure 6-71 shows a plot of the results.

6.5.2 Analysis of the Results

The data are analyzed to determine if there is a trend in the bias as a function of the independent variables. A least mean squares linear regression is performed to fit the data of K_{eff} as a function of the independent variable. This is done with both the ULSTATS program and with the Excel LINEST function. The results agree.

Table 6-77. Critical Experiment Models and Results - Powder Cases

File Name	Enr (wt%)	H/X	AEF (eV)	K	σ
Caa35	4.89	526.2	4.88E-02	1.0040	0.0008
Caa36	4.89	526.2	4.77E-02	1.0071	0.0008
Caa37	4.89	734	4.17E-02	1.0017	0.0008
Caa38	4.89	1094.2	3.61E-02	0.9974	0.0007
Caa39	4.89	991	3.74E-02	0.9995	0.0008
Cas11	2.00	195.2	1.98E-01	1.0032	0.0008
Cas13	2.00	293.9	1.16E-01	1.0036	0.0008
Cas15	2.00	406.3	8.31E-02	1.0019	0.0008
Cas16	2.00	495.9	7.02E-02	0.9988	0.0008
Cas17	2.00	613.6	6.03E-02	1.0005	0.0008
Cas19	2.00	971.7	4.66E-02	0.9940	0.0006
Cas21	3.00	133.4	2.34E-01	1.0147	0.0010
Cas22	3.00	133.4	2.35E-01	1.0152	0.0009
Cas23	3.00	133.4	2.34E-01	1.0158	0.0008
Cas24	3.00	133.4	2.34E-01	1.0139	0.0008
Cas25	3.00	133.4	2.34E-01	1.0153	0.0009
Cas29	3.00	276.9	9.18E-02	1.0134	0.0010
Cas34	4.98	488	5.35E-02	1.0014	0.0008

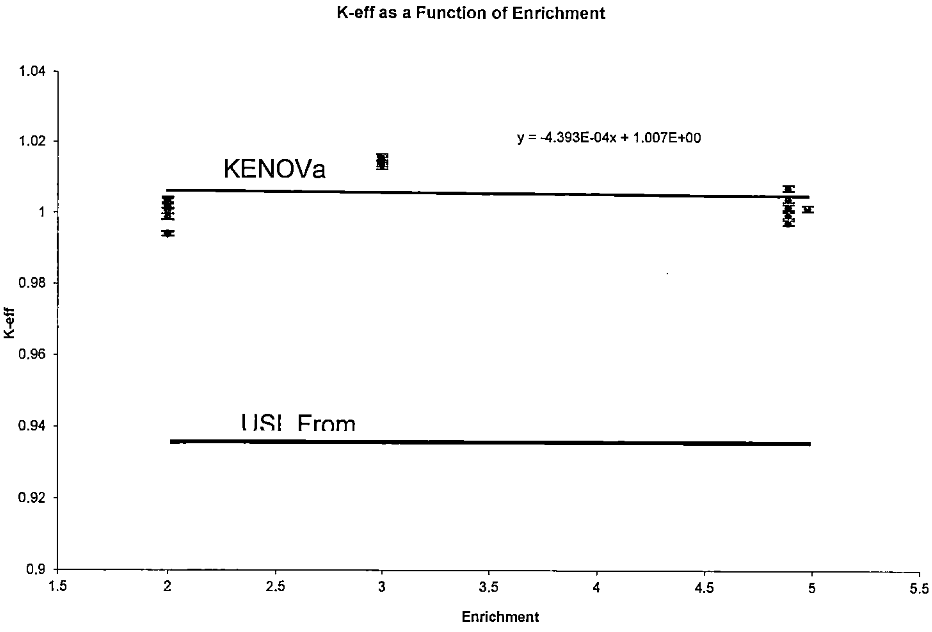

Figure 6-64. k-eff Vs Enrichment – Powder

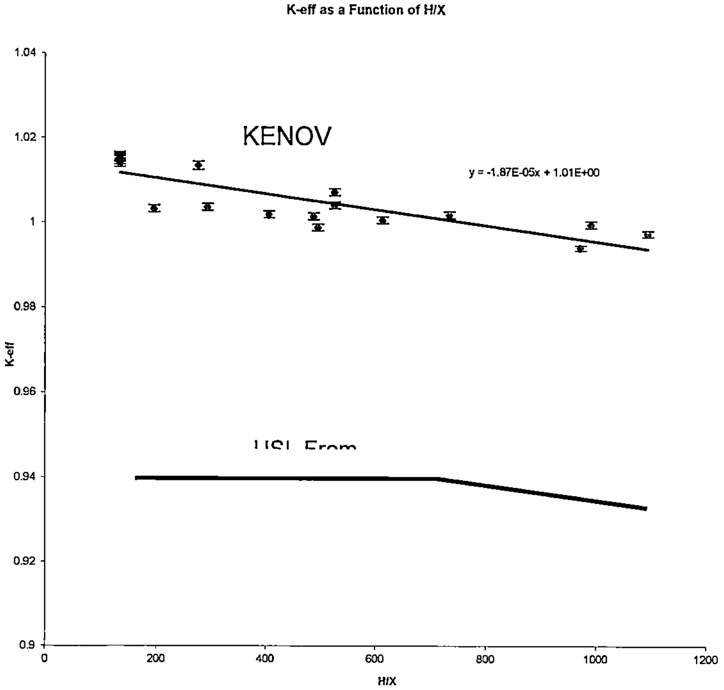

Figure 6-65. k–eff as a Function of H/X – Powder

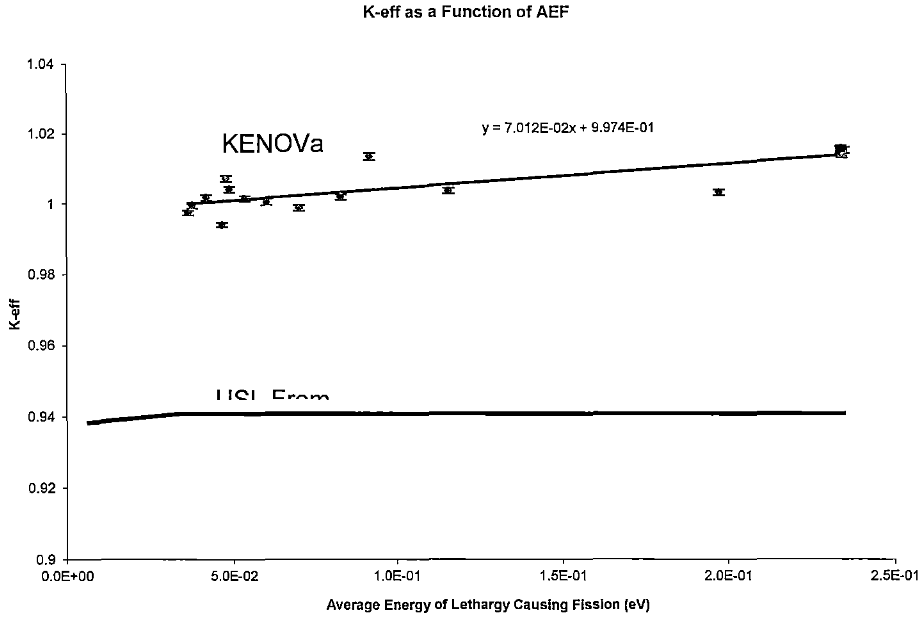

Figure 6-66. k-eff Vs AEF – Powder

Table 6-78. Critical Experiment Models for Pellet Cases

File Name	WaterV:FuelV	Enr (wt%)	H/X	AEF (eV)	K	σ
Bw1484sl.in	1.841	2.46	216.10	1.30E-01	0.9979	0.0009
Caa02.inp	2.710	4.89	76.10	3.15E-01	0.9975	0.0010
Caa03.inp	2.710	4.89	75.70	1.35E-01	1.0032	0.0011
Caa04.inp	8.220	4.89	230.00	1.23E-01	0.9922	0.0009
Caa05.inp	8.220	4.89	230.00	1.12E-01	0.9940	0.0009
Epru65.in	1.196	2.35	163.60	2.48E-01	0.9974	0.0010
Epru75.in	2.408	2.35	329.4	1.09E-01	1.0001	0.0009
P2438slg.in	2.918	2.35	398.7	9.08E-02	1.0026	0.0007
P2827slg.in	2.918	2.35	398.7	9.04E-02	1.0017	0.0008
P3314slg.in	1.600	4.31	105.4	2.16E-01	1.0026	0.0010
P3602n11.in	1.600	2.35	218.6	1.73E-01	1.0092	0.0008
P3602n12.in	1.600	2.35	218.6	1.66E-01	1.0087	0.0009
P3602n13.in	1.600	2.35	218.6	1.60E-01	1.0057	0.0009
P3602n14.in	1.600	2.35	218.6	1.54E-01	1.0007	0.0007
P3602n21.in	2.918	2.35	398.7	9.12E-02	1.0052	0.0007
P3602n22.in	2.918	2.35	398.7	9.37E-02	1.0089	0.0008
P3602n31.in	1.600	4.31	105.4	2.98E-01	1.0124	0.0010
P3602n32.in	1.600	4.31	105.4	2.86E-01	1.0111	0.0010
P3602n33.in	1.600	4.31	105.4	2.76E-01	1.0100	0.0009
P3602n34.in	1.600	4.31	105.4	2.69E-01	1.0088	0.0009
P3602n35.in	1.600	4.31	105.4	2.65E-01	1.0069	0.0009
P3602n36.in	1.600	4.31	105.4	2.57E-01	1.0041	0.0009
P3602n41.in	3.883	4.31	256.1	1.16E-01	1.0190	0.0008
P3602n42.in	3.883	4.31	256.1	1.09E-01	1.0164	0.0009
P3602n43.in	3.883	4.31	256.1	1.05E-01	1.0124	0.0008
P3926sl1.in	1.600	2.35	218.6	1.52E-01	1.0011	0.0008
P3926sl2.in	1.600	4.31	105.4	2.59E-01	1.0011	0.0008

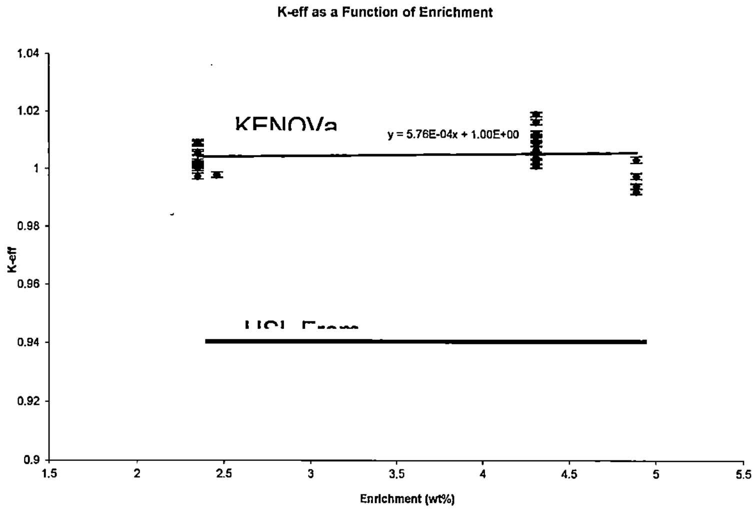

Figure 6-67. k-eff Vs Enrichment – Pellets

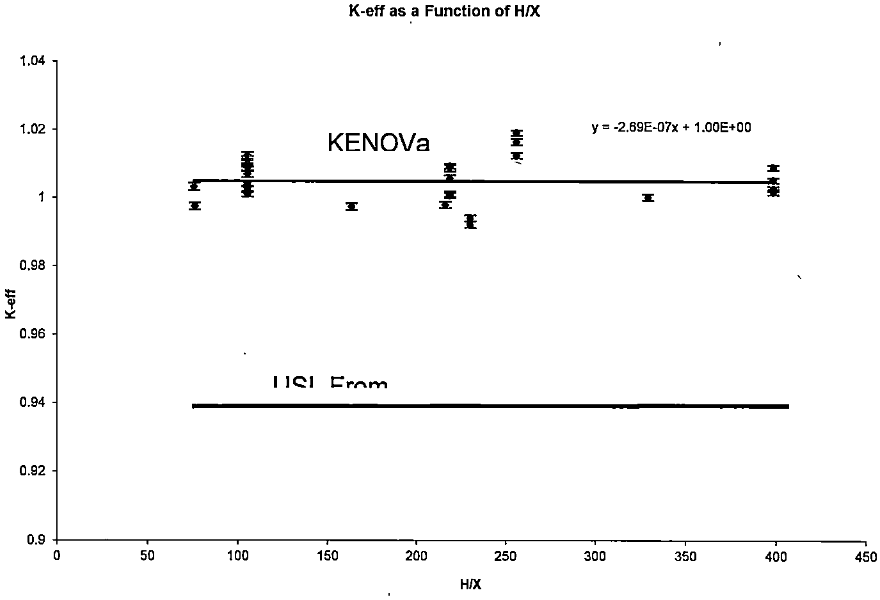

Figure 6-68. k-eff Vs H/X – Pellets

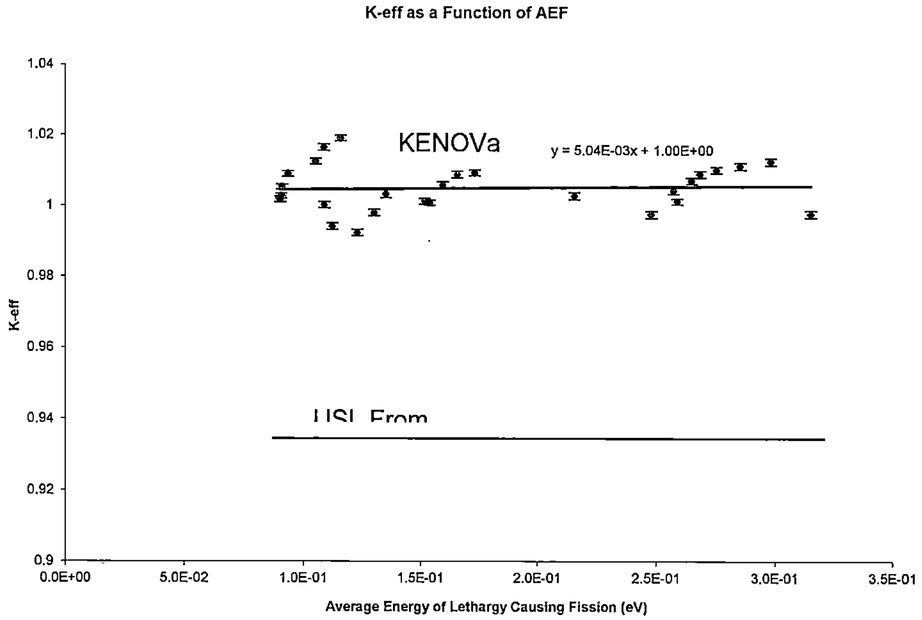

Figure 6-69. k-eff Vs AEF – Pellets

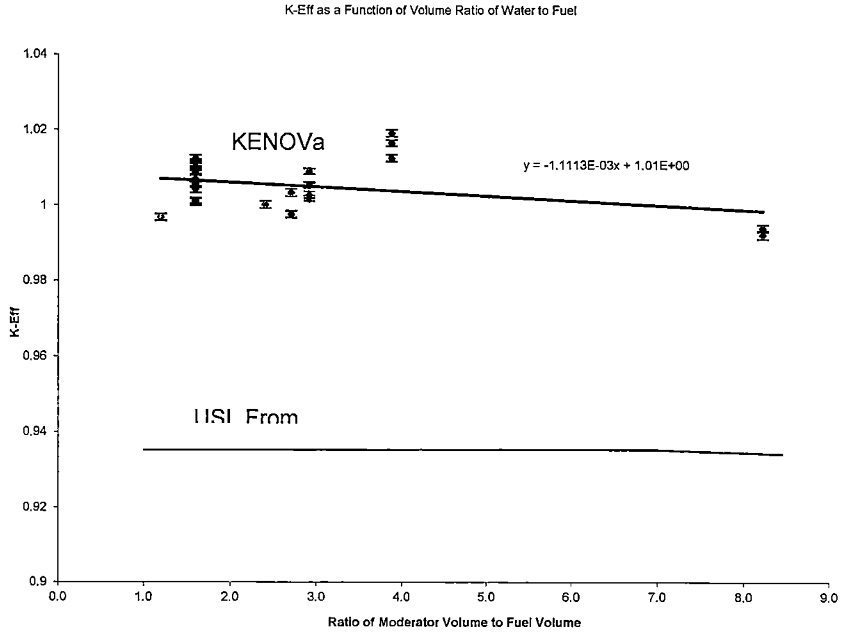

Figure 6-70. k-eff Vs Water to Fuel Volume Ratio – Pellets

Table 6-79. Critical Experiment Models with Borated Plates

Filename	B-10 (g/cm^2)	K	σ
P2438ba.in	0.067000	0.9977	0.0008
P2615ba.in	0.067000	0.9998	0.0009
P3314ba.in	0.067000	0.9992	0.0008
P3314bc.in	0.026300	1.0009	0.0008
P3314bf1.in	0.023600	1.0026	0.0008
P3314bf2.in	0.047200	1.0030	0.0009
P3314bs1.in	0.004600	0.9957	0.0009
P3314bs2.in	0.006900	0.9943	0.0008
P3314bs3.in	0.004600	1.0003	0.0010
P3314bs4.in	0.006900	1.0010	0.0009
P3602bb.in	0.040800	1.0034	0.0009
P3602bs1.in	0.004556	1.0014	0.0008
P3602bs2.in	0.004113	1.0049	0.0009
Pat80l1.in	0.046100	0.9979	0.0023
Pat80l2.in	0.046100	0.9959	0.0009
Pat80ss1.in	0.046100	0.9980	0.0009
Pat80ss2.in	0.046100	0.9952	0.0009

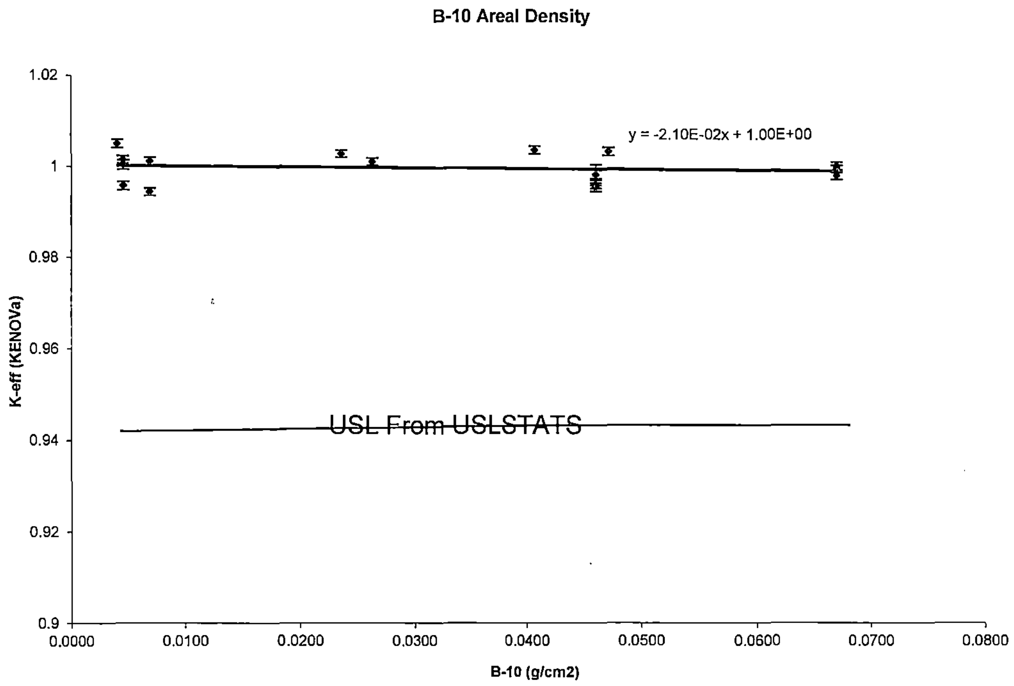

Figure 6-71. k-eff Vs B-10 Areal Density

6.5.3 USL Determination

The USL results for the powder cases (from USLSTATS output) are given below:

Enrichment:

```
USL Method 1 (Confidence Band with
    Administrative Margin)          USL1 = 0.9360 (   2.0000   < X <   4.9800)
```

H/X:

```
USL Method 1 (Confidence Band with
    Administrative Margin)          USL1 = 0.9559 + (-1.8674E-05)*X (X >   761.67)
                                         = 0.9416                   (X <= 761.67)
```

AEF:

```
USL Method 1 (Confidence Band with
    Administrative Margin)          USL1 = 0.9393 + ( 7.0102E-02)*X (X <    3.64354E-2)
                                         = 0.9418                    (X >=  0.036)
```

The USL for analysis of a powder payload for the packages will be 0.9360.

The USLSTAT results for the pellet cases are given below.

Enrichment:

```
USL Method 1 (Confidence Band with
    Administrative Margin)          USL1 = 0.9380 (   2.3500   < X <   4.8900)
```

H/X:

```
USL Method 1 (Confidence Band with
    Administrative Margin)          USL1 = 0.9376 (   75.700   < X <   398.70)
```

AEF:

```
USL Method 1 (Confidence Band with
    Administrative Margin)          USL1 = 0.9376 ( 9.04169E-2< X < 0.31550)
```

Water to Fuel Volume Ratio:

```
USL Method 1 (Confidence Band with
    Administrative Margin)          USL1 = 0.9448 + (-1.1113E-03)*X (X >     7.0081)
                                         = 0.9370                    (X <=    7.008)
```

The USL for analysis of a powder payload for the packages will depend on the water to fuel volume ratio.

The USLSTAT results for the B-10 cases are given below (File bor):

```
USL Method 1 (Confidence Band with

    Administrative Margin)            USL1 = 0.9438 - ( 2.0952E-02)*X (X >   7.9393E-3)
                                           = 0.9436                   (X <=   0.008)
```

The USL for B-10 Content will depend on the value. Since the B-10 areal density is constant for each package, the B-10 based USL for each package is determined below:

$$\text{B-10 Areal Density} = 2 \text{ x } (\text{B-10 Density}) \text{ x } (\text{thickness})$$

For the TNF-XI (Ref 9) the total areal density between any 2 fuel-containing cylinders is equal to twice the sum of the areal densities of two borated stainless steel plates and the BORA resin.

$$\begin{aligned}\text{B-10 } (\text{g/cm}^2) &= 2 \text{ x } [(7.85\text{g/cc}) \text{ x } (0.0075) \text{ x } (0.18) \text{ x } (0.2\text{cm})] + \\ &\quad [(1.74\text{g/cc}) \text{ x } (0.1) \text{ x } (0.135) \text{ x } (3.4\text{cm})] \\ &= 0.164\text{g/cm}^2\end{aligned}$$

Therefore the B-10 USL for the TNF-XI is 0.9404. It is important to note that the although B-10 areal density for the TNF-XI is outside of the range of variables analyzed, but the B-10 results had a much higher USL with a very small trend as shown in Figure 8.

6.5.4 USL Results Summary

The plots of k_{eff} as a function of the independent variables tend to show a noticeable positive bias. This is expected because infinite homogeneous KENOVa models, and KENOVa models that are run with cell weighted cross sections tend to be conservative, and therefore overestimate k_{eff}. It is then important to note that USLSTATS takes no credit for a positive bias.

Although the experiments fall short of 5% enrichment, it is generally acceptable to extrapolate slightly outside of the range, as stated in section 4.1 of Reference [8]. Therefore the 5% enriched fuel can be applied to both of these benchmarks.

In the powder cases it was determined that the minimum value of the USL is 0.9360, based on the USLSTATS results from the enrichment analysis. The USL from H/X could be lower if H/X > 761.67, but this is unlikely.

In the pellet cases it was determined that the water to fuel volume ratio results in the minimum USL.

The analysis of critical experiments with borated separators shows that the bias is nearly independent of boron areal density, and that the resulting USL is much higher the two just cited. Therefore, the boron separator cases will not determine the USL for either pellet or powder contents.

6.6 Computer Program Description

6.6.1 KENO Va Code

SCALE 4.4 [3] is an extensive computer package that has many applications including cross section processing, criticality studies, and heat transfer analyses among others. The package is comprised of many functional modules, which can be run independently of each other. Control Modules were created to combine certain functional modules in order to make the input requirements less complex and shorter. For the purpose of this analysis, only four functional modules are used and two control modules; the Control Module CSAS25, which includes the three dimensional criticality code KENO-Va and the preprocessing codes BONAMI-S and NITAWL-II, and control module CSAS2X, which includes an additional XSDRNPM-S sequence for calculating cell-averaged cross sections.

KENO Va, in conjunction with a suitable working library of nuclear cross section data, is used to calculate the multiplication factor, k_{eff}, of systems of fissile material. It can also compute lifetime and generation time, energy dependent leakages, energy and region-dependent absorptions, fissions, fluxes, and fission densities. KENO Va utilizes a three-dimensional Monte-Carlo computation scheme. KENO Va is capable of modeling complex geometries including facilities for handling arrays, arrays of arrays, and holes.

SCALE 4.4 is set up so that any number of cross-section libraries may be used with the preprocessing functional and control modules. For the purpose of this report, only the 44-group ENDF/B-V library is used.

The preprocessing codes used for this document are the functional modules BONAMI-S and NITAWL-II. They are consolidated into the control module CSAS25. BONAMI-S has the function of performing Bondarenko calculations for resonance self-shielding. The cross-sections and Bondarenko factor data are pulled from an AMPX master library. The output is placed into a master library as well. Dancoff approximations allow for different fuel lattice cell geometries. The main function of NITAWL-II is to change the format of the master cross-section libraries to one that the criticality code (KENO Va) can access and provide the Nordheim Integral Treatment for resonance self-shielding.

The sequence of operations in CSAS25 is vital to perform resonance self-shielding and other calculations concerning the handling of the cross-sections. The sequence uses the Material Information Processor (MIP) which reads the standard composition data and other important data such as theoretical density. The MIP checks the preprocessing input data and creates binary input files that the functional modules access.

The data for the preprocessing is controlled entirely by the MIP. It requires data to specify the cross-section library, the composition of each mixture, and the geometry of the fuel unit cell. The compositions of the mixtures are specified by either some percentage of theoretical atom density, by atomic density or by selecting the material from the choices provided in the MIP list of standard materials. The temperature of the mixture may also be specified. The fuel lattice cell region is identified by a certain geometric pitch, which is the spacing between two adjacent fuel rods (e.g. square pitch), the mixtures associated with the fuel, clad, and gap regions, and the dimensions of those regions. The data is entered as free form, which allows input in an unstructured style.

6.6.2 Sample Computer Program Input

Sample input decks for the 5.00 wt.% enriched array cases are provided for both accident and normal geometries. Input decks for other enrichments and fuel/water mixture heights are similar. Input decks for the single package cases are identical to the corresponding array cases except that Unit 100 is now the global array.

6.6.2.1 Accident Geometry – Homogeneous UO_2 – Water Mixture - 5.00 Wt.% U-235 - 40 cm Fuel Height, Array Case (TNFXI_239_40.IN)

Proprietary Information on Pages 6-123 through 6-124
Withheld Pursuant to 10 CFR 2.390

6.6.2.2 Normal Geometry – Homogeneous UO_2 – Water Mixture - 5.00 Wt.% U-235 - 40 cm Fuel Height - Array Case (NH_500_239_40.IN)

Proprietary Information on Pages 6-126 through 6-128
Withheld Pursuant to 10 CFR 2.390

6.6.2.3 Accident Geometry – Heterogeneous UO_2 – Water Mixture - 5.00 Wt.% U-235 - 0.13 cm Pellet Radius - 40 cm Fuel Height, Array Case (TNFXI_197_13_40.IN)

Proprietary Information on Pages 6-130 through 6-131
Withheld Pursuant to 10 CFR 2.390

6.6.2.4 Normal Geometry – Heterogeneous UO_2 - Water Mixture - 5.00 Wt.% U-235 - 0.15 cm pellet radius, 40 cm Fuel Height, Array Case (NP_500_197_15_40.IN)

Proprietary Information on Pages 6-133 through 6-135
Withheld Pursuant to 10 CFR 2.390

6.7 References

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5. ANS/ANSI-8.1, *American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*, 1983.
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APPENDIX A.6
TNF-XI CRITICALITY EVALUATION

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APPENDIX A.6
TNF-XI CRITICALITY EVALUATION

The TNF-XI provides criticality control to meet the criticality performance requirements specified in Section 71.55 and 71.59 of 10 CFR Part 71. The criticality control design ensures that the effective multiplication factor (k_{eff}) of the contained fuel is no greater than an upper subcritical limit (USL) for the most reactive configuration. The USL includes a confidence band with an administrative safety margin of 0.05. The design has a criticality safety index (CSI) given in 10 CFR 71.59(b) as CSI = 50/"N". The number "N" is based on all of the following conditions being satisfied:

1. Five times "N" undamaged packages with nothing between the packages are subcritical.
2. Two times "N" damaged packages, if each package is subjected to the tests specified in 10 CFR 71.73 ("hypothetical accident conditions"), are subcritical with optimum interspersed hydrogenous moderation; and
3. The value of "N" cannot be less than 0.5.

A.6.1 DESCRIPTION OF CRITICALITY DESIGN

The design criteria for the TNF-XI require that the package remain subcritical under normal conditions of transport (NCT) and hypothetical accident conditions (HAC) as defined 10 CFR Part 71.

A.6.1.1 Design Features

The TNF-XI package consists of a stainless steel outer shell and lid that encases a body of phenolic foam. Four individually sealed stainless steel inner wells/cavities are located in the body, containing three pails per well. The fuel is placed in polyethylene bags or plastic bags with hydrogen concentration less than polyethylene, which are placed inside stainless steel pails. Fuel may be in the form of UO_2 powder, pellets, or scrap. The maximum mass of polyethylene allowed in each cavity is 390 g. *The UO_2 powder may contain impurities (powder scrap). The aluminum and carbon impurities in the UO_2 powder shall not exceed 5,000 ppm and 10,000 ppm, respectively.* Criticality control is provided by a borated stainless steel sleeve in each pail and a boron containing resin (BORA) surrounding each well/cavity. Each well/cavity lid consists of layers of phenolic foam and aluminum honeycomb.

A.6.1.2 Summary Table of Criticality Evaluation

As required by 10 CFR Part 71.55(b), the *TNF-XI* is shown to be subcritical for the most reactive credible configuration and moderation by water to the most reactive credible extent. The cask is shown to be subcritical for five times "N" packages with void between packages and no in-leakage of water, as required by 10 CFR Part 71.59(a)(1). In addition, as required by 10 CFR Part 71.59(a)(2), two times "N" packages is shown to be subcritical with the fissile material in its most reactive configuration, optimum water moderation and close full water reflection consistent with its damaged condition. *Criticality calculations are performed for UO_2 powder scrap, including impurities as specified in ASTM C753 [7], and conservatively specified as aluminum and carbon not exceeding 5,000 ppm and 10,000 ppm, respectively.*

Criticality calculations are performed for UO_2 powder, pellets and scrap pellets at enrichments of 4.05, 4.15, 4.25, 4.35, 4.45, 4.55, 4.65, 4.75, 4.85, 4.95, and 5.00 wt% U-235. The calculations determine k_{eff} with the CSAS5 control module of SCALE6 [1] for various configurations, including all uncertainties to assure criticality safety under all credible conditions.

The results of the evaluation demonstrate that the maximum expected k_{eff}, including statistical uncertainty, will be less than the USL determined from a statistical analysis of benchmark criticality experiments. The statistical analysis procedure includes a confidence band with an administrative safety margin of 0.05.

Table A.6-1 lists the bounding results for all conditions of transport for powder *and powder scrap*. The highest calculated k_{eff} for powder, including 2σ uncertainty, is an HAC array of TNF-XI packages containing UO_2 powder with an initial U-235 enrichment of 5.00 wt. % filled to a height of 44 cm. The maximum allowed initial enrichment is also listed in Table A.6-1. An 8x9x8 array was used for the NCT UO_2 powder array analyses and a 6x6x6 array for the HAC evaluations. *The criticality calculations performed for UO_2 powder scrap, including impurities as specified in ASTM C753 [7] and conservatively specified as aluminum and carbon not exceeding 5,000 ppm and 10,000 ppm, respectively, demonstrate that the impact of the impurities is negligible. The difference in reactivity between UO_2 powder and UO_2 powder scrap with conservative aluminum and carbon impurities not exceeding 5,000 ppm and 10,000 ppm, respectively, is statistically insignificant. Regarding the possible presence of the other impurities as specified in ASTM C753 [7], their impact on the reactivity is either insignificant or even beneficial.*

Table A.6-2 lists the bounding results for all conditions of transport for pellets and scrap. The highest calculated k_{eff} for pellets and scrap, including 2σ uncertainty, is an HAC array of TNF-XI packages containing UO_2 scrap with an initial U-235 enrichment of 4.45 wt. % filled to a height of 41.2 cm and a pitch of 0.8 cm. The maximum allowed initial enrichment is also listed in Table A.6-2. An 8x9x8 array was used for the NCT UO_2 pellet and scrap array analyses and a 6x6x6 array for the HAC evaluations.

These criticality calculations were performed with CSAS5 of SCALE6. For each case, the result includes (1) the KENO-calculated k_{KENO}, (2) the one sigma uncertainty σ_{KENO}, and (3) the final k_{eff}, which is equal to $k_{KENO} + 2\sigma_{KENO}$.

The criterion for sub-criticality is that

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

where USL is the upper subcritical limit established by an analysis of benchmark criticality experiments. Two different USLs are developed for these analyses. From Section A.6.8.2, the minimum USL over the parameter range for UO_2 powder is 0.9388. The minimum USL over the parameter range for enriched UO_2 pellets and scrap is 0.9398. From Table A.6-2, for the most reactive case,

$$k_{KENO} + 2\sigma_{KENO} = 0.9364 + 2\ (0.0007) = 0.9379 \leq 0.9398.$$

A.6.1.3 Criticality Safety Index

The design has a CSI, given in 10 CFR 71.59(b) as CSI = 50/“N”, of 0.5 for transport of UO_2 powder, pellets and scrap.

A.6.2 FISSILE MATERIAL CONTENTS

The TNF-XI package is capable of transporting UO_2 powder *(and powder scrap)*, pellets, and scrap up to a maximum enrichment of 5.00 wt % U-235. For each enrichment, the mass of UO_2 was varied to determine the maximum acceptable UO_2 mass limit. Table A.6-3 gives the UO_2 mass limits for the TNF-XI as a function of form (powder or pellet and scrap) and enrichment. For the pellet/scrap analysis, some of the mass limits are found to be slightly higher than the values given in Chapter 6. For these occurrences (4.25 wt %, 4.45 wt %, and 4.95 wt %), the mass limit from Chapter 6 is conservatively applied. It is expected that the fissile material will be divided evenly among the four cavities. Therefore, no cavity may exceed one quarter of the total UO_2 mass limit of the entire package.

A.6.3 GENERAL CONSIDERATIONS

The following subsections describe the physical models and materials of the TNF-XI packaging used for input to the CSAS5 module of SCALE6 to perform the criticality evaluation for UO_2 powder, pellets, and scrap. The models developed are for a single package and arrays of packages both for NCT and HAC.

A.6.3.1 Model Configuration

The TNF-XI model is based upon drawings in Section 1.3 of the SAR. An axially finite model of the normal geometry of the TNF-XI package is provided in Figure A.6-1. This figure shows the material constituent radial and axial dimensions. The model construct consists of four cavities inserted into the primary body of phenolic foam [ ]. Each cavity is surrounded by BORA resin, which acts as a neutron absorber. At the bottom of each cavity is a borated stainless steel disk upon which a pail rests. Each pail is modeled as a sealed stainless steel can that contains the fuel/polyethylene/water mixture and is lined with borated stainless steel. For the NCT model, void is present between the pail and cavity wall and between the top of the pail and bottom of the lid. For conservatism, the pails in each cavity are pushed inward toward each other. The lid to each cavity consists of layers of phenolic foam [ ], aluminum honeycomb, and [ ]. The entire package is surrounded by a thin layer of stainless steel. Figures A.6-2 and A.6-3 show the NCT KENO model.

An axially finite model of the damaged geometry (HAC) of the TNF-XI package is provided in Figure A.6-4. The effects of the certification test results are incorporated in the damaged model. The axial crush of the package was modeled as a 1.5 cm decrease in height. This is applied to the model construct by reducing the thickness of the bottom foam 1.5 cm. The side crush of the body results in a 2 cm reduction in this direction. This reduction was incorporated in the model by reducing each lateral face by 1 cm. Damage by a punch bar is modeled as a hole on one side, 3.9 cm deep and 15 cm in diameter. In addition, it is assumed that 2.7 cm of foam is consumed in fire on all surfaces and therefore is modeled as charred foam and that the top foam disk for each canister is also charred. One of the four cavity lids also has charred foam in the bottom disk. In the damaged model, the fuel lattice exists both inside and outside the pail, and void space within the package not containing the fuel lattice contains water.

A finite square lattice of packages is modeled for both the NCT and HAC. The NCT lattice is a 8x9x8 array and the HAC lattice is an array of 6x6x6 packages. The array of packages is surrounded by a water reflector (KENO water albedo). The package arrays are modeled as close fitting and virtually in contact to provide the most reactive array configuration.

Differences in the KENO model and the actual package are listed below:

- The criticality safety analysis model of the loaded TNF-XI package differs from the actual package in the allowance for water intrusion into the containment. The UO_2 mass and the water content are varied to optimally moderate the package. As the contents of the package have been demonstrated to remain 'dry' under hypothetical accident conditions, the optimal internal moderation treatment is a very large conservatism.
- By ignoring spatial effects, the TNF-XI undamaged and damaged arrays are modeled as close fitting and in virtual contact when in fact structure deformation and bowing would provide additional spacing between individual packages.
- The aluminum honeycomb in the top lid is modeled as solid aluminum with an accordingly reduced density for simplicity.
- The upper phenolic foam disk ([ ]) in the lid is modeled as 0.4 cm thinner than actual and as charred [ ] foam instead of [ ] (for the damaged package). The difference in charred foam densities is negligible and the reduction in the disk thickness is conservative.
- The contents in the actual package are contained within pails loaded into four compartments in the package. Each individual compartment contains three pails, each 20.5 cm high with a borated stainless steel liner 18.0 in height and 0.2 cm thick starting 2.5 cm from the bottom of each can. The three pails are modeled as a single can with a height of 61.2 cm with a borated stainless steel liner 53.7 cm in height starting 7.5 cm from the container bottom.
- The phenolic foam [ ] in the bottom corner of the package is modeled as [ ] for simplicity. Due primarily to the low density of the foam, the effects are negligible.
- The perforated aluminum disk is modeled as 3.0 cm thick, although the actual thickness is 1.5 cm. This difference is shown to be within the statistical uncertainty of the reactivity calculation methods employed.

A.6.3.2 Material Properties

The material properties for the CSAS5 evaluations are taken directly from the SCALE6 standard compositions. The materials are summarized in Table A.6-4.

For powder, the fuel mixture (mixture #1) is a homogenized mixture of UO_2, polyethylene and water. The volume fractions are calculated based on the known mass of UO_2, polyethylene and the known volume (with variable height) occupied by the mixture. The density of the polyethylene is also varied from the nominal 0.92 g/cc to ensure that this parameter has negligible effect on the reactivity of the system within the range of 0.90 g/cc to 0.96 g/cc. Water (mixture #2) is used for the HAC analysis only. *For powder scrap, the fuel mixture includes impurities, as defined in ASTM C753 [7] or, conservatively, as aluminum and carbon not exceeding 5,000 ppm and 10,000 ppm, respectively.*

For pellets and scrap, the fuel lattice (mixture #500) is a lattice of UO_2 (mixture #1) in a homogeneous mixture of water and polyethylene (mixture #2). The volume fractions of the moderator are calculated based on the known mass of polyethylene and the known volume (with variable height) occupied by the mixture. Water (mixture #11) is used for the HAC analysis only.

The other materials in the TNF-XI package are taken directly from the criticality analyses in Chapter 6. Stainless steel is the SCALE standard composition with nominal density. The BORA resin (material #4) has a density of 1.74 g/cc and the boron in the resin is natural boron. The B-10 is taken at 75% credit or 13.5 wt% (0.75*18).

The other boron containing material in the TNF-XI package is borated stainless steel (mixture #3) with 0.75 wt% natural boron.

Two phenolic foam compositions are utilized. **[ ]** (mixture #5) at a density of 0.20 g/cc is the main foam modeled. **[ ]** foam (mixture #6) at a density of 0.15 g/cc is modeled in the upper plugs. In the HAC model, the carbonized foam (mixture #7) is modeled as carbon with a density of 0.116 g/cc. Water is not added to the foam in the HAC model since it decreases reactivity by reducing the communication between packages in the array.

The aluminum honeycomb (mixture #9) in the upper plugs is modeled as plain aluminum with a reduced density of 1.08 g/cc.

A.6.3.3 Computer Codes and Cross Section Libraries

The CSAS5 module of the SCALE6 code is used for the criticality analysis [1]. The 238groupndf5 cross section library is utilized with all cross sections at room temperature (293 or 300 K). The CSAS5 module uses the lattice cell option for the pellet/scrap analyses and the infinite homogenized fuel mixture option for the powder analyses. The NITAWL code is used to process the cross sections through the *parm=nitawl* card in the CSAS5 input.

All cases are run with at least 2000 neutrons per generation for 805 generations. The 1 sigma uncertainty is typically less than 0.001.

A.6.3.4 Lattice Cell Modeling for CSAS5

[ ]

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Fuel pellets are best represented by the square and triangular pitches lattice, while fuel scrap is best represented by the spherical-hexagonal lattice. The analysis utilizes the spherical-hexagonal lattice to bound both scrap and pellets since it is the most reactive configuration, as demonstrated in A.6.6.2.

A.6.3.5 Demonstration of Maximum Reactivity

This section describes the criticality analysis. The analyses are performed with the CSAS5 module of the SCALE6 system. A series of criticality calculations are performed for the TNF-XI packaging to determine the most reactive configurations for UO_2 powder and UO_2 pellets and scrap.

For the NCT analysis, both single package and array, the pails are conservatively allowed to fill with water and mix with the fuel to obtain the optimum level of moderation. Both the single package and array are closely reflected all around with 12" of full density water.

For the HAC array analysis, the pails and the inner cavity are conservatively allowed to fill with water and mix with the fuel to obtain the optimum level of moderation. The pail and cavity volume unoccupied by the fuel and water mixture is allowed to fill with full density water to provider further moderation and reflection. The array is closely reflected all around with 12" of full density water.

A.6.3.5.1 Bases and Assumptions

For the NCT analyses, the packaging geometry in accordance with the drawings shown in Chapter 1 is utilized with the exceptions as noted in Section 6.3.1. The results of the drop tests performed for the TNF-XI package documented in Chapter 2 demonstrate that the package does not undergo significant damage during HAC. The inner containment remains leak tight and the minimal local deformation of the outer container surface occurs. In order to bound this local deformation, a uniform reduction of 1.5 cm is applied to the height of the package and 2 cm is applied to sides of the package. By conservatively ignoring deformation and bowing, this reduces the separation distance between the packages in the array. Section A.6.3.1 addresses how the model treats additional conservatism under HAC due to a punch bar and charring. All calculations are performed using UO_2 fuel material without a burnable absorber like Gadolinia. Therefore, the results of these calculations are conservatively applied to fuel containing burnable absorbers.

The TNF-XI package is modeled with KENO V.a using the available geometry input. This option allows a model to be constructed that uses regular geometric shapes to define the material boundaries.

The following conservative assumptions are also incorporated into the criticality calculations:

1. The fuel (powder, pellet, and scrap) is modeled at 100% theoretical density.
2. Temperature is at $20^{\circ}C$ (293K) or $27^{\circ}C$ (300K), depending on the available data.
3. The maximum allowed 390 g of polyethylene is assumed for the fuel moderator mixture/cell.
4. The optimum moderator to fuel ratio is utilized by varying the fill height of the pail under NCT and the pail and cavity under HAC.
5. For pellets and scrap, the optimum pitch/radius combination is utilized.

A.6.4 EVALUATION OF SINGLE PACKAGE

Single package evaluations were performed for the TNF-XI package with UO_2 powder and scrap for NCT only. The TNF-XI package with UO_2 pellets is bounded by the scrap analysis.

A.6.4.1 Single Package with Powder *and Powder Scrap* Configuration

A single package analysis is performed for the NCT. Under NCT, the cavity interior and pail remain leak-tight. However, the pail is conservatively allowed to fill with water in the analysis, which forms a homogeneous mixture with the polyethylene bags and fuel. The package is closely reflected all around with 12" (30.48 cm) of full density water (water albedo).

The fuel mixture is modeled as a pure theoretical mixture of UO_2 powder (10.96 g/cm^3), polyethylene (0.92 g/cc), and water. The volume fraction of water is altered by varying the height, H, of the mixture while keeping the mass of the UO_2 constant. In this way optimum moderation is achieved. *For impurity analysis, the fuel mixture includes impurities as defined in ASTM C753 [7] or impurities such as aluminum and carbon not exceeding 5,000 ppm and 10,000 ppm, respectively.*

The volume of the fuel, polyethylene, and water may be obtained from Equations 1 and 3 through 5. These volumes may then be used to calculate the volume fractions for the homogeneous mixture of fuel and moderator by dividing the volume of each component (UO_2, polyethylene, and water) by the total volume, V_T.

Evaluations are performed for UO_2 powder *and powder scrap* enrichments from 4.45 to 5.00 wt % U-235. For each enrichment, the fuel mixture height is varied from a full pail (61.2 cm) to 45 cm in height.

A.6.4.2 Single Package with Scrap Configuration

A single package analysis is performed for the NCT. Under NCT, the cavity interior and pail remain leak-tight. However, the pail is conservatively allowed to fill with water in the analysis, which forms a homogeneous mixture with the polyethylene bags. The package is closely reflected all around with 12" (30.48 cm) of full density water (water albedo).

The fuel lattice is modeled as spherical UO_2 pellets (10.96 g/cm^3) in a polyethylene (0.92 g/cc) and water mixture. The volume fraction of water is altered by varying the height of the mixture while keeping the mass of the UO_2 constant. In this way optimum moderation is achieved. Furthermore, the pitch and radius of the pellets is varied to determine the optimum combination.

The volume of the fuel, polyethylene, and water may be obtained from Equations 1 and 3 through 5. These volumes may then be used to calculate the volume fractions for the homogeneous moderator mixture of water and polyethylene by dividing the volume of each component by the sum of the water and polyethylene volumes (V_w and V_{poly}). For a given volume ratio of moderator to fuel, the pitch and radius are related as given in Equation 9 for a spherical lattice, which is demonstrated to be bounding for pellets and scrap in A.6.6.2.

The optimal fuel lattice height is first determined. This analysis is performed for 236 kg of UO_2 with 4.55 wt % U-235. Table A.6-5 displays the results and demonstrates that the package is most reactive when completely filled ($H = 61.2$ cm). While there may be some small variation in the optimal fill height for the various enrichments, the effect is small, as demonstrated by the HAC results in Section 0. Furthermore, there is ample margin between the maximum k_{eff} and the USL. Therefore, the single package analysis presented in Section A.6.4.3 is performed with maximally filled pails.

Evaluations are performed for UO_2 scrap enrichments from 4.05 to 5.00 wt % U-235. For each enrichment, the pitch is varied from 0.1 to 1.2 cm. If the results did not clearly demonstrate that the optimum pitch lied within that range, pitches from 1.3 to 2.0 cm were also considered.

A.6.4.3 Single Package Results

For the single package powder NCT evaluation, k_{eff} values are shown in Table A.6-6 through Table A.6-12 for the different powder enrichments. The bounding k_{eff} is for 4.95% enrichment with 238 kg UO_2 at a value of 0.8997.

For the single package pellet and scrap NCT evaluation, k_{eff} values are shown in Table A.6-13 through Table A.6-23 for the different powder enrichments. The bounding k_{eff} is for 4.95% enrichment with 204 kg UO_2 at a value of 0.9106.

A.6.5 EVALUATION OF PACKAGE ARRAY FOR NORMAL CONDITIONS OF TRANSPORTATION

Package array evaluations were performed for the TNF-XI package with UO_2 powder and scrap for NCT. The TNF-XI package with UO_2 pellets is bounded by the scrap analysis. The NCT array consists of an 8x9x8 lattice of packages.

A.6.5.1 NCT Package Array with Powder Configuration

The single package model described in Section A.6.4.1 is utilized as the basis for the NCT array evaluation. An 8x9x8 array of packages is modeled. The array of packages is closely reflected all around with 12" (30.48 cm) of full density water. However, there is nothing between the packages because they are in physical contact due to the cuboid geometry of the package. This array configuration is the most reactive because it allows the maximum "communication" between the packages.

As in the single packaging evaluation, the optimum moderation was determined by varying the fill height of the homogenized fuel and moderator mixture.

Evaluations are performed for UO_2 powder enrichments from 4.45 to 5.00 wt % U-235. For each enrichment, the fuel mixture height is varied from a full pail (61.2 cm) to 45 cm in height.

A.6.5.2 NCT Package Array with Scrap Configuration

The single package model described in Section A.6.4.2 is utilized as the basis for the NCT array evaluation. An 8x9x8 array of packages is modeled. The array of packages is closely reflected all around with 12" (30.48 cm) of full density water. However, there is nothing between the packages because they are in physical contact due to the cuboid geometry of the package. This array configuration is the most reactive because it allows the maximum "communication" between the packages.

As in the single packaging evaluation, the optimum moderation was determined by varying the fill height of the heterogeneous fuel and moderator mixture.

The optimal fuel lattice height is again determined. This analysis is performed for 236 kg of UO_2 with 4.55 wt % U-235. Table A.6-24 displays the results and demonstrates that the package is most reactive when completely filled ($H = 61.2$ cm). While there may be some small variation in the optimal fill height for the various enrichments, the effect is small, as demonstrated by the HAC results in Section A.6.6.3. Furthermore, there is ample margin between the maximum k_{eff} and the USL. Therefore, the single package analysis presented in Section A.6.5.3 is performed with maximally filled pails.

Since the most reactive configuration is with the pail completely filled, the system is likely undermoderated. Therefore, it is possible that a reduction in UO_2 mass may actually increase the reactivity. A range of masses were examined at 4.55 wt% U-235 with the pails completely filled to verify that this is not the case. The results shown in Figure A.6-5 clearly demonstrate that reactivity trends with UO_2 mass, almost linearly.

Evaluations are performed for UO_2 scrap enrichments from 4.05 to 5.00 wt % U-235. For each enrichment, the pitch is varied from 0.1 to 1.2 cm. If the results did not clearly demonstrate that the optimum pitch lied within that range, pitches from 1.3 to 2.0 cm were also considered.

A.6.5.3 NCT Package Array Results

For the NCT package array with powder evaluation, k_{eff} values are shown in Table A.6-25 through Table A.6-31 for the different powder enrichments. The bounding k_{eff} is for 5.00% enrichment with 232 kg UO_2 at a value of 0.9164.

For the NCT package array with pellet and scrap evaluation, k_{eff} values are shown in Table A.6-32 through Table A.6-42 for the different powder enrichments. The bounding k_{eff} is for 4.95% enrichment with 204 kg UO_2 at a value of 0.9267.

A.6.6 EVALUATION OF PACKAGE ARRAY FOR HYPOTHETICAL ACCIDENT CONDITIONS

Package array evaluations were performed for the TNF-XI package with UO_2 powder and scrap for HAC. The TNF-XI package with UO_2 pellets is bounded by the scrap analysis. The HAC array consists of a 6x6x6 lattice of packages.

The HAC geometry is similar to the NCT geometry. For HAC, the height of the package is decreased by reducing the thickness of the bottom foam by 1.5 cm to model the axial crush. The width of the package in the x and y directions is decreased by reducing the foam thickness by 1 cm on each side to model the side crush. A 15 cm diameter, 3.9 cm deep hole filled with water is included on one side to model the punch bar damage. In addition, it is assumed that 2.7 cm of foam is consumed in fire on all surfaces and therefore is modeled as charred foam and that the top foam disk for each canister is also charred. One of the four cavity lids also has charred foam in the bottom disk. In the damaged model, the fuel lattice exists both inside and outside the pail, and void space within the package not containing the fuel lattice contains water.

A.6.6.1 HAC Package Array with Powder Configuration

The HAC package array model is similar to the NCT package array described in Section A.6.5.1. However, the geometry of the package is adjusted to account for the effects of the certification test results as described in Section A.6.3.1. Also, the homogenized fuel and moderator mixture is allowed to fill both the pails and the inner cavities, rather than just the pails as in the NCT evaluation. A 6x6x6 array of packages is modeled. The array of packages is closely reflected all around with 12" (30.48 cm) of full density water. However, there is nothing between the packages because they are in physical contact due to the cuboid geometry of the package. This array configuration is the most reactive because it allows the maximum "communication" between the packages.

The volume of the fuel, polyethylene, and water may be obtained from Equations 2 and 3 through 5. These volumes may then be used to calculate the volume fractions for the homogeneous mixture of fuel and moderator by dividing the volume of each component (UO_2, polyethylene, and water) by the total volume, V_T. The remaining volume of the pails and cavities is filled with full density water.

Evaluations are performed for UO_2 powder enrichments from 4.45 to 5.00 wt % U-235. For each enrichment, the fuel mixture height is varied from 50 cm to 40 cm in height.

A study was also performed to ensure that varying polyethylene densities would not significantly affect the reactivity of the system. The TNF-XI under HAC with 232 kg of UO_2 at 5.00 wt % U-235 was examined for this purpose since it was the most reactive enrichment/mass combination. The results are presented in Table A.6-64 and clearly demonstrate that minor variations in polyethylene density have a negligible effect on the reactivity of the system. This analysis was only carried out for powder since the homogenous system is more sensitive to the moderator properties than the heterogeneous system.

A.6.6.2 HAC Package Array with Scrap Configuration

The HAC package array model is similar to the NCT package array described in Section A.6.5.1. However, the geometry of the package is adjusted to account for the effects of the certification test results as described in Section A.6.3.1. Also, the heterogeneous fuel and moderator mixture is allowed to fill both the pails and the inner cavities, rather than just the pails as in the NCT evaluation. A 6x6x6 array of packages is modeled. The array of packages is closely reflected all around with 12" (30.48 cm) of full density water. However, there is nothing between the packages because they are in physical contact due to the cuboid geometry of the package. This array configuration is the most reactive because it allows the maximum "communication" between the packages.

The volume of the fuel, polyethylene, and water may be obtained from Equations 2 and 3 through 5. These volumes may then be used to calculate the volume fractions for the homogeneous moderator mixture of water and polyethylene by dividing the volume of each component by the sum of the water and polyethylene volumes (V_w and V_{poly}).

For a given volume ratio of moderator to fuel, the pitch and radius are related as given in Equations 6, 7, and 9 for a square pitch lattice, triangular pitch lattice, and spherical lattice, respectively. These three lattice types were evaluated to determine which is the most reactive. To ensure that the most reactive configuration was captured, the each lattice was evaluated at three different fill heights and at pitches varied from 0.1 to 1.2 cm for each fill height. The results presented in Tables A.6-43 through A.6-45 demonstrate that the spherical lattice is bounding for both pellets and scrap. For brevity, only the most reactive pitch is listed from fill heights that are less than optimal.

As in the NCT analysis, a range of masses were examined at 4.55 wt% U-235 with the pails filled to 41.2 cm to verify that a decrease in UO_2 mass does not result in an increase in reactivity. The results shown in Figure A.6-6 clearly demonstrate that reactivity trends with UO_2 mass, almost linearly.

Evaluations are performed for UO_2 scrap enrichments from 4.05 to 5.00 wt % U-235. For each enrichment, various fill heights are analyzed. For each enrichment and fill height combination, the pitch is varied from 0.1 to 1.2 cm. For brevity, only the results for the most reactive pitch are listed from fill heights that are less than optimal.

A.6.6.3 HAC Package Array Results

For the HAC package array with powder evaluation, k_{eff} values are shown in Table A.6-46 through Table A.6-52 for the different powder enrichments. The bounding k_{eff} is for 5.00% enrichment with 232 kg UO_2 at a value of 0.9352.

For the HAC package array with pellet and scrap evaluation, k_{eff} values are shown in Table A.6-53 through Table A.6-63 for the different powder enrichments. The bounding k_{eff} is for 4.95% enrichment with 204 kg UO_2 at a value of 0.9378.

A.6.7 FISSILE MATERIAL PACKAGES FOR AIR TRANSPORT

Not applicable to the TNF-XI.

A.6.7.1 Air Transport Configuration

Not applicable to the TNF-XI.

A.6.7.2 Air Transport Results

Not applicable to the TNF-XI.

A.6.8 BENCHMARK EVALUATIONS

The criticality safety analysis of the TNF-XI packaging uses the CSAS5 module of the SCALE6 system of codes. The CSAS5 control module allows simplified data input to the functional modules BONAMI, NITAWL, and KENO V.a. These modules process the required cross-section data and calculate the k_{eff} of the system. BONAMI performs resonance self-shielding calculations for nuclides that have Bondarenko data associated with their cross sections. NITAWL-S applies a Nordheim resonance self-shielding correction to nuclides having resonance parameters. Finally, KENO V.a calculates the effective neutron multiplication (k_{eff}) of a 3-D system. The benchmark calculations performed for this module are described herein. The methodology employed is based on the guidance provided in reference [5].

The analysis presented herein uses the fresh fuel in the form of low enriched UO_2 powder and pellets/ scrap for criticality analysis. The analysis employs the 238-group ENDF/B-V cross-section library because it has a small bias and is appropriate for low enriched hydrogen moderated systems. An upper subcritical limit (USL-1) is determined for both powder and pellet evaluation using the results of these benchmark calculations.

The parameters that are independent variables of USL functions are U-235 enrichment, energy of average lethargy of fission (EALF) and hydrogen-to-fissile ratio (H/X).

Eighteen critical experiments [3] are selected for the UO_2 powder USL evaluation. The material and geometrical characteristics of these criticality experiments are summarized in Table A.6-65. The critical experiments, the calculated results and their U-235 enrichment and H/X values are listed in Table A.6-66.

Twenty-three critical experiments are selected for the UO_2 pellet USL evaluation. All of the 23 critical experiments are part of the NUREG/CR-6361 critical experiments [2]. The experiments are square lattice containing UO_2, H_2O and aluminum. The fifteen P3602 experiments have steel reflecting walls. The material and geometrical characteristics of these criticality experiments are summarized in Table A.6-67. The critical experiments, the calculated results and their U-235 enrichment and H/X values are listed in Table A.6-68.

A.6.8.1 Applicability of Benchmark Experiments

The pertinent parameters for each experiment are included in Tables A.6-66 and A.6-68 along with the results of each run. The best linear correlation is observed for the powder experiments enrichment with a correlation of -0.78. All other parameters show much lower correlation ratios indicating no real correlation. All parameters were evaluated for trends and to determine the most conservative USL using the USLSTATS 6 Program [4].

In addition, the sufficiency of the number of experiments used for the pellet and powder analyses benchmarking is also determined herein. The 18 experiments chosen for powder benchmarking are the most representative critical benchmarks. Additional experiments are available from the International Handbook of Evaluated Criticality Safety Benchmark Experiments but most of these experiments are based on Uranyl Nitrate solutions with an enrichment of 10.0 wt. % U-235. Therefore, only these 18 experiments were employed as powder benchmarks. The test of normalcy performed by the USLSTATS program indicates that the benchmark data is normal.

The 23 experiments chosen for pellet benchmarking are sufficient from a 95% probability, 95% statistical confidence level (95/95 basis) since one needs 20 experiments for this purpose. However, these experiments are also selected because they represent those set of experiments that adequately represent the system being evaluated – fuel pins (or pellets) in an array without the presence of poison material or soluble poison. The USLSTATS program employed herein also indicates that the benchmark data is normal.

The upper subcritical limit (USL) is calculated in accordance to NUREG/CR-6361 [2]. USL Method 1 (USL-1) applies a statistical calculation of the bias and its uncertainty plus an administrative margin (0.05) to the linear fit of results of the experimental benchmark data. Results from the USL evaluation are presented in Table A.6-69 for UO_2 powder and Table A.6-70 for UO_2 pellets.

The criticality evaluation used the same cross section set, fuel materials and similar material/geometry options that were used in the benchmark calculations.

A.6.8.2 Bias Determination

It is clear from the USL functions shown in Table A.6-69 that the USL for enrichment is the limiting USL for the UO_2 powder evaluations. The powder USL is 0.9388.

For pellets and scrap, it is not as obvious which parameter is limiting. Therefore, the limiting value for each parameter is determined and the corresponding USL is calculated from the USL functions in Table A.6-70. The results are presented in Table A.6-71. The lowest USL value is obtained for the H/X trending parameter. This corresponds to the HAC cases with 196 kg UO_2 enriched to 5.00 wt% U-235 and a fill height of 41.2 cm. The pellet USL is 0.9398.

A.6.9 REFERENCES

1. SCALE6: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstations and Personal Computers, Oak Ridge National Laboratory, Radiation Shielding Information Center Code Package CCC-750, February 2009.

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

3. Oak Ridge National Laboratory, "Validation of KENO V.a Comparison with Critical Experiments," ORNL/CSD/TM-238, December 1986.

4. USLSTATS: A Utility to Calculate Upper Subcritical Limits for Criticality Safety Applications, Version 6, Oak Ridge National Laboratory, January 26, 2009.

5. U.S. Nuclear Regulatory Commission, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages," NUREG/CR-5661, Published April 1997, ORNL/TM-11936.

6. ORNL/TM-2005/39, Version 6, Vol. II, Section F17, "KENO-VI: A General Quadratic Version of the KENO Program", January 2009.

7. *ASTM C753-04, "Standard Specification for Nuclear-Grade, Sinterable Uranium Dioxide Powder", June 2009.*

A.6.10 APPENDICES

A.6.10.1 Example Powder Input Listing

This input represents the most reactive powder case of 232 kg of UO_2 with 5.00 wt % enrichment. This input models the 6x6x6 HAC array with a fill height of 44 cm.

Proprietary Information on Pages A.6-16 through A.6-18
Withheld Pursuant to 10 CFR 2.390

A.6.10.2 Example Pellet/Scrap Input Listing

This input represents the most reactive pellet/scrap case of 204 kg of UO_2 with 4.95 wt % enrichment. This input models the 6x6x6 HAC array with a fill height of 41.2 cm and a pitch of 0.6 cm.

Proprietary Information on Pages A.6-20 through A.6-23
Withheld Pursuant to 10 CFR 2.390

Table A.6-1 Summary of Criticality Results for Powder

Normal Conditions of Transport (NCT)						
	Powder		*Powder Scrap with ASTM C753 Impurities*		*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*	
	Single	8x9x8 Array	*Single*	*8x9x8 Array*	*Single*	*8x9x8 Array*
Case	k_{eff}	k_{eff}	k_{eff}	k_{eff}	k_{eff}	k_{eff}
5.00 wt% U-235 – 232kg UO_2	0.8993	0.9164	*0.8968*	*0.9132*	*0.8959*	*0.9129*
4.95 wt% U-235 – 238 kg UO_2	0.8997	0.9157	*0.8963*	*0.9120*	*0.8953*	*0.9115*
4.85 wt% U-235 – 248 kg UO_2	0.8981	0.9143	*0.8934*	*0.9103*	*0.8931*	*0.9090*
4.75 wt% U-235 – 259 kg UO_2	0.8964	0.9122	*0.8918*	*0.9084*	*0.8909*	*0.9073*
4.65 wt% U-235 – 271 kg UO_2	0.8927	0.9084	*0.8902*	*0.9067*	*0.8884*	*0.9036*
4.55 wt% U-235 – 286 kg UO_2	0.8916	0.9072	*0.8865*	*0.9040*	*0.8850*	*0.9015*
4.45 wt% U-235 – 300 kg UO_2	0.8870	0.9028	*0.8836*	*0.9007*	*0.8822*	*0.9007*
Hypothetical Accident Conditions (HAC)						
	Powder		*Powder Scrap with ASTM C753 Impurities*		*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*	
	Single	6x6x6 Array	*Single*	*6x6x6 Array*	*Single*	*6x6x6 Array*
Case	k_{eff}	k_{eff}	k_{eff}	k_{eff}	k_{eff}	k_{eff}
5.00 wt% U-235 – 232kg UO_2	-	0.9352	-	-	-	*0.9313*
4.95 wt% U-235 – 238 kg UO_2	-	0.9352	-	-	-	*0.9321*
4.85 wt% U-235 – 248 kg UO_2	-	0.9345	-	-	-	*0.9315*
4.75 wt% U-235 – 259 kg UO_2	-	0.9341	-	-	-	*0.9306*
4.65 wt% U-235 – 271 kg UO_2	-	0.9344	-	-	-	*0.9311*
4.55 wt% U-235 – 286 kg UO_2	-	0.9341	-	-	-	*0.9302*
4.45 wt% U-235 – 300 kg UO_2	-	0.9335	-	-	-	*0.9298*

Table A.6-2 Summary of Criticality Results for Pellets and Scrap

Normal Conditions of Transport (NCT)		
	Single	8x9x8 Array
Case	k_{eff}	k_{eff}
5.00 wt% U-235 – 196 kg UO_2	0.90975	0.92540
4.95 wt% U-235 – 204 kg UO_2	0.91059	0.92666
4.85 wt% U-235 – 208 kg UO_2	0.90834	0.92518
4.75 wt% U-235 – 216 kg UO_2	0.90902	0.92510
4.65 wt% U-235 – 224 kg UO_2	0.90695	0.92380
4.55 wt% U-235 – 236 kg UO_2	0.90622	0.92378
4.45 wt% U-235 – 248 kg UO_2	0.90696	0.92354
4.35 wt% U-235 – 256 kg UO_2	0.90493	0.92137
4.25 wt% U-235 – 272 kg UO_2	0.90418	0.92007
4.15 wt% U-235 – 284 kg UO_2	0.90165	0.91836
4.05 wt% U-235 – 300 kg UO_2	0.90075	0.91742
Hypothetical Accident Conditions (HAC)		
	Single	6x6x6 Array
Case	k_{eff}	k_{eff}
5.00 wt% U-235 – 196 kg UO_2	-	0.93503
4.95 wt% U-235 – 204 kg UO_2	-	0.93782
4.85 wt% U-235 – 208 kg UO_2	-	0.93594
4.75 wt% U-235 – 216 kg UO_2	-	0.93654
4.65 wt% U-235 – 224 kg UO_2	-	0.93488
4.55 wt% U-235 – 236 kg UO_2	-	0.93617
4.45 wt% U-235 – 248 kg UO_2	-	0.93788
4.35 wt% U-235 – 256 kg UO_2	-	0.93618
4.25 wt% U-235 – 272 kg UO_2	-	0.93744
4.15 wt% U-235 – 284 kg UO_2	-	0.93690
4.05 wt% U-235 – 300 kg UO_2	-	0.93741

Table A.6-3 TNF-XI Allowable UO_2 Masses

Max ^{235}U Enrichment (wt. percent)	**Homogeneous UO_2 Powder** ***and Powder Scrap***[1] **Maximum Loading (kg)**	**Heterogeneous UO_2 Material (Pellet and Scrap) Maximum Loading (kg)**
≤ 4.05	300	300
4.15		284
4.25		271
4.35		256
4.45		247
4.55	286	236
4.65	271	224
4.75	259	216
4.85	248	208
4.95	238	202
5.0	232	196

1- Powder scrap defined as powder with impurities such as aluminum and carbon not exceeding 5,000 ppm and 10,000 ppm, respectively.

Table A.6-4 KENO Mixture Numbers

Mixture Number	**Powder**	**Pellets and Scrap**

Table A.6-5 Optimal Fill Height for NCT Single Package with Scrap with 236 kg UO_2, 4.55 wt % U-235

Fill Height (cm)	V_m/V_f	**Pitch (cm)**	k_{keno}	σ_{keno}	k_{eff}
41.2	3.7711	1.1	0.87919	0.00055	0.88029
46.2	4.3471	1.1	0.89343	0.00048	0.89439
51.2	4.9231	1.2	0.90137	0.00049	0.90235
56.2	5.4991	0.9	0.90491	0.00048	0.90587
61.2	**6.0752**	**0.9**	**0.90520**	**0.00051**	**0.90622**

Table A.6-6 Single NCT TNF-XI with 232 kg UO_2 Powder, 5.00 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	0.8955	0.0007	0.8969	***0.8954***	***0.0007***	***0.8968***	*0.8941*	*0.0007*	*0.8955*
60	**0.8977**	**0.0008**	**0.8993**	*0.8935*	*0.0008*	*0.8950*	***0.8945***	***0.0007***	***0.8959***
59	0.8957	0.0007	0.8971	*0.8924*	*0.0007*	*0.8937*	*0.8919*	*0.0007*	*0.8933*
58	0.8976	0.0006	0.8988	*0.8921*	*0.0007*	*0.8936*	*0.8914*	*0.0010*	*0.8934*
57	0.8950	0.0007	0.8964	*0.8905*	*0.0008*	*0.8920*	*0.8920*	*0.0008*	*0.8935*
55	0.8936	0.0007	0.8950	*0.8890*	*0.0006*	*0.8903*	*0.8898*	*0.0007*	*0.8912*
53	0.8912	0.0007	0.8926	*0.8865*	*0.0007*	*0.8879*	*0.8868*	*0.0007*	*0.8883*
51	0.8875	0.0007	0.8889	*0.8838*	*0.0007*	*0.8852*	*0.8817*	*0.0008*	*0.8833*
49	0.8851	0.0007	0.8865	*0.8796*	*0.0007*	*0.8811*	*0.8789*	*0.0007*	*0.8804*
47	0.8795	0.0007	0.8810	*0.8762*	*0.0008*	*0.8778*	*0.8736*	*0.0007*	*0.8750*
45	0.8753	0.0007	0.8767	*0.8693*	*0.0009*	*0.8710*	*0.8658*	*0.0007*	*0.8672*

Table A.6-7 Single NCT TNF-XI with 238 kg UO_2 Powder, 4.95 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.8983**	**0.0007**	**0.8997**	*0.8949*	*0.0007*	*0.8962*	***0.8939***	***0.0007***	***0.8953***
60	0.8960	0.0008	0.8975	***0.8948***	***0.0007***	***0.8963***	*0.8922*	*0.0007*	*0.8936*
59	0.8956	0.0008	0.8972	*0.8924*	*0.0007*	*0.8939*	*0.8915*	*0.0007*	*0.8929*
58	0.8951	0.0007	0.8964	*0.8915*	*0.0008*	*0.8930*	*0.8909*	*0.0008*	*0.8924*
57	0.8943	0.0007	0.8957	*0.8906*	*0.0007*	*0.8920*	*0.8899*	*0.0008*	*0.8915*
55	0.8927	0.0007	0.8940	*0.8888*	*0.0007*	*0.8902*	*0.8879*	*0.0007*	*0.8892*
53	0.8893	0.0007	0.8907	*0.8864*	*0.0007*	*0.8878*	*0.8840*	*0.0007*	*0.8854*
51	0.8863	0.0007	0.8877	*0.8822*	*0.0008*	*0.8839*	*0.8820*	*0.0008*	*0.8837*
49	0.8820	0.0007	0.8834	*0.8790*	*0.0008*	*0.8806*	*0.8770*	*0.0007*	*0.8784*
47	0.8770	0.0008	0.8786	*0.8737*	*0.0007*	*0.8751*	*0.8718*	*0.0008*	*0.8734*
45	0.8721	0.0008	0.8736	*0.8684*	*0.0008*	*0.8701*	*0.8640*	*0.0008*	*0.8656*

Table A.6-8 Single NCT TNF-XI with 248 kg UO_2 Powder, 4.85 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.8966**	**0.0008**	**0.8982**	*0.8911*	*0.0008*	*0.8926*	*0.8914*	*0.0007*	*0.8928*
60	0.8937	0.0007	0.8950	***0.8918***	***0.0008***	***0.8934***	***0.8917***	***0.0007***	***0.8931***
59	0.8943	0.0008	0.8959	*0.8907*	*0.0007*	*0.8921*	*0.8888*	*0.0008*	*0.8903*
58	0.8926	0.0006	0.8939	*0.8900*	*0.0008*	*0.8916*	*0.8890*	*0.0007*	*0.8903*
57	0.8913	0.0008	0.8929	*0.8884*	*0.0007*	*0.8898*	*0.8866*	*0.0007*	*0.8881*
55	0.8904	0.0007	0.8918	*0.8857*	*0.0007*	*0.8872*	*0.8856*	*0.0008*	*0.8871*
53	0.8866	0.0007	0.8880	*0.8838*	*0.0007*	*0.8852*	*0.8824*	*0.0007*	*0.8838*
51	0.8834	0.0007	0.8849	*0.8809*	*0.0007*	*0.8823*	*0.8779*	*0.0007*	*0.8794*
49	0.8801	0.0006	0.8814	*0.8754*	*0.0007*	*0.8769*	*0.8731*	*0.0007*	*0.8745*
47	0.8728	0.0007	0.8742	*0.8710*	*0.0007*	*0.8724*	*0.8677*	*0.0007*	*0.8692*
45	0.8667	0.0008	0.8682	*0.8640*	*0.0009*	*0.8657*	*0.8616*	*0.0007*	*0.8630*

Table A.6-9 Single NCT TNF-XI with 259 kg UO_2 Powder, 4.75 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.8949**	**0.0007**	**0.8963**	***0.8903***	***0.0008***	***0.8918***	***0.8895***	***0.0007***	***0.8909***
60	0.8931	0.0007	0.8945	*0.8884*	*0.0007*	*0.8897*	*0.8885*	*0.0007*	*0.8899*
59	0.8915	0.0007	0.8929	*0.8887*	*0.0007*	*0.8900*	*0.8869*	*0.0007*	*0.8883*
58	0.8902	0.0008	0.8918	*0.8873*	*0.0007*	*0.8887*	*0.8843*	*0.0007*	*0.8858*
57	0.8888	0.0008	0.8903	*0.8869*	*0.0007*	*0.8883*	*0.8848*	*0.0007*	*0.8863*
55	0.8851	0.0007	0.8866	*0.8828*	*0.0008*	*0.8845*	*0.8829*	*0.0007*	*0.8844*
53	0.8837	0.0007	0.8851	*0.8801*	*0.0007*	*0.8814*	*0.8780*	*0.0008*	*0.8796*
51	0.8789	0.0007	0.8803	*0.8763*	*0.0008*	*0.8778*	*0.8731*	*0.0007*	*0.8746*
49	0.8764	0.0008	0.8780	*0.8706*	*0.0007*	*0.8720*	*0.8691*	*0.0007*	*0.8705*
47	0.8698	0.0007	0.8712	*0.8655*	*0.0007*	*0.8669*	*0.8628*	*0.0007*	*0.8642*
45	0.8626	0.0007	0.8641	*0.8581*	*0.0007*	*0.8595*	*0.8566*	*0.0007*	*0.8580*

Table A.6-10 Single NCT TNF-XI with 271 kg UO_2 Powder, 4.65 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.8911**	**0.0008**	**0.8927**	***0.8888***	***0.0007***	***0.8902***	***0.8870***	***0.0007***	***0.8884***
60	0.8897	0.0007	0.8912	*0.8871*	*0.0007*	*0.8885*	*0.8850*	*0.0007*	*0.8864*
59	0.8893	0.0007	0.8906	*0.8862*	*0.0007*	*0.8876*	*0.8842*	*0.0008*	*0.8857*
58	0.8874	0.0008	0.8891	*0.8847*	*0.0007*	*0.8862*	*0.8822*	*0.0007*	*0.8835*
57	0.8866	0.0007	0.8880	*0.8825*	*0.0007*	*0.8838*	*0.8812*	*0.0007*	*0.8826*
55	0.8844	0.0007	0.8858	*0.8827*	*0.0008*	*0.8842*	*0.8784*	*0.0008*	*0.8800*
53	0.8794	0.0008	0.8810	*0.8767*	*0.0008*	*0.8784*	*0.8750*	*0.0009*	*0.8767*
51	0.8767	0.0008	0.8784	*0.8738*	*0.0007*	*0.8752*	*0.8707*	*0.0007*	*0.8721*
49	0.8708	0.0007	0.8722	*0.8665*	*0.0007*	*0.8679*	*0.8644*	*0.0009*	*0.8661*
47	0.8658	0.0007	0.8671	*0.8612*	*0.0006*	*0.8625*	*0.8580*	*0.0007*	*0.8594*
45	0.8586	0.0007	0.8600	*0.8549*	*0.0007*	*0.8563*	*0.8500*	*0.0008*	*0.8516*

Table A.6-11 Single NCT TNF-XI with 286 kg UO_2 Powder, 4.55 wt % U-235

	Powder			***Powder Scrap with ASTM C753 Impurities***			***Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)***		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.8901**	**0.0007**	**0.8917**	***0.8851***	***0.0007***	***0.8865***	***0.8836***	***0.0007***	***0.8850***
60	0.8870	0.0007	0.8884	*0.8833*	*0.0007*	*0.8848*	*0.8818*	*0.0007*	*0.8832*
59	0.8853	0.0007	0.8868	*0.8827*	*0.0007*	*0.8840*	*0.8819*	*0.0007*	*0.8833*
58	0.8843	0.0008	0.8859	*0.8812*	*0.0008*	*0.8828*	*0.8794*	*0.0007*	*0.8809*
57	0.8835	0.0007	0.8849	*0.8786*	*0.0007*	*0.8801*	*0.8777*	*0.0007*	*0.8792*
55	0.8804	0.0007	0.8818	*0.8750*	*0.0008*	*0.8765*	*0.8744*	*0.0007*	*0.8758*
53	0.8761	0.0007	0.8775	*0.8720*	*0.0008*	*0.8735*	*0.8707*	*0.0008*	*0.8723*
51	0.8705	0.0007	0.8719	*0.8675*	*0.0007*	*0.8690*	*0.8641*	*0.0008*	*0.8657*
49	0.8653	0.0008	0.8669	*0.8625*	*0.0008*	*0.8640*	*0.8588*	*0.0008*	*0.8603*
47	0.8590	0.0007	0.8604	*0.8557*	*0.0008*	*0.8573*	*0.8530*	*0.0007*	*0.8544*
45	0.8514	0.0007	0.8527	*0.8487*	*0.0008*	*0.8502*	*0.8435*	*0.0007*	*0.8448*

Table A.6-12 Single NCT TNF-XI with 300 kg UO_2 Powder, 4.45 wt % U-235

	Powder			***Powder Scrap with ASTM C753 Impurities***			***Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)***		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.8856**	**0.0007**	**0.8870**	*0.8810*	*0.0008*	*0.8825*	***0.8807***	***0.0008***	***0.8822***
60	0.8840	0.0007	0.8854	***0.8822***	***0.0007***	***0.8836***	*0.8795*	*0.0008*	*0.8810*
59	0.8818	0.0008	0.8834	*0.8791*	*0.0008*	*0.8806*	*0.8773*	*0.0007*	*0.8787*
58	0.8816	0.0007	0.8830	*0.8760*	*0.0007*	*0.8774*	*0.8761*	*0.0007*	*0.8775*
57	0.8794	0.0008	0.8810	*0.8742*	*0.0007*	*0.8756*	*0.8738*	*0.0008*	*0.8754*
55	0.8752	0.0010	0.8772	*0.8720*	*0.0007*	*0.8734*	*0.8701*	*0.0008*	*0.8717*
53	0.8706	0.0007	0.8720	*0.8676*	*0.0006*	*0.8688*	*0.8653*	*0.0007*	*0.8668*
51	0.8667	0.0007	0.8680	*0.8630*	*0.0008*	*0.8645*	*0.8596*	*0.0008*	*0.8611*
49	0.8613	0.0007	0.8628	*0.8574*	*0.0007*	*0.8589*	*0.8520*	*0.0007*	*0.8535*
47	0.8529	0.0007	0.8543	*0.8509*	*0.0007*	*0.8524*	*0.8452*	*0.0008*	*0.8467*
45	0.8461	0.0008	0.8477	*0.8412*	*0.0008*	*0.8427*	*0.8381*	*0.0008*	*0.8396*

Table A.6-13 Single NCT TNF-XI with 196 kg UO_2 Scrap, 5.00 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.89959	0.00074	0.90107
0.2	0.90290	0.00074	0.90438
0.3	0.90609	0.00073	0.90755
0.4	0.90540	0.00070	0.90680
0.5	**0.90837**	**0.00069**	**0.90975**
0.6	0.90774	0.00067	0.90908
0.7	0.90712	0.00073	0.90858
0.8	0.90558	0.00062	0.90682
0.9	0.90454	0.00082	0.90618
1.0	0.90352	0.00077	0.90506
1.1	0.90186	0.00075	0.90336
1.2	0.90055	0.00068	0.90191

1) $V_m/V_f = 7.5191$

Table A.6-14 Single NCT TNF-XI with 204 kg UO_2 Scrap, 4.95 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.89997	0.00070	0.90137
0.2	0.90415	0.00077	0.90569
0.3	0.90573	0.00070	0.90713
0.4	0.90724	0.00073	0.90870
0.5	0.90792	0.00067	0.90926
0.6	0.90804	0.00065	0.90934
0.7	0.90931	0.00064	0.91059
0.8	**0.90923**	**0.00068**	**0.91059**
0.9	0.90768	0.00078	0.90924
1.0	0.90741	0.00070	0.90881
1.1	0.90609	0.00070	0.90749
1.2	0.90350	0.00068	0.90486

1) $V_m/V_f = 7.1850$

Table A.6-15 Single NCT TNF-XI with 208 kg UO_2 Scrap, 4.85 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.89862	0.00075	0.90012
0.2	0.90172	0.00070	0.90312
0.3	0.90226	0.00067	0.90360
0.4	0.90573	0.00066	0.90705
0.5	0.90627	0.00071	0.90769
0.6	**0.90680**	**0.00077**	**0.90834**
0.7	0.90617	0.00070	0.90757
0.8	0.90529	0.00070	0.90669
0.9	0.90593	0.00081	0.90755
1.0	0.90587	0.00076	0.90739
1.1	0.90381	0.00070	0.90521
1.2	0.90306	0.00075	0.90456

1) $V_m/V_f = 7.0276$

Table A.6-16 Single NCT TNF-XI with 216 kg UO_2 Scrap, 4.75 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.89837	0.00064	0.89965
0.2	0.89943	0.00076	0.90095
0.3	0.90254	0.00070	0.90394
0.4	0.90441	0.00073	0.90587
0.5	0.90513	0.00086	0.90685
0.6	0.90517	0.00082	0.90681
0.7	0.90755	0.00069	0.90893
0.8	**0.90756**	**0.00073**	**0.90902**
0.9	0.90520	0.00075	0.90670
1.0	0.90457	0.00076	0.90609
1.1	0.90359	0.00073	0.90505
1.2	0.90168	0.00072	0.90312

1) $V_m/V_f = 6.7303$

Table A.6-17 Single NCT TNF-XI with 224 kg UO_2 Scrap, 4.65 wt % U-235[1]

Pitch (cm)	**k_{keno}**	**σ_{keno}**	**k_{eff}**
0.1	0.89555	0.00066	0.89687
0.2	0.89834	0.00074	0.89982
0.3	0.90083	0.00079	0.90241
0.4	0.90250	0.00066	0.90382
0.5	0.90474	0.00075	0.90624
0.6	0.90483	0.00063	0.90609
0.7	**0.90551**	**0.00072**	**0.90695**
0.8	0.90443	0.00070	0.90583
0.9	0.90455	0.00064	0.90583
1.0	0.90303	0.00073	0.90449
1.1	0.90252	0.00071	0.90394
1.2	0.90175	0.00078	0.90331

1) $V_m/V_f = 6.4542$

Table A.6-18 Single NCT TNF-XI with 236 kg UO_2 Scrap, 4.55 wt % U-235[1]

Pitch (cm)	**k_{keno}**	**σ_{keno}**	**k_{eff}**
0.1	0.89566	0.00056	0.89678
0.2	0.89790	0.00048	0.89886
0.3	0.90097	0.00051	0.90199
0.4	0.90253	0.00050	0.90353
0.5	0.90365	0.00052	0.90469
0.6	0.90504	0.00050	0.90604
0.7	0.90528	0.00046	0.90620
0.8	0.90514	0.00049	0.90612
0.9	**0.90520**	**0.00051**	**0.90622**
1.0	0.90510	0.00050	0.90610
1.1	0.90358	0.00046	0.90450
1.2	0.90323	0.00055	0.90433

1) $V_m/V_f = 6.0752$

Table A.6-19 Single NCT TNF-XI with 248 kg UO_2 Scrap, 4.45 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.89264	0.00068	0.89400
0.2	0.89668	0.00073	0.89814
0.3	0.89969	0.00081	0.90131
0.4	0.90212	0.00084	0.90380
0.5	0.90271	0.00078	0.90427
0.6	0.90516	0.00069	0.90654
0.7	0.90528	0.00066	0.90660
0.8	**0.90544**	**0.00076**	**0.90696**
0.9	0.90505	0.00071	0.90647
1.0	0.90518	0.00069	0.90656
1.1	0.90324	0.00071	0.90466
1.2	0.90461	0.00071	0.90603

1) $V_m/V_f = 5.7328$

Table A.6-20 Single NCT TNF-XI with 256 kg UO_2 Scrap, 4.35 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.88965	0.00064	0.89093
0.2	0.89327	0.00072	0.89471
0.3	0.89610	0.00068	0.89746
0.4	0.89969	0.00086	0.90141
0.5	0.90016	0.00069	0.90154
0.6	0.90063	0.00074	0.90211
0.7	**0.90363**	**0.00065**	**0.90493**
0.8	0.90314	0.00070	0.90454
0.9	0.90223	0.00070	0.90363
1.0	0.90251	0.00076	0.90403
1.1	0.90124	0.00068	0.90260
1.2	0.90013	0.00067	0.90147

1) $V_m/V_f = 5.5224$

Table A.6-21 Single NCT TNF-XI with 272 kg UO_2 Scrap, 4.25 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.88624	0.00075	0.88774
0.2	0.89125	0.00080	0.89285
0.3	0.89365	0.00072	0.89509
0.4	0.89531	0.00068	0.89667
0.5	0.89910	0.00082	0.90074
0.6	0.90127	0.00063	0.90253
0.7	0.90200	0.00069	0.90338
0.8	**0.90274**	**0.00072**	**0.90418**
0.9	0.90236	0.00071	0.90378
1.0	0.90223	0.00071	0.90365
1.1	0.90235	0.00070	0.90375
1.2	0.90097	0.00069	0.90235

1) $V_m/V_f = 5.1387$

Table A.6-22 Single NCT TNF-XI with 284 kg UO_2 Scrap, 4.15 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.88578	0.00071	0.88720
0.2	0.88738	0.00082	0.88902
0.3	0.89128	0.00071	0.89270
0.4	0.89345	0.00071	0.89487
0.5	0.89679	0.00073	0.89825
0.6	0.89781	0.00068	0.89917
0.7	0.90013	0.00070	0.90153
0.8	0.89971	0.00065	0.90101
0.9	0.89937	0.00069	0.90075
1.0	0.89896	0.00071	0.90038
1.1	0.89956	0.00071	0.90098
1.2	**0.90017**	**0.00074**	**0.90165**
1.3	0.89971	0.00082	0.90135
1.4	0.89922	0.00067	0.90056
1.5	0.89616	0.00077	0.89770
1.6	0.89642	0.00069	0.89780
1.7	0.89517	0.00065	0.89647
1.8	0.89382	0.00069	0.89520
1.9	0.89131	0.00070	0.89271
2.0	0.89023	0.00069	0.89161

1) $V_m/V_f = 4.8794$

Table A.6-23 Single NCT TNF-XI with 300 kg UO_2 Scrap, 4.05 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.87983	0.00071	0.88125
0.2	0.88491	0.00078	0.88647
0.3	0.88767	0.00070	0.88907
0.4	0.89064	0.00072	0.89208
0.5	0.89522	0.00066	0.89654
0.6	0.89581	0.00079	0.89739
0.7	0.89680	0.00066	0.89812
0.8	0.89761	0.00074	0.89909
0.9	0.89800	0.00070	0.89940
1.0	**0.89941**	**0.00067**	**0.90075**
1.1	0.89763	0.00069	0.89901
1.2	0.89800	0.00083	0.89966
1.3	0.89828	0.00071	0.89970
1.4	0.89854	0.00073	0.90000
1.5	0.89700	0.00072	0.89844
1.6	0.89599	0.00070	0.89739
1.7	0.89544	0.00071	0.89686
1.8	0.89447	0.00082	0.89611
1.9	0.89263	0.00074	0.89411
2.0	0.89006	0.00069	0.89144

1) $V_m/V_f = 4.5658$

Table A.6-24 Optimal Fill Height for NCT Package Array with Scrap[1]

Fill Height (cm)	V_m/V_f	**Pitch (cm)**	k_{keno}	σ_{keno}	k_{eff}
41.2	3.7711	1.1	0.89347	0.00048	0.89443
46.2	4.3471	1.1	0.90875	0.00048	0.90971
51.2	4.9231	0.8	0.91655	0.00050	0.91755
56.2	5.4991	1.1	0.92038	0.00050	0.92138
61.2	**6.0752**	**0.7**	**0.92268**	**0.00055**	**0.92378**

1) 236 kg UO_2, 4.55 wt % U-235

Table A.6-25 NCT TNF-XI Package Array with 232 kg UO_2 Powder, 5.00 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.9150**	**0.0007**	**0.9164**	***0.9118***	***0.0007***	***0.9132***	***0.9113***	***0.0008***	***0.9129***
60	0.9123	0.0007	0.9138	*0.9102*	*0.0007*	*0.9116*	*0.9090*	*0.0007*	*0.9104*
59	0.9118	0.0008	0.9134	*0.9090*	*0.0007*	*0.9104*	*0.9084*	*0.0007*	*0.9098*
58	0.9126	0.0007	0.9141	*0.9088*	*0.0008*	*0.9103*	*0.9076*	*0.0007*	*0.9089*
57	0.9107	0.0008	0.9122	*0.9070*	*0.0007*	*0.9084*	*0.9083*	*0.0007*	*0.9097*
55	0.9098	0.0007	0.9112	*0.9038*	*0.0008*	*0.9053*	*0.9055*	*0.0007*	*0.9068*
53	0.9067	0.0008	0.9082	*0.9032*	*0.0007*	*0.9046*	*0.9018*	*0.0007*	*0.9033*
51	0.9039	0.0007	0.9052	*0.8998*	*0.0007*	*0.9012*	*0.8981*	*0.0007*	*0.8996*
49	0.9003	0.0007	0.9018	*0.8961*	*0.0007*	*0.8975*	*0.8946*	*0.0007*	*0.8960*
47	0.8935	0.0007	0.8950	*0.8910*	*0.0007*	*0.8924*	*0.8888*	*0.0007*	*0.8902*
45	0.8882	0.0007	0.8897	*0.8850*	*0.0008*	*0.8865*	*0.8834*	*0.0007*	*0.8848*

Table A.6-26 NCT TNF-XI Package Array with 238 kg UO_2 Powder, 4.95 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	0.9137	0.0007	0.9151	*0.9102*	*0.0007*	*0.9116*	*0.9100*	*0.0008*	*0.9115*
60	**0.9143**	**0.0007**	**0.9157**	*0.9094*	*0.0006*	*0.9107*	***0.9102***	***0.0007***	***0.9115***
59	0.9123	0.0007	0.9136	***0.9105***	***0.0008***	***0.9120***	*0.9066*	*0.0007*	*0.9080*
58	0.9108	0.0008	0.9124	*0.9074*	*0.0006*	*0.9087*	*0.9071*	*0.0007*	*0.9085*
57	0.9086	0.0007	0.9099	*0.9065*	*0.0007*	*0.9079*	*0.9064*	*0.0007*	*0.9078*
55	0.9089	0.0007	0.9103	*0.9050*	*0.0007*	*0.9065*	*0.9038*	*0.0008*	*0.9053*
53	0.9070	0.0009	0.9087	*0.9020*	*0.0007*	*0.9034*	*0.9006*	*0.0007*	*0.9020*
51	0.9014	0.0007	0.9028	*0.8970*	*0.0007*	*0.8984*	*0.8974*	*0.0007*	*0.8988*
49	0.8972	0.0009	0.8989	*0.8926*	*0.0008*	*0.8941*	*0.8916*	*0.0007*	*0.8930*
47	0.8909	0.0007	0.8923	*0.8896*	*0.0007*	*0.8910*	*0.8870*	*0.0007*	*0.8885*
45	0.8860	0.0007	0.8874	*0.8833*	*0.0008*	*0.8848*	*0.8810*	*0.0008*	*0.8825*

Table A.6-27 NCT TNF-XI Package Array with 248 kg UO_2 Powder, 4.85 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.9128**	**0.0007**	**0.9142**	***0.9088***	***0.0007***	***0.9103***	*0.9063*	*0.0007*	*0.9076*
60	0.9100	0.0007	0.9113	*0.9073*	*0.0007*	*0.9086*	***0.9076***	***0.0007***	***0.9090***
59	0.9100	0.0008	0.9116	*0.9074*	*0.0007*	*0.9089*	*0.9069*	*0.0007*	*0.9083*
58	0.9099	0.0007	0.9112	*0.9060*	*0.0007*	*0.9074*	*0.9049*	*0.0008*	*0.9065*
57	0.9068	0.0007	0.9081	*0.9041*	*0.0008*	*0.9058*	*0.9034*	*0.0007*	*0.9049*
55	0.9060	0.0006	0.9072	*0.9031*	*0.0008*	*0.9046*	*0.9009*	*0.0007*	*0.9023*
53	0.9031	0.0007	0.9044	*0.8984*	*0.0007*	*0.8997*	*0.8977*	*0.0007*	*0.8991*
51	0.8983	0.0008	0.8999	*0.8945*	*0.0007*	*0.8958*	*0.8917*	*0.0008*	*0.8933*
49	0.8940	0.0007	0.8954	*0.8901*	*0.0007*	*0.8915*	*0.8876*	*0.0007*	*0.8890*
47	0.8882	0.0007	0.8896	*0.8849*	*0.0007*	*0.8863*	*0.8845*	*0.0006*	*0.8858*
45	0.8824	0.0007	0.8839	*0.8782*	*0.0008*	*0.8798*	*0.8756*	*0.0007*	*0.8770*

Table A.6-28 NCT TNF-XI Package Array with 259 kg UO_2 Powder, 4.75 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.9107**	**0.0008**	**0.9123**	***0.9070***	***0.0007***	***0.9084***	***0.9060***	***0.0006***	***0.9073***
60	0.9093	0.0007	0.9106	*0.9035*	*0.0008*	*0.9052*	*0.9047*	*0.0007*	*0.9062*
59	0.9094	0.0008	0.9110	*0.9043*	*0.0007*	*0.9057*	*0.9038*	*0.0007*	*0.9051*
58	0.9062	0.0008	0.9077	*0.9028*	*0.0007*	*0.9042*	*0.9013*	*0.0008*	*0.9029*
57	0.9047	0.0008	0.9062	*0.9019*	*0.0007*	*0.9034*	*0.9026*	*0.0007*	*0.9039*
55	0.9026	0.0007	0.9039	*0.8997*	*0.0007*	*0.9011*	*0.8966*	*0.0007*	*0.8980*
53	0.8989	0.0007	0.9003	*0.8958*	*0.0007*	*0.8971*	*0.8933*	*0.0008*	*0.8948*
51	0.8951	0.0007	0.8965	*0.8905*	*0.0007*	*0.8918*	*0.8899*	*0.0008*	*0.8915*
49	0.8909	0.0007	0.8922	*0.8877*	*0.0007*	*0.8890*	*0.8846*	*0.0008*	*0.8862*
47	0.8843	0.0008	0.8860	*0.8798*	*0.0007*	*0.8812*	*0.8776*	*0.0007*	*0.8791*
45	0.8779	0.0007	0.8793	*0.8740*	*0.0007*	*0.8755*	*0.8707*	*0.0008*	*0.8723*

Table A.6-29 NCT TNF-XI Package Array with 271 kg UO_2 Powder, 4.65 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.9069**	**0.0007**	**0.9083**	***0.9053***	***0.0007***	***0.9067***	***0.9023***	***0.0006***	***0.9036***
60	0.9066	0.0007	0.9080	*0.9046*	*0.0008*	*0.9062*	*0.9007*	*0.0007*	*0.9021*
59	0.9045	0.0007	0.9058	*0.9019*	*0.0007*	*0.9033*	*0.9009*	*0.0007*	*0.9023*
58	0.9026	0.0007	0.9039	*0.8999*	*0.0007*	*0.9013*	*0.9005*	*0.0008*	*0.9022*
57	0.9016	0.0007	0.9030	*0.8993*	*0.0007*	*0.9007*	*0.8969*	*0.0007*	*0.8982*
55	0.9004	0.0008	0.9020	*0.8972*	*0.0007*	*0.8986*	*0.8937*	*0.0007*	*0.8951*
53	0.8962	0.0007	0.8975	*0.8923*	*0.0007*	*0.8937*	*0.8909*	*0.0008*	*0.8925*
51	0.8913	0.0007	0.8927	*0.8880*	*0.0007*	*0.8894*	*0.8856*	*0.0006*	*0.8869*
49	0.8846	0.0007	0.8860	*0.8822*	*0.0007*	*0.8835*	*0.8787*	*0.0008*	*0.8802*
47	0.8797	0.0007	0.8811	*0.8771*	*0.0008*	*0.8787*	*0.8743*	*0.0007*	*0.8757*
45	0.8721	0.0007	0.8735	*0.8690*	*0.0009*	*0.8707*	*0.8644*	*0.0008*	*0.8660*

Table A.6-30 NCT TNF-XI Package Array with 286 kg UO_2 Powder, 4.55 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.9055**	**0.0008**	**0.9071**	***0.9026***	***0.0007***	***0.9040***	***0.9002***	***0.0007***	***0.9015***
60	0.9039	0.0007	0.9054	*0.9001*	*0.0007*	*0.9016*	*0.8987*	*0.0008*	*0.9003*
59	0.9033	0.0006	0.9045	*0.9006*	*0.0007*	*0.9020*	*0.8983*	*0.0007*	*0.8998*
58	0.9015	0.0007	0.9029	*0.8971*	*0.0007*	*0.8984*	*0.8964*	*0.0007*	*0.8979*
57	0.8998	0.0008	0.9013	*0.8959*	*0.0008*	*0.8975*	*0.8934*	*0.0007*	*0.8948*
55	0.8953	0.0007	0.8967	*0.8916*	*0.0006*	*0.8928*	*0.8910*	*0.0007*	*0.8923*
53	0.8928	0.0008	0.8944	*0.8887*	*0.0007*	*0.8901*	*0.8859*	*0.0008*	*0.8875*
51	0.8866	0.0007	0.8879	*0.8826*	*0.0007*	*0.8840*	*0.8794*	*0.0007*	*0.8808*
49	0.8830	0.0007	0.8845	*0.8755*	*0.0008*	*0.8771*	*0.8738*	*0.0008*	*0.8754*
47	0.8735	0.0008	0.8750	*0.8713*	*0.0007*	*0.8727*	*0.8666*	*0.0008*	*0.8683*
45	0.8675	0.0007	0.8690	*0.8643*	*0.0008*	*0.8658*	*0.8582*	*0.0007*	*0.8595*

Table A.6-31 NCT TNF-XI Package Array with 300 kg UO_2 Powder, 4.45 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
61.2	**0.9011**	**0.0009**	**0.9029**	***0.8993***	***0.0007***	***0.9007***	***0.8993***	***0.0007***	***0.9007***
60	0.9014	0.0007	0.9027	*0.8974*	*0.0007*	*0.8987*	*0.8953*	*0.0008*	*0.8969*
59	0.8989	0.0008	0.9004	*0.8938*	*0.0007*	*0.8951*	*0.8933*	*0.0007*	*0.8947*
58	0.8977	0.0008	0.8993	*0.8923*	*0.0007*	*0.8937*	*0.8918*	*0.0007*	*0.8932*
57	0.8952	0.0007	0.8965	*0.8907*	*0.0007*	*0.8921*	*0.8903*	*0.0008*	*0.8919*
55	0.8905	0.0008	0.8921	*0.8890*	*0.0006*	*0.8902*	*0.8854*	*0.0007*	*0.8869*
53	0.8864	0.0007	0.8879	*0.8832*	*0.0007*	*0.8845*	*0.8797*	*0.0007*	*0.8811*
51	0.8819	0.0007	0.8834	*0.8772*	*0.0007*	*0.8785*	*0.8751*	*0.0008*	*0.8766*
49	0.8752	0.0008	0.8768	*0.8721*	*0.0007*	*0.8734*	*0.8686*	*0.0007*	*0.8700*
47	0.8687	0.0008	0.8702	*0.8661*	*0.0007*	*0.8676*	*0.8617*	*0.0007*	*0.8631*
45	0.8617	0.0008	0.8632	*0.8572*	*0.0007*	*0.8586*	*0.8530*	*0.0007*	*0.8544*

Table A.6-32 NCT TNF-XI Package Array with 196 kg UO_2 Scrap, 5.00 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.91575	0.00075	0.91725
0.2	0.91728	0.00066	0.91860
0.3	0.91909	0.00076	0.92061
0.4	0.92060	0.00078	0.92216
0.5	**0.92412**	**0.00064**	**0.92540**
0.6	0.92374	0.00066	0.92506
0.7	0.92364	0.00073	0.92510
0.8	0.92300	0.00075	0.92450
0.9	0.92103	0.00075	0.92253
1.0	0.91889	0.00069	0.92027
1.1	0.91818	0.00069	0.91956
1.2	0.91624	0.00063	0.91750

1) $V_m/V_f = 7.5191$

Table A.6-33 NCT TNF-XI Package Array with 204 kg UO_2 Scrap, 4.95 wt % U-235[1]

Pitch (cm)	**k_{keno}**	**σ_{keno}**	**k_{eff}**
0.1	0.91784	0.00064	0.91912
0.2	0.91899	0.00075	0.92049
0.3	0.92306	0.00074	0.92454
0.4	0.92325	0.00069	0.92463
0.5	0.92364	0.00074	0.92512
0.6	**0.92530**	**0.00068**	**0.92666**
0.7	0.92434	0.00070	0.92574
0.8	0.92416	0.00071	0.92558
0.9	0.92499	0.00078	0.92655
1.0	0.92187	0.00067	0.92321
1.1	0.92241	0.00071	0.92383
1.2	0.91991	0.00068	0.92127

1) $V_m/V_f = 7.1850$

Table A.6-34 NCT TNF-XI Package Array with 208 kg UO_2 Scrap, 4.85 wt % U-235[1]

Pitch (cm)	**k_{keno}**	**σ_{keno}**	**k_{eff}**
0.1	0.91442	0.00070	0.91582
0.2	0.91842	0.00063	0.91968
0.3	0.91934	0.00079	0.92092
0.4	0.92226	0.00069	0.92364
0.5	0.92186	0.00064	0.92314
0.6	0.92347	0.00065	0.92477
0.7	0.92357	0.00065	0.92487
0.8	**0.92366**	**0.00076**	**0.92518**
0.9	0.92317	0.00071	0.92459
1.0	0.92048	0.00068	0.92184
1.1	0.92007	0.00074	0.92155
1.2	0.91831	0.00075	0.91981

1) $V_m/V_f = 7.0276$

Table A.6-35 NCT TNF-XI Package Array with 216 kg UO_2 Scrap, 4.75 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.91290	0.00065	0.91420
0.2	0.91577	0.00069	0.91715
0.3	0.92000	0.00067	0.92134
0.4	0.92008	0.00065	0.92138
0.5	0.92117	0.00072	0.92261
0.6	**0.92356**	**0.00077**	**0.92510**
0.7	0.92257	0.00061	0.92379
0.8	0.92195	0.00073	0.92341
0.9	0.92133	0.00065	0.92263
1.0	0.92068	0.00067	0.92202
1.1	0.91874	0.00075	0.92024
1.2	0.91724	0.00068	0.91860

1) $V_m/V_f = 6.7303$

Table A.6-36 NCT TNF-XI Package Array with 224 kg UO_2 Scrap, 4.65 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.91024	0.00072	0.91168
0.2	0.91439	0.00077	0.91593
0.3	0.91629	0.00072	0.91773
0.4	0.91846	0.00060	0.91966
0.5	0.91995	0.00065	0.92125
0.6	0.92152	0.00075	0.92302
0.7	**0.92248**	**0.00066**	**0.92380**
0.8	0.91980	0.00064	0.92108
0.9	0.92201	0.00071	0.92343
1.0	0.92035	0.00068	0.92171
1.1	0.91914	0.00067	0.92048
1.2	0.91622	0.00059	0.91740

1) $V_m/V_f = 6.4542$

Table A.6-37 NCT TNF-XI Package Array with 236 kg UO_2 Scrap, 4.55 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.91054	0.00049	0.91152
0.2	0.91401	0.00052	0.91505
0.3	0.91596	0.00047	0.91690
0.4	0.91912	0.00047	0.92006
0.5	0.91926	0.00052	0.92030
0.6	0.92173	0.00046	0.92265
0.7	**0.92268**	**0.00055**	**0.92378**
0.8	0.92202	0.00046	0.92294
0.9	0.92161	0.00045	0.92251
1.0	0.92184	0.00046	0.92276
1.1	0.92047	0.00046	0.92139
1.2	0.91889	0.00047	0.91983

1) $V_m/V_f = 6.0752$

Table A.6-38 NCT TNF-XI Package Array with 248 kg UO_2 Scrap, 4.45 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.90886	0.00066	0.91018
0.2	0.91217	0.00069	0.91355
0.3	0.91428	0.00068	0.91564
0.4	0.91895	0.00082	0.92059
0.5	0.91824	0.00069	0.91962
0.6	0.91986	0.00071	0.92128
0.7	0.92214	0.00069	0.92352
0.8	**0.92206**	**0.00074**	**0.92354**
0.9	0.92160	0.00074	0.92308
1.0	0.92040	0.00068	0.92176
1.1	0.92061	0.00069	0.92199
1.2	0.92018	0.00067	0.92152

1) $V_m/V_f = 5.7328$

Table A.6-39 NCT TNF-XI Package Array with 256 kg UO_2 Scrap, 4.35 wt % U-235[1]

Pitch (cm)	**k_{keno}**	**σ_{keno}**	**k_{eff}**
0.1	0.90585	0.00050	0.90685
0.2	0.90943	0.00044	0.91031
0.3	0.91184	0.00049	0.91282
0.4	0.91391	0.00051	0.91493
0.5	0.91692	0.00047	0.91786
0.6	0.91779	0.00055	0.91889
0.7	0.91942	0.00050	0.92042
0.8	0.91965	0.00067	0.92099
0.9	0.91929	0.00069	0.92067
1.0	**0.92015**	**0.00061**	**0.92137**
1.1	0.91887	0.00068	0.92023
1.2	0.91686	0.00068	0.91822
1.3	0.91638	0.00069	0.91776
1.4	0.91436	0.00064	0.91564
1.5	0.91505	0.00073	0.91651
1.6	0.91172	0.00069	0.91310
1.7	0.91145	0.00068	0.91281
1.8	0.90995	0.00065	0.91125
1.9	0.90620	0.00067	0.90754
2.0	0.90485	0.00067	0.90619

1) $V_m/V_f = 5.5224$

Table A.6-40 NCT TNF-XI Package Array with 272 kg UO_2 Scrap, 4.25 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.90348	0.00058	0.90464
0.2	0.90764	0.00053	0.90870
0.3	0.91050	0.00047	0.91144
0.4	0.91255	0.00047	0.91349
0.5	0.91599	0.00049	0.91697
0.6	0.91633	0.00051	0.91735
0.7	0.91827	0.00057	0.91941
0.8	0.91883	0.00051	0.91985
0.9	**0.91911**	**0.00048**	**0.92007**
1.0	0.91831	0.00056	0.91943
1.1	0.91908	0.00049	0.92006
1.2	0.91837	0.00051	0.91939
1.3	0.91720	0.00067	0.91854
1.4	0.91689	0.00065	0.91819
1.5	0.91458	0.00075	0.91608
1.6	0.91369	0.00068	0.91505
1.7	0.91263	0.00075	0.91413
1.8	0.90945	0.00069	0.91083
1.9	0.90900	0.00080	0.91060
2.0	0.90656	0.00068	0.90792

1) $V_m/V_f = 5.1387$

Table A.6-41 NCT TNF-XI Package Array with 284 kg UO_2 Scrap, 4.15 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.90108	0.00053	0.90214
0.2	0.90402	0.00048	0.90498
0.3	0.90780	0.00047	0.90874
0.4	0.91041	0.00055	0.91151
0.5	0.91164	0.00060	0.91284
0.6	0.91427	0.00050	0.91527
0.7	0.91630	0.00042	0.91714
0.8	0.91604	0.00051	0.91706
0.9	0.91623	0.00056	0.91735
1.0	**0.91732**	**0.00052**	**0.91836**
1.1	0.91719	0.00046	0.91811
1.2	0.91654	0.00052	0.91758
1.3	0.91565	0.00075	0.91715
1.4	0.91540	0.00066	0.91672
1.5	0.91128	0.00068	0.91264
1.6	0.91376	0.00067	0.91510
1.7	0.91080	0.00066	0.91212
1.8	0.91120	0.00074	0.91268
1.9	0.90910	0.00064	0.91038
2.0	0.90565	0.00067	0.90699

1) $V_m/V_f = 4.8794$

Table A.6-42 NCT TNF-XI Package Array with 300 kg UO_2 Scrap, 4.05 wt % U-235[1]

Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
0.1	0.89740	0.00058	0.89856
0.2	0.90135	0.00056	0.90247
0.3	0.90450	0.00047	0.90544
0.4	0.90688	0.00048	0.90784
0.5	0.90925	0.00047	0.91019
0.6	0.91221	0.00049	0.91319
0.7	0.91234	0.00054	0.91342
0.8	0.91517	0.00048	0.91613
0.9	0.91441	0.00051	0.91543
1.0	**0.91650**	**0.00046**	**0.91742**
1.1	0.91629	0.00045	0.91719
1.2	0.91533	0.00046	0.91625
1.3	0.91493	0.00069	0.91631
1.4	0.91371	0.00076	0.91523
1.5	0.91558	0.00072	0.91702
1.6	0.91259	0.00076	0.91411
1.7	0.91113	0.00075	0.91263
1.8	0.90992	0.00074	0.91140
1.9	0.90675	0.00067	0.90809
2.0	0.90774	0.00063	0.90900

1) $V_m/V_f = 4.5658$

Table A.6-43 Square Pitch Lattice for HAC Package Array[1]

Fill Height (cm)	V_m/V_f	Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
36.2	5.4744	0.6	0.93050	0.00070	0.93190
41.2	6.3637	0.1	0.92356	0.00080	0.92516
		0.2	0.92521	0.00058	0.92637
		0.3	0.92980	0.00072	0.93124
		0.4	0.93232	0.00067	0.93366
		0.5	0.93318	0.00069	0.93456
		0.6	**0.93353**	**0.00074**	**0.93501**
		0.7	0.93250	0.00069	0.93388
		0.8	0.93109	0.00067	0.93243
		0.9	0.92999	0.00065	0.93129
		1.0	0.92889	0.00074	0.93037
		1.1	0.92626	0.00075	0.92776
		1.2	0.92399	0.00085	0.92569
46.2	7.2530	0.6	0.93165	0.00061	0.93287

1) 236 kg UO_2 Scrap with 4.55 wt % U-235

Table A.6-44 Triangular Pitch Lattice for HAC Package Array[1]

Fill Height (cm)	V_m/V_f	Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
36.2	5.4744	0.7	0.92962	0.00073	0.93108
41.2	6.3637	0.1	0.92035	0.00073	0.92181
		0.2	0.92498	0.00070	0.92638
		0.3	0.92875	0.00071	0.93017
		0.4	0.93057	0.00069	0.93195
		0.5	0.93255	0.00071	0.93397
		0.6	0.93143	0.00064	0.93271
		0.7	**0.93391**	**0.00074**	**0.93539**
		0.8	0.93223	0.00084	0.93391
		0.9	0.93006	0.00070	0.93146
		1.0	0.93080	0.00073	0.93226
		1.1	0.92804	0.00066	0.92936
		1.2	0.92664	0.00066	0.92796
46.2	7.2530	0.7	0.93135	0.00067	0.93269

1) 236 kg UO_2 Scrap with 4.55 wt % U-23

Table A.6-45 Spherical Lattice for HAC Package Array[1]

Fill Height (cm)	V_m/V_f	Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
36.2	5.4744	1.1	0.93343	0.00083	0.93509
41.2	6.3637	0.1	0.92535	0.00072	0.92679
		0.2	0.92895	0.00081	0.93057
		0.3	0.93073	0.00069	0.93211
		0.4	0.93132	0.00073	0.93278
		0.5	0.93380	0.00068	0.93516
		0.6	0.93466	0.00070	0.93606
		0.7	**0.93477**	**0.00070**	**0.93617**
		0.8	0.93427	0.00064	0.93555
		0.9	0.93380	0.00069	0.93518
		1.0	0.93292	0.00083	0.93458
		1.1	0.93188	0.00062	0.93312
		1.2	0.93091	0.00073	0.93237
46.2	7.2530	0.5	0.93298	0.00073	0.93444

1) 236 kg UO_2 Scrap with 4.55 wt % U-235

Table A.6-46 HAC TNF-XI Package Array with 232 kg UO_2 Powder, 5.00 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
50	0.9284	0.0007	0.9298	-	-	-	*0.9274*	*0.0007*	*0.9288*
49	0.9309	0.0008	0.9324	-	-	-	***0.9299***	***0.0007***	***0.9313***
48	0.9313	0.0007	0.9327	-	-	-	*0.9292*	*0.0009*	*0.9310*
47	0.9320	0.0008	0.9335	-	-	-	*0.9294*	*0.0007*	*0.9308*
46	0.9314	0.0008	0.9330	-	-	-	*0.9295*	*0.0007*	*0.9308*
45	0.9302	0.0007	0.9316	-	-	-	*0.9291*	*0.0007*	*0.9306*
44	**0.9339**	**0.0007**	**0.9352**	-	-	-	*0.9294*	*0.0007*	*0.9309*
43	0.9325	0.0007	0.9338	-	-	-	*0.9298*	*0.0008*	*0.9313*
42	0.9309	0.0008	0.9324	-	-	-	*0.9276*	*0.0007*	*0.9290*
41	0.9300	0.0007	0.9313	-	-	-	*0.9276*	*0.0007*	*0.9290*
40	0.9293	0.0007	0.9307	-	-	-	*0.9273*	*0.0007*	*0.9286*

Table A.6-47 HAC TNF-XI Package Array with 238 kg UO_2 Powder, 4.95 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
50	0.9302	0.0008	0.9317	-	-	-	*0.9287*	*0.0006*	*0.9300*
49	0.9327	0.0007	0.9341	-	-	-	*0.9294*	*0.0007*	*0.9308*
48	0.9312	0.0007	0.9325	-	-	-	*0.9292*	*0.0008*	*0.9307*
47	0.9317	0.0007	0.9331	-	-	-	*0.9303*	*0.0007*	*0.9317*
46	**0.9328**	**0.0006**	**0.9341**	-	-	-	***0.9307***	***0.0007***	***0.9321***
45	0.9325	0.0007	0.9339	-	-	-	*0.9288*	*0.0007*	*0.9302*
44	0.9312	0.0007	0.9326	-	-	-	*0.9280*	*0.0007*	*0.9294*
43	0.9312	0.0008	0.9328	-	-	-	*0.9286*	*0.0007*	*0.9300*
42	0.9306	0.0007	0.9320	-	-	-	*0.9276*	*0.0008*	*0.9291*
41	0.9310	0.0008	0.9325	-	-	-	*0.9271*	*0.0008*	*0.9287*
40	0.9299	0.0007	0.9313	-	-	-	*0.9270*	*0.0007*	*0.9284*

Table A.6-48 HAC TNF-XI Package Array with 248 kg UO_2 Powder, 4.85 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
50	0.9310	0.0008	0.9325	-	-	-	*0.9285*	*0.0007*	*0.9298*
49	0.9306	0.0007	0.9321	-	-	-	*0.9280*	*0.0007*	*0.9295*
48	0.9317	0.0007	0.9330	-	-	-	*0.9287*	*0.0007*	*0.9302*
47	**0.9332**	**0.0007**	**0.9345**	-	-	-	***0.9300***	***0.0007***	***0.9315***
46	0.9316	0.0007	0.9331	-	-	-	*0.9283*	*0.0007*	*0.9297*
45	0.9330	0.0007	0.9344	-	-	-	*0.9291*	*0.0007*	*0.9305*
44	0.9320	0.0007	0.9333	-	-	-	*0.9292*	*0.0007*	*0.9307*
43	0.9310	0.0008	0.9325	-	-	-	*0.9290*	*0.0007*	*0.9303*
42	0.9303	0.0007	0.9317	-	-	-	*0.9276*	*0.0008*	*0.9291*
41	0.9303	0.0007	0.9317	-	-	-	*0.9267*	*0.0007*	*0.9281*
40	0.9275	0.0007	0.9289	-	-	-	*0.9245*	*0.0007*	*0.9259*

Table A.6-49 HAC TNF-XI Package Array with 259 kg UO_2 Powder, 4.75 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
50	0.9312	0.0008	0.9327	-	-	-	*0.9284*	*0.0007*	*0.9297*
49	0.9305	0.0008	0.9322	-	-	-	*0.9287*	*0.0007*	*0.9301*
48	**0.9327**	**0.0007**	**0.9341**	-	-	-	***0.9292***	***0.0007***	***0.9306***
47	0.9311	0.0007	0.9326	-	-	-	*0.9288*	*0.0008*	*0.9304*
46	0.9317	0.0009	0.9336	-	-	-	*0.9288*	*0.0007*	*0.9301*
45	0.9322	0.0007	0.9337	-	-	-	*0.9288*	*0.0008*	*0.9303*
44	0.9309	0.0007	0.9323	-	-	-	*0.9269*	*0.0007*	*0.9282*
43	0.9289	0.0007	0.9303	-	-	-	*0.9252*	*0.0007*	*0.9267*
42	0.9288	0.0007	0.9303	-	-	-	*0.9261*	*0.0008*	*0.9276*
41	0.9278	0.0008	0.9294	-	-	-	*0.9240*	*0.0007*	*0.9254*
40	0.9254	0.0008	0.9269	-	-	-	*0.9238*	*0.0007*	*0.9253*

Table A.6-50 HAC TNF-XI Package Array with 271 kg UO_2 Powder, 4.65 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
50	0.9308	0.0006	0.9320	-	-	-	*0.9294*	*0.0007*	*0.9309*
49	0.9306	0.0007	0.9320	-	-	-	*0.9296*	*0.0007*	*0.9310*
48	0.9323	0.0008	0.9338	-	-	-	*0.9283*	*0.0007*	*0.9298*
47	0.9314	0.0008	0.9329	-	-	-	*0.9277*	*0.0008*	*0.9293*
46	**0.9330**	**0.0007**	**0.9344**	-	-	-	***0.9298***	***0.0006***	***0.9311***
45	0.9306	0.0007	0.9320	-	-	-	*0.9283*	*0.0007*	*0.9297*
44	0.9292	0.0007	0.9306	-	-	-	*0.9259*	*0.0007*	*0.9273*
43	0.9309	0.0007	0.9323	-	-	-	*0.9244*	*0.0008*	*0.9259*
42	0.9285	0.0008	0.9301	-	-	-	*0.9240*	*0.0007*	*0.9254*
41	0.9262	0.0008	0.9277	-	-	-	*0.9244*	*0.0007*	*0.9259*
40	0.9250	0.0008	0.9267	-	-	-	*0.9211*	*0.0007*	*0.9225*

Table A.6-51 HAC TNF-XI Package Array with 286 kg UO_2 Powder, 4.55 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
50	0.9325	0.0007	0.9339	-	-	-	***0.9289***	***0.0007***	***0.9302***
49	0.9322	0.0007	0.9336	-	-	-	*0.9287*	*0.0007*	*0.9302*
48	0.9323	0.0007	0.9336	-	-	-	*0.9278*	*0.0007*	*0.9292*
47	**0.9327**	**0.0007**	**0.9341**	-	-	-	*0.9261*	*0.0007*	*0.9275*
46	0.9314	0.0007	0.9328	-	-	-	*0.9277*	*0.0008*	*0.9293*
45	0.9309	0.0008	0.9325	-	-	-	*0.9261*	*0.0007*	*0.9275*
44	0.9303	0.0007	0.9318	-	-	-	*0.9268*	*0.0007*	*0.9282*
43	0.9269	0.0008	0.9285	-	-	-	*0.9246*	*0.0007*	*0.9260*
42	0.9264	0.0007	0.9278	-	-	-	*0.9239*	*0.0008*	*0.9255*
41	0.9253	0.0008	0.9268	-	-	-	*0.9205*	*0.0007*	*0.9218*
40	0.9238	0.0007	0.9252	-	-	-	*0.9199*	*0.0007*	*0.9213*

Table A.6-52 HAC TNF-XI Package Array with 300 kg UO_2 Powder, 4.45 wt % U-235

	Powder			*Powder Scrap with ASTM C753 Impurities*			*Powder Scrap with 5,000 ppm Aluminum and 10,000 ppm Carbon Impurities (Maximum)*		
Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}	k_{keno}	σ_{keno}	k_{eff}
53	0.9319	0.0007	0.9333	-	-	-	*0.9268*	*0.0007*	*0.9283*
52	0.9309	0.0008	0.9325	-	-	-	***0.9284***	***0.0007***	***0.9298***
51	**0.9320**	**0.0008**	**0.9335**	-	-	-	*0.9282*	*0.0007*	*0.9296*
50	0.9316	0.0007	0.9330	-	-	-	*0.9267*	*0.0007*	*0.9280*
49	0.9314	0.0007	0.9328	-	-	-	*0.9268*	*0.0008*	*0.9283*
48	0.9306	0.0006	0.9319	-	-	-	*0.9279*	*0.0007*	*0.9292*
47	0.9311	0.0006	0.9323	-	-	-	*0.9272*	*0.0006*	*0.9285*
46	0.9305	0.0007	0.9319	-	-	-	*0.9258*	*0.0007*	*0.9272*
45	0.9289	0.0007	0.9303	-	-	-	*0.9247*	*0.0007*	*0.9261*
44	0.9279	0.0007	0.9293	-	-	-	*0.9243*	*0.0007*	*0.9256*
43	0.9252	0.0007	0.9267	-	-	-	*0.9223*	*0.0007*	*0.9236*

Table A.6-53 HAC TNF-XI Package Array with 196 kg UO_2 Scrap, 5.00 wt % U-235

Fill Height (cm)	V_m/V_f	Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
36.2	6.7957	0.6	0.93349	0.00077	0.93503
41.2	7.8665	0.1	0.92641	0.00072	0.92785
		0.2	0.92931	0.00063	0.93057
		0.3	0.93215	0.00077	0.93369
		0.4	0.93283	0.00070	0.93423
		0.5	0.93246	0.00075	0.93396
		0.6	**0.93357**	**0.00073**	**0.93503**
		0.7	0.93264	0.00067	0.93398
		0.8	0.92954	0.00073	0.93100
		0.9	0.92864	0.00073	0.93010
		1.0	0.92742	0.00071	0.92884
		1.1	0.92637	0.00063	0.92763
		1.2	0.92413	0.00066	0.92545
46.2	8.9373	0.5	0.92889	0.00070	0.93029

Table A.6-54 HAC TNF-XI Package Array with 204 kg UO_2 Scrap, 4.95 wt % U-235

Fill Height (cm)	V_m/V_f	Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
36.2	6.4900	0.7	0.93590	0.00065	0.93720
41.2	7.5188	0.1	0.92990	0.00064	0.93118
		0.2	0.93163	0.00069	0.93301
		0.3	0.93469	0.00068	0.93605
		0.4	0.93506	0.00076	0.93658
		0.5	0.93560	0.00083	0.93726
		0.6	**0.93626**	**0.00078**	**0.93782**
		0.7	0.93395	0.00072	0.93539
		0.8	0.93425	0.00090	0.93605
		0.9	0.93189	0.00076	0.93341
		1.0	0.93264	0.00068	0.93400
		1.1	0.92991	0.00073	0.93137
		1.2	0.92895	0.00079	0.93053
46.2	8.5476	0.3	0.93232	0.00082	0.93396

Table A.6-55 HAC TNF-XI Package Array with 208 kg UO_2 Scrap, 4.85 wt % U-235

Fill Height (cm)	V_m/V_f	**Pitch (cm)**	k_{keno}	σ_{keno}	k_{eff}
36.2	6.3459	0.7	0.93355	0.00076	0.93507
41.2	7.3550	0.1	0.92416	0.00071	0.92558
		0.2	0.93005	0.00065	0.93135
		0.3	0.93163	0.0007	0.93303
		0.4	0.93342	0.00077	0.93496
		0.5	0.93402	0.00076	0.93554
		0.6	**0.93438**	**0.00078**	**0.93594**
		0.7	0.93344	0.00065	0.93474
		0.8	0.93187	0.00071	0.93329
		0.9	0.9312	0.0007	0.93260
		1.0	0.92967	0.00075	0.93117
		1.1	0.9285	0.00078	0.93006
		1.2	0.92743	0.00068	0.92879
46.2	8.3640	0.4	0.92986	0.00076	0.93138

Table A.6-56 HAC TNF-XI Package Array with 216 kg UO_2 Scrap, 4.75 wt % U-235

Fill Height (cm)	V_m/V_f	**Pitch (cm)**	k_{keno}	σ_{keno}	k_{eff}
36.2	6.0739	0.8	0.93186	0.00073	0.93332
41.2	7.0455	0.1	0.92766	0.00073	0.92912
		0.2	0.92990	0.00075	0.93140
		0.3	0.93014	0.00065	0.93144
		0.4	0.93316	0.00061	0.93438
		0.5	0.93446	0.00077	0.93600
		0.6	0.93356	0.00076	0.93508
		0.7	**0.93518**	**0.00068**	**0.93654**
		0.8	0.93310	0.00069	0.93448
		0.9	0.93199	0.00069	0.93337
		1.0	0.93028	0.00067	0.93162
		1.1	0.92981	0.00074	0.93129
		1.2	0.92752	0.00067	0.92886
46.2	8.0172	0.5	0.93051	0.00071	0.93193

Table A.6-57 HAC TNF-XI Package Array with 224 kg UO_2 Scrap, 4.65 wt % U-235

Fill Height (cm)	V_m/V_f	Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
36.2	5.8212	0.9	0.93193	0.00076	0.93345
41.2	6.7582	0.1	0.92480	0.00072	0.92624
		0.2	0.92702	0.00073	0.92848
		0.3	0.93074	0.00069	0.93212
		0.4	0.93169	0.00072	0.93313
		0.5	0.93293	0.00075	0.93443
		0.6	0.93219	0.00068	0.93355
		0.7	**0.93306**	**0.00091**	**0.93488**
		0.8	0.93256	0.00068	0.93392
		0.9	0.93323	0.00077	0.93477
		1.0	0.93160	0.00070	0.93300
		1.1	0.92891	0.00065	0.93021
		1.2	0.92914	0.00067	0.93048
46.2	7.6951	0.5	0.93174	0.00068	0.93310

Table A.6-58 HAC TNF-XI Package Array with 236 kg UO_2 Scrap, 4.55 wt % U-235

Fill Height (cm)	V_m/V_f	Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
36.2	5.4744	1.1	0.93343	0.00083	0.93509
41.2	6.3637	0.1	0.92535	0.00072	0.92679
		0.2	0.92895	0.00081	0.93057
		0.3	0.93073	0.00069	0.93211
		0.4	0.93132	0.00073	0.93278
		0.5	0.93380	0.00068	0.93516
		0.6	0.93466	0.00070	0.93606
		0.7	**0.93477**	**0.00070**	**0.93617**
		0.8	0.93427	0.00064	0.93555
		0.9	0.93380	0.00069	0.93518
		1.0	0.93292	0.00083	0.93458
		1.1	0.93188	0.00062	0.93312
		1.2	0.93091	0.00073	0.93237
46.2	7.2530	0.5	0.93298	0.00073	0.93444

Table A.6-59 HAC TNF-XI Package Array with 248 kg UO_2 Scrap, 4.45 wt % U-235

Fill Height (cm)	V_m/V_f	**Pitch (cm)**	k_{keno}	σ_{keno}	k_{eff}
36.2	5.1611	0.7	0.93126	0.00076	0.93278
41.2	6.0074	0.1	0.92430	0.00074	0.92578
		0.2	0.92911	0.00061	0.93033
		0.3	0.93214	0.00064	0.93342
		0.4	0.93234	0.00063	0.93360
		0.5	0.93419	0.00069	0.93557
		0.6	0.93558	0.00071	0.93700
		0.7	0.93552	0.00066	0.93684
		0.8	**0.93640**	**0.00074**	**0.93788**
		0.9	0.93484	0.00079	0.93642
		1.0	0.93245	0.00074	0.93393
		1.1	0.93357	0.00066	0.93489
		1.2	0.93326	0.00064	0.93454
46.2	6.8537	0.6	0.93483	0.00068	0.93619

Table A.6-60 HAC TNF-XI Package Array with 256 kg UO_2 Scrap, 4.35 wt % U-235

Fill Height (cm)	V_m/V_f	**Pitch (cm)**	k_{keno}	σ_{keno}	k_{eff}
36.2	4.9686	0.6	0.92804	0.00079	0.92962
41.2	5.7884	0.1	0.92142	0.00072	0.92286
		0.2	0.92565	0.00076	0.92717
		0.3	0.92887	0.00068	0.93023
		0.4	0.92979	0.00071	0.93121
		0.5	0.93271	0.00075	0.93421
		0.6	0.93410	0.00070	0.93550
		0.7	0.93436	0.00072	0.93580
		0.8	0.93420	0.00071	0.93562
		0.9	0.93456	0.00071	0.93598
		1.0	**0.93476**	**0.00071**	**0.93618**
		1.1	0.93306	0.00069	0.93444
		1.2	0.93116	0.00066	0.93248
46.2	6.6082	0.6	0.93381	0.00085	0.93551

Table A.6-61 HAC TNF-XI Package Array with 272 kg UO_2 Scrap, 4.25 wt % U-235

Fill Height (cm)	V_m/V_f	Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
41.2	5.3891	0.8	0.93537	0.00071	0.93679
46.2	6.1607	0.1	0.92543	0.00068	0.92679
		0.2	0.92756	0.00079	0.92914
		0.3	0.93094	0.00069	0.93232
		0.4	0.93387	0.00071	0.93529
		0.5	0.93423	0.00064	0.93551
		0.6	0.93485	0.00069	0.93623
		0.7	**0.93606**	**0.00069**	**0.93744**
		0.8	0.93453	0.00064	0.93581
		0.9	0.93415	0.00075	0.93565
		1.0	0.93342	0.00073	0.93488
		1.1	0.93136	0.00075	0.93286
		1.2	0.93266	0.00070	0.93406
51.2	6.9323	0.6	0.93235	0.00071	0.93377

Table A.6-62 HAC TNF-XI Package Array with 284 kg UO_2 Scrap, 4.15 wt % U-235

Fill Height (cm)	V_m/V_f	Pitch (cm)	k_{keno}	σ_{keno}	k_{eff}
41.2	5.1191	0.9	0.93381	0.00063	0.93507
46.2	5.8581	0.1	0.92375	0.00075	0.92525
		0.2	0.92652	0.00062	0.92776
		0.3	0.92930	0.00072	0.93074
		0.4	0.93306	0.00067	0.93440
		0.5	0.93426	0.00071	0.93568
		0.6	0.93414	0.00071	0.93556
		0.7	**0.93540**	**0.00075**	**0.93690**
		0.8	0.93519	0.00067	0.93653
		0.9	0.93472	0.00069	0.93610
		1.0	0.93524	0.00071	0.93666
		1.1	0.93399	0.00072	0.93543
		1.2	0.93094	0.00075	0.93244
51.2	6.5971	0.7	0.93300	0.00070	0.93440

Table A.6-63 HAC TNF-XI Package Array with 300 kg UO_2 Scrap, 4.05 wt % U-235

Fill Height (cm)	V_m/V_f	**Pitch (cm)**	k_{keno}	σ_{keno}	k_{eff}
41.2	4.7928	1.1	0.93398	0.00076	0.93550
46.2	5.4924	0.1	0.92273	0.00064	0.92401
		0.2	0.92639	0.00064	0.92767
		0.3	0.92813	0.00074	0.92961
		0.4	0.93138	0.00062	0.93262
		0.5	0.93300	0.00066	0.93432
		0.6	0.93245	0.00075	0.93395
		0.7	0.93441	0.00070	0.93581
		0.8	0.93503	0.00069	0.93641
		0.9	**0.93587**	**0.00077**	**0.93741**
		1.0	0.93486	0.00073	0.93632
		1.1	0.93523	0.00064	0.93651
		1.2	0.93332	0.00068	0.93468
51.2	6.1920	0.7	0.93489	0.00076	0.93641

Table A.6-64 Polyethylene Density Sensitivity Study under HAC with 232 kg UO_2 Powder, 5.00 wt % U-235

Fill Height (cm)	k_{keno}	σ_{keno}	k_{eff}
Polyethylene Density 0.90 g/cc			
50	0.9303	0.0008	0.9319
49	0.9288	0.0007	0.9302
48	0.9305	0.0008	0.9321
47	0.9313	0.0009	0.9330
46	0.9315	0.0009	0.9332
45	0.9307	0.0008	0.9323
44	**0.9337**	**0.0007**	**0.9350**
43	0.9310	0.0007	0.9324
42	0.9320	0.0008	0.9335
41	0.9309	0.0007	0.9323
40	0.9301	0.0007	0.9314
Polyethylene Density 0.94 g/cc			
50	0.9276	0.0007	0.9290
49	0.9300	0.0007	0.9313
48	0.9316	0.0007	0.9330
47	0.9313	0.0008	0.9328
46	0.9312	0.0006	0.9325
45	0.9312	0.0007	0.9326
44	0.9317	0.0008	0.9333
43	**0.9317**	**0.0008**	**0.9334**
42	0.9296	0.0007	0.9310
41	0.9295	0.0007	0.9309
40	0.9291	0.0007	0.9305
Polyethylene Density 0.96 g/cc			
50	0.9292	0.0007	0.9306
49	0.9286	0.0007	0.9300
48	0.9312	0.0007	0.9326
47	0.9293	0.0008	0.9309
46	0.9308	0.0007	0.9322
45	0.9309	0.0008	0.9325
44	**0.9326**	**0.0008**	**0.9342**
43	0.9324	0.0007	0.9339
42	0.9314	0.0009	0.9332
41	0.9294	0.0007	0.9308
40	0.9291	0.0007	0.9306

Table A.6-65 Description of Criticality Experiments for UO_2 Powder

Case ID	**Material Composition**	**Geometry**
CAA35	UO_2F_2 solution	H_2O reflected, SS cylinder
CAA36	UO_2F_2 solution	H_2O reflected, aluminum box
CAA37	UO_2F_2 solution	H_2O reflected, SS cylinder
CAA38	UO_2F_2 solution	H_2O reflected, aluminum sphere
CAA39	UO_2F_2 solution	H_2O reflected, SS cylinder
CAS11	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS13	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS15	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS16	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS17	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS19	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS21	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS22	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS23	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS24	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS25	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS29	Homogeneous $U(3)F_4$ and paraffin	Reflected rectangular parallelepiped
CAS34	$U(4.98)O_2F_2$ solution	Reflected rectangular parallelepiped

Table A.6-66 Benchmark Results for Powder Experiments

No.	**Experiment ID**	**U-235 Enrichment in wt%**	**H/X**	**EALF**	**k_{keno}**	**σ**
1	CAA35	4.89	524.0000	0.0515	1.0007	0.0010
2	CAA36	4.89	524.0000	0.0503	1.0043	0.0008
3	CAA37	4.89	734.0000	0.0436	1.0018	0.0008
4	CAA38	4.89	991.0000	0.0378	0.9972	0.0007
5	CAA39	4.89	994.0000	0.0392	0.9991	0.0008
6	CAS11	2.00	195.2000	0.2053	0.9988	0.0009
7	CAS13	2.00	293.6000	0.1210	1.0035	0.0009
8	CAS15	2.00	406.3000	0.0875	1.0013	0.0008
9	CAS16	2.00	495.9000	0.0742	0.9995	0.0008
10	CAS17	2.00	613.6000	0.0637	0.9987	0.0008
11	CAS19	2.00	971.7000	0.0495	0.9942	0.0007
12	CAS21	3.00	133.4000	0.2424	1.0098	0.0009
13	CAS22	3.00	133.4000	0.2429	1.0092	0.0010
14	CAS23	3.00	133.4000	0.2427	1.0099	0.0010
15	CAS24	3.00	133.4000	0.2421	1.0121	0.0008
16	CAS25	3.00	133.4000	0.2420	1.0101	0.0009
17	CAS29	3.00	276.9000	0.0958	1.0131	0.0009
18	CAS34	4.98	488.0000	0.0566	1.0008	0.0008
	Correlation	-0.07	-0.78	0.71		

Table A.6-67 Description of Criticality Experiments for UO_2 Pellets

Case ID	Material Composition	Geometry
bw1484sl	UO_2, H_2O, aluminum	Square lattice
epru65	UO_2, H_2O, aluminum, lead	Square lattice
epru75	UO_2, H_2O, aluminum	
p2438slg	UO_2, H_2O, aluminum	Square lattice
p2827slg	UO_2, H_2O, aluminum	Square lattice
p3314slg	UO_2, H_2O, aluminum	Square lattice
p3602n11	UO_2, H_2O, aluminum, steel	Square lattice, steel reflecting walls
p3602n12		
p3602n13		
p3602n14		
p3602n21		
p3602n22		
p3602n31		
p3602n32		
p3602n33		
p3602n34		
p3602n35		
p3602n36		
p3602n41		
p3602n42		
p3602n43		
p3926sl1	UO_2, H_2O, aluminum	Square lattice
p3926sl2	UO_2, H_2O, aluminum	

Table A.6-68 Benchmark Results for Pellet Experiments

No.	**Experiment ID**	**U-235 Enrichment in wt%**	**H/X**	**EALF**	**k_{keno}**	**σ**
1	bw1484sl	2.46	216.1000	0.1418	0.9925	0.0008
2	epru65	2.35	163.6000	0.2616	0.9937	0.0009
3	epru75	2.35	329.4000	0.1158	0.9965	0.0009
4	p2438slg	2.35	398.7000	0.0976	0.9968	0.0008
5	p2827slg	2.35	398.7000	0.0976	0.9940	0.0008
6	p3314slg	4.31	105.4000	0.2375	0.9952	0.0011
7	p3602n11	2.35	218.6000	0.1840	0.9954	0.0009
8	p3602n12	2.35	218.6000	0.1775	0.9993	0.0009
9	p3602n13	2.35	218.6000	0.1714	0.9993	0.0009
10	p3602n14	2.35	218.6000	0.1654	0.9963	0.0009
11	p3602n21	2.35	398.7000	0.0975	0.9985	0.0009
12	p3602n22	2.35	398.7000	0.1004	0.9993	0.0009
13	p3602n31	4.31	105.4000	0.3211	1.0028	0.0010
14	p3602n32	4.31	105.4000	0.3083	1.0023	0.0009
15	p3602n33	4.31	105.4000	0.2977	1.0038	0.0010
16	p3602n34	4.31	105.4000	0.2918	1.0013	0.0010
17	p3602n35	4.31	105.4000	0.2864	0.9988	0.0009
18	p3602n36	4.31	105.4000	0.2811	0.9975	0.0010
19	p3602n41	4.31	256.1000	0.1253	1.0067	0.0009
20	p3602n42	4.31	256.1000	0.1188	1.0023	0.0009
21	p3602n43	4.31	256.1000	0.1152	1.0007	0.0008
22	p3926sl1	2.35	218.6000	0.1638	0.9924	0.0009
23	p3926sl2	4.31	105.4000	0.2812	0.9941	0.0010
Correlation		0.57	-0.14	0.16		

Table A.6-69 USL Functions for UO_2 Powder

Parameter	**Application Range**	**USL Function**	
EALF in eV	[0.0378, 0.2429]	0.9399 + 4.7091e-02 * X	X < 0.04594
		0.9420	X >= 0.04594
U-235 Enrichment in wt%	[2.00, 4.98]	0.9388	
H/X	[133.40, 994.00]	0.9529 – 1.4560e-05 * X	X > 698.76
		0.9427	X <= 698.76

Table A.6-70 USL Functions for UO_2 Pellets

Parameter	**Application Range**	**USL Function**	
EALF in eV	[0.0975, 0.3211]	0.9394 + 7.6453e-03 * X	
U-235 Enrichment in wt%	[2.35, 4.31]	0.9350 + 2.2017e-03* X	X < 4.0920
		0.9440	X >= 4.0920
H/X	[105.40, 398.70]	0.9419 – 5.0469e-06 * X	

Table A.6-71 USL Analysis for UO_2 Pellets

Parameter	**Limiting Value**	**USL**
EALF in eV	6.61476E-2[1]	0.9399
U-235 Enrichment in wt%	4.05	0.9439
H/X	425[2]	0.9398

1) HAC with 196 kg of 5.00 wt % U-235, fill height of 41.2 cm (V_m/V_f = 7.8665), 0.1 cm pitch
2) HAC with 196 kg of 5.00 wt % U-235, fill height of 41.2 cm (V_m/V_f = 7.8665), all pitches

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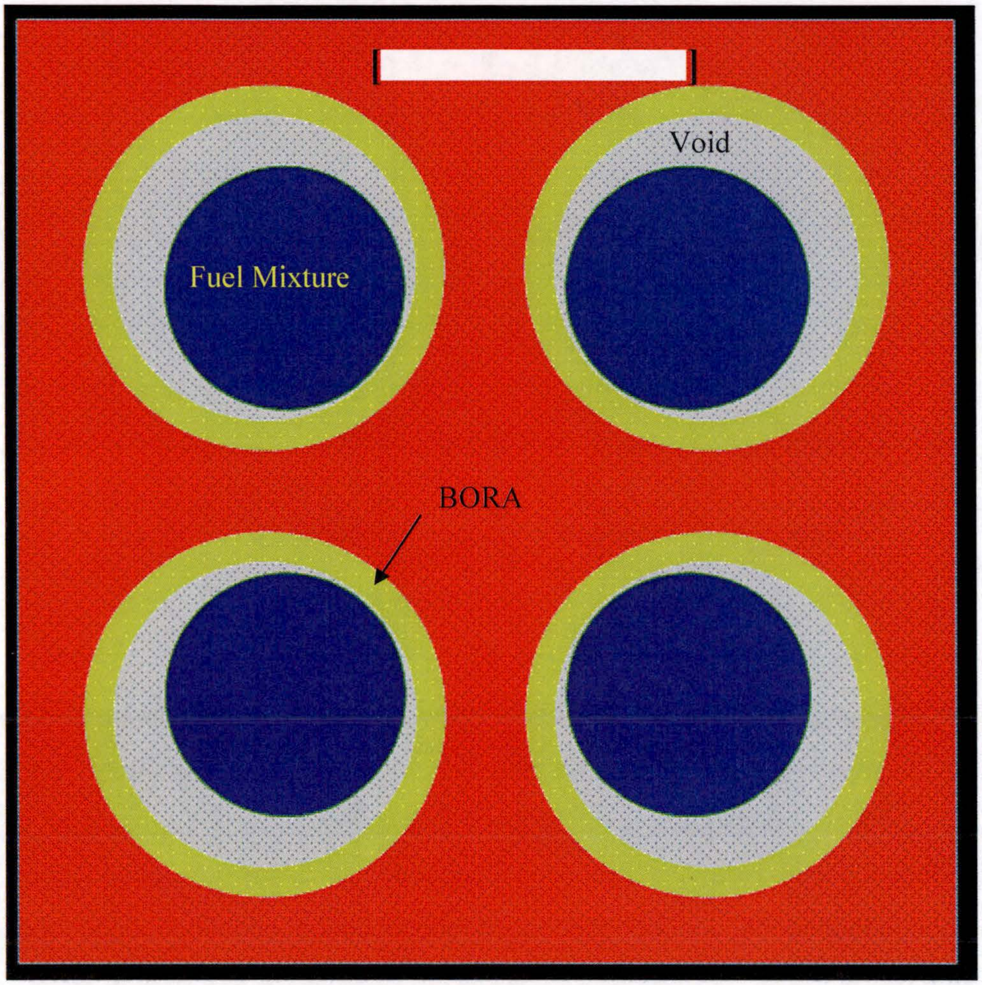


Figure A.6-2 TNF-XI NCT KENO Model Cross-Section

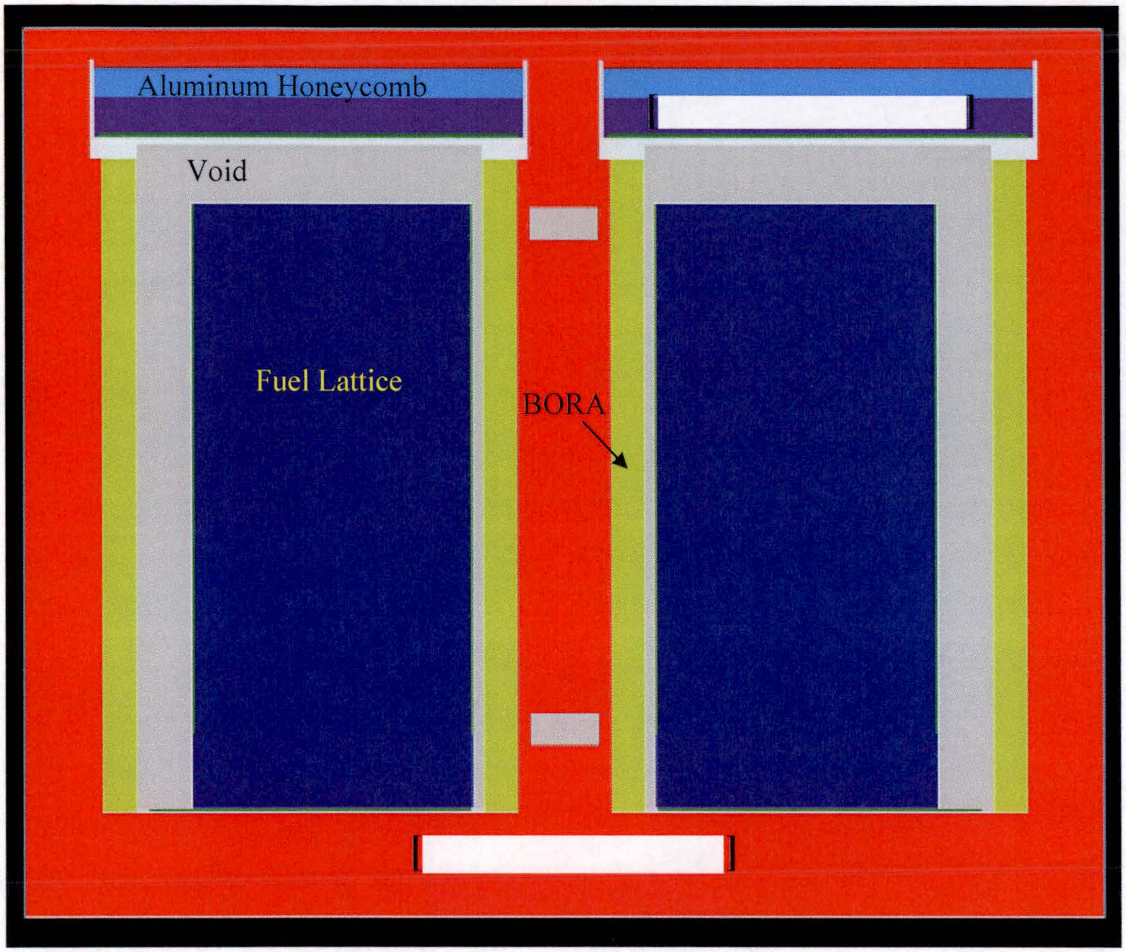
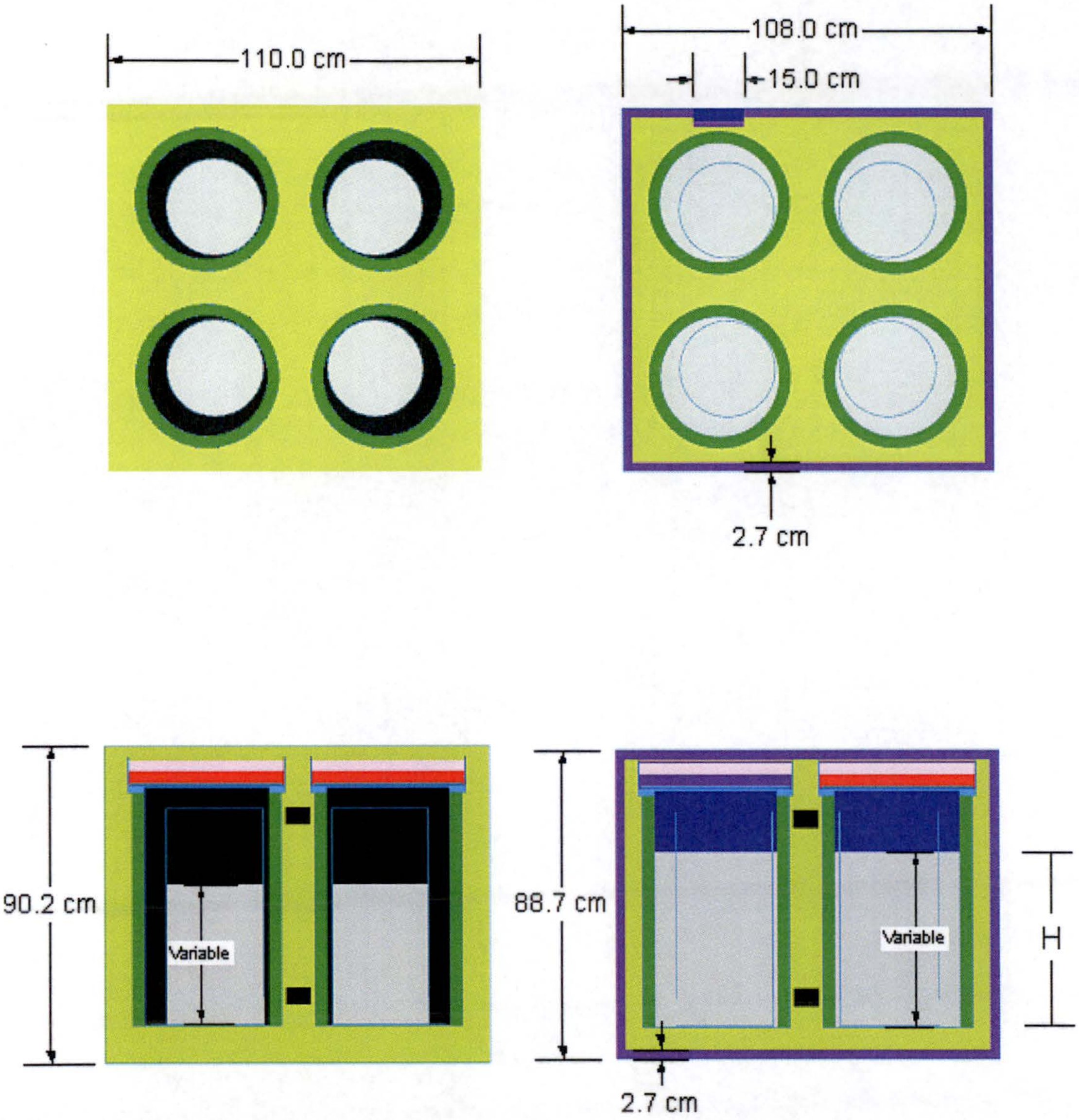


Figure A.6-3 TNF-XI NCT KENO Model Axial View



Normal Geometry

Damaged Geometry

Figure A.6-4 TNF-XI HAC KENO Model Dimensions

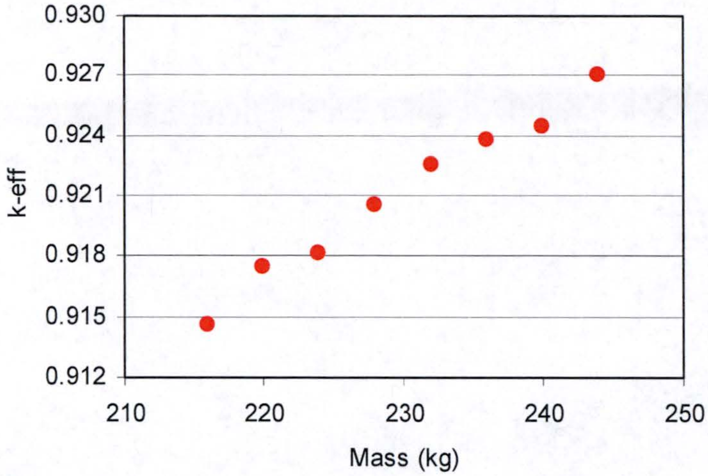


Figure A.6-5 Mass Sensitivity for NCT Array (4.55 wt% U-235, 61.2 cm Fill Height)

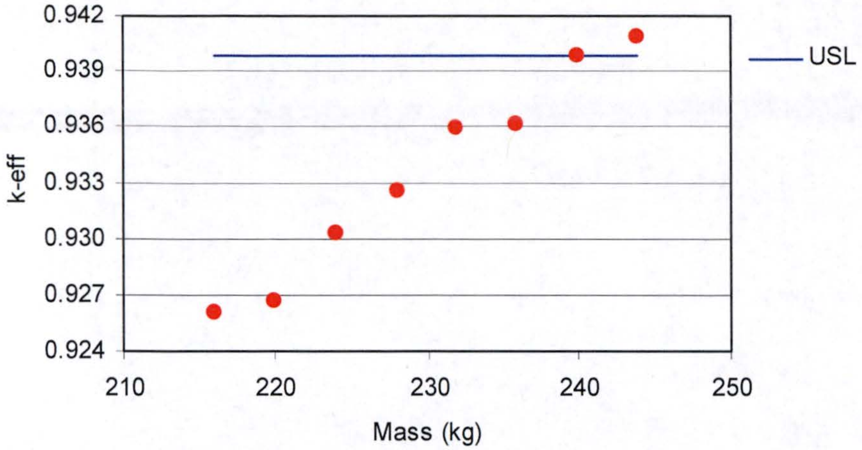


Figure A.6-6 Mass Sensitivity for HAC Array (4.55 wt% U-235, 41.2 cm Fill Height)

APPENDIX B.6
TNF-XI CRITICALITY EVALUATION FOR CONTENT 7

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Appendix B.6 is newly added in Revision 11A.

LIST OF TABLES

LIST OF FIGURES

APPENDIX B.6
TNF-XI CRITICALITY EVALUATION FOR CONTENT 7

In this appendix, the criticality evaluation pertaining to the transport of material identified as Content 7 is presented. As described in Chapter 6 (Section 6.1), Content 7 consists of uranium oxides in the form of powder and scrap with uranium quantity not exceeding 5 kg per cavity, enriched to a maximum of 5% of ^{235}U and mixed with residues consisting in incinerator ashes or earth, sand and residues from dissolution. The approach of the criticality evaluation for Content 7 is identical to that employed in Appendix A.6 except a simplified but more conservative packaging model is used. The simplified packaging model contains the radioactive material in a single cylindrical cavity wrapped by a layer of BORA resin enclosed between two cylindrical steel walls.

B.6.1 DESCRIPTION OF CRITICALITY DESIGN

B.6.1.1 Design Features

The TNF-XI package design features are described in Appendix A.6, Section A.6.1.1. The fuel (Content 7) may be in the form of UO_2 powder and scrap. The authorized quantity of uranium is limited to 5 kg per cavity. The authorized quantity of uranium oxides and residues is limited to 75 kg per cavity. The radioactive material may be placed in plastic bags made with a material more hydrogenated than water and less than or equal to polyethylene.

B.6.1.2 Summary Table of Criticality Evaluation

Table B.6-1 lists the bounding results for all conditions of transport for Content 7. [

]

B.6.1.3 Criticality Safety Index

The design has a CSI, given in 10 CFR 71.59(b) as CSI = 50/“N”, of 0.0 for transport of Content 7.

B.6.2 FISSILE MATERIAL CONTENTS

Content 7 consists of uranium oxides (UO_2, UO_3 or U_3O_8) in the form of powder and scrap, enriched to a maximum of 5% of ^{235}U and mixed with residues consisting of incinerator ashes or earth, sand and residues from dissolution.

The radioactive material of this content is compliant with the definition of un-irradiated uranium according to the 10 CFR 71. This ensures the maximal radiation level authorized under routine conditions of transport at contact is in compliance with the applicable regulation.

The TNF-XI package loaded with Content 7 must meet the requirements applicable to a Type A Package containing fissile material similar to the TNF-XI package loaded with the contents described in Appendix A.6.

The residue incinerator ashes consist of mainly silica, alumina, aluminosilicates, metal oxides, phosphates, aluminum metal, charred wood and charred plastic in undefined part. The earth, sand and dissolved residues consist of mainly silica, alumina, titania, iron oxide and aluminosilicate. Other organic or inorganic compounds may be present in the form of traces. The residues are chemically stable, contain no liquid and are compatible with the material of the pails (steel).

The authorized quantity of uranium is limited to 5 kg per cavity. The authorized quantity of uranium oxides and residues is limited to 75 kg per cavity.

The radioactive material may be put in plastic bags made with a material more hydrogenated than water and less than or equal to polyethylene. The mass of those plastic bags is not limited. The operating temperature of the plastic bag must be equal or greater than 100 °C (in steady-state conditions). The material of the plastic bags must be compatible with the residues.

B.6.3 GENERAL CONSIDERATIONS

B.6.3.1 Model Configuration

B.6.3.2 Material Properties

As shown in Table B.6-2, seven material compositions (mixtures) are used in the Content 7 criticality evaluation model. The material properties of the first six mixtures are identical to those used in Appendix A.6. Mixture Number 7 is the material used as the in-cavity reflector in the simplified TNF-XI model. For Mixture Number 7, nine materials are used in the sensitivity study to determine the optimal in-cavity reflector material. The compositions of three reflector materials (polyethylene, water and stainless steel) are identical to those used in Appendix A.6. The compositions of the remaining six reflector materials are specified in Table B.6-3.

B.6.3.3 Computer Codes and Cross Section Library

The computer codes and neutron cross section library used in the Content 7 evaluation are described in Appendix A.6, Section A.6.3.3.

B.6.3.4 Lattice Cell Modeling for CSAS5

B.6.3.5 Demonstration of Maximum Reactivity

[ ]

B.6.4 SINGLE PACKAGE – NCT AND HAC

As demonstrated in Section B.6.3.1, the simplified packaging model bounds a single package under NCT and HAC. As described in Section B.6.6, the maximum k_{eff} value of the Content 7 criticality evaluation using the simplified packaging model is under the USL. Therefore, the maximum k_{eff} value of the single package under NCT and HAC is also under the USL.

B.6.5 PACKAGE ARRAY NCT

As demonstrated in Section B.6.3.1, the simplified packaging model bounds an infinite array of packages under NCT. As described in Section B.6.6, the maximum k_{eff} value of the Content 7 criticality evaluation using the simplified packaging model is under the USL. Therefore, the maximum k_{eff} value of the package array under NCT is also under the USL.

B.6.6 PACKAGE ARRAY HAC

As demonstrated in Section B.6.3.1, the simplified packaging model bounds an infinite array of packages under HAC. Therefore, the package array under HAC is evaluated using the simplified packaging model.

B.6.6.1 Most Reactive Configuration

Using the most reactive configuration of the simplified packaging model with Content 7 determined in Section B.6.3.5, the criticality evaluation for Content 7 is performed by varying the density of the moderator (interspersed external moderation) between the simplified packages. The maximum allowable fissile material (5 kg uranium per cavity) with the maximum allowable enrichment (5.0 wt. % ^{235}U) is used.

B.6.6.2 Criticality Evaluation Results

As shown in Table B.6-1, the maximum k_{eff} is 0.83871 with 0% interspersed external moderation, which is below the USL (0.9397) determined in Section B.6.8. Therefore, the maximum k_{eff} value of the package array under HAC is also under the USL.

B.6.7 FISSILE MATERIAL PACKAGE FOR AIR TRANSPORT

Not applicable to the TNF-XI.

B.6.8 BENCHMARK EVALUATIONS

The benchmark evaluation is described in Appendix A.6. The USL is evaluated against EALF, ^{235}U enrichment and H/X parameters, as shown in Appendix A.6, Table A.6-71. For Content 7, the USL is re-evaluated as shown in Table B.6-10. The USL is 0.9397.

B.6.9 REFERENCES

1. SCALE6: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstations and Personal Computers, Oak Ridge National Laboratory, Radiation Shielding Information Center Code Package CCC-750, February 2009.

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

3. Oak Ridge National Laboratory, "Validation of KENO V.a Comparison with Critical Experiments," ORNL/CSD/TM-238, December 1986.

4. USLSTATS: A Utility to Calculate Upper Subcritical Limits for Criticality Safety Applications, Version 6, Oak Ridge National Laboratory, January 26, 2009.

5. U.S. Nuclear Regulatory Commission, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages," NUREG/CR-5661, Published April 1997, ORNL/TM-11936.

6. ORNL/TM-2005/39, Version 6, Vol. II, Section F17, "KENO-VI: A General Quadratic Version of the KENO Program," January 2009.

7. ASTM C753-04, "Standard Specification for Nuclear-Grade, Sinterable Uranium Dioxide Powder," June 2009.

B.6.10 APPENDIX

B.6.10.1 KENO Input Listing

Table B.6-1 Criticality Evaluation for Content 7

Water Density for Interspersed Moderation in g/cm^3	**k_{keno}**	**σ**	**k_{eff}**
1.0	0.83459	0.00054	0.83567
0.9	0.83467	0.00056	0.83579
0.8	0.83458	0.00064	0.83586
0.7	0.83482	0.0006	0.83602
0.6	0.83517	0.00055	0.83627
0.5	0.83495	0.00054	0.83603
0.4	0.83523	0.00053	0.83629
0.3	0.83596	0.00063	0.83722
0.2	0.83648	0.00056	0.83760
0.1	0.83744	0.00054	0.83852
0(1)	**0.83761**	**0.00055**	**0.83871**

(1) The air is used for the interspersed moderation with zero water density.

Table B.6-2 KENO Mixtures

Mixture Number	**Materials**
1	Fissile
2	Polyethylene
3	Borated Stainless Steel
4	BORA Resin
5	Stainless Steel
6	Water
7	In-Cavity Reflector

Table B.6-3 In-Cavity Reflector Material Property

Table B.6-4 Sensitivity Study – Simplified Packaging Model

Configuration		k_{keno}	σ	k_{eff}
Full Packaging Model	Single under NCT	0.90689	0.00070	0.90829
	Single under HAC	0.92594	0.00077	0.92748
	Array under NCT	0.92365	0.00061	0.92487
	Array under HAC	0.93458	0.00073	0.93604
Simplified Packaging Model		**0.99531**	**0.00066**	**0.99663**

Table B.6-5 Sensitivity Study – Content 7 Global Shapes

Scrap Radius (cm)	**Cylinder**			**Hemisphere**			**Sphere**		
	k_{keno}	σ	k_{eff}	k_{keno}	σ	k_{eff}	k_{keno}	σ	k_{eff}
0.01	0.79763	0.00055	0.79873	0.74946	0.00067	0.75080	0.81112	0.00053	0.81218
0.05	0.80188	0.00051	0.80290	0.75352	0.00056	0.75464	0.81718	0.00051	0.81820
0.10	0.80198	0.00057	0.80312	0.75523	0.00056	0.75635	**0.81782**	**0.00054**	**0.81890**
0.15	0.80146	0.00053	0.80252	0.75383	0.00057	0.75497	0.81554	0.00059	0.81672
0.20	0.79983	0.00051	0.80085	0.74964	0.00051	0.75066	0.81320	0.00055	0.81430
0.25	0.79398	0.00054	0.79506	0.74535	0.00054	0.74643	0.80895	0.00054	0.81003
0.30	0.78881	0.00051	0.78983	0.74029	0.00056	0.74141	0.80242	0.00052	0.80346

Table B.6-6 Sensitivity Study – Content 7 Global Positions

Axial Location	**Radial Location**	k_{keno}	σ	k_{eff}
Bottom	Centered	0.81782	0.00054	0.81890
	Off-Centered	0.79171	0.00053	0.79277
Middle	Centered	**0.83750**	**0.00058**	**0.83866**
	Off-Centered	0.80962	0.00052	0.81066
Top	Centered	0.81942	0.00050	0.82042
	Off-Centered	0.79333	0.00058	0.79449

Table B.6-7 Sensitivity Study – In-Cavity Reflector

	k_{keno}	σ	k_{eff}
	0.63705	0.00055	0.63815
	0.82669	0.00056	0.82781
	0.83750	**0.00058**	**0.83866**
	0.70569	0.00058	0.70685
	0.72250	0.00059	0.72368
	0.71554	0.00052	0.71658
	0.72401	0.00060	0.72521
	0.73215	0.00058	0.73331
	0.71353	0.00055	0.71463

Table B.6-8 Sensitivity Study – V_m/V_f

V_m/V_f	k_{keno}	σ	k_{eff}
1	0.51744	0.00049	0.51842
2	0.66162	0.00058	0.66278
3	0.74058	0.00054	0.74166
4	0.78729	0.00059	0.78847
4.5	0.80103	0.00058	0.80219
5	0.81340	0.00054	0.81448
5.5	0.82106	0.00062	0.82230
6	0.82793	0.00056	0.82905
6.5	0.83324	0.00053	0.83430
7	0.83552	0.00054	0.83660
7.5	0.83750	0.00058	0.83866
8	**0.83942**	**0.00053**	**0.84048**
9	0.83620	0.00050	0.83720
10	0.83244	0.00051	0.83346
11	0.82718	0.00049	0.82816
12	0.81953	0.00047	0.82047
13	0.81080	0.00049	0.81178
14	0.80400	0.00043	0.80486
15	0.79387	0.00045	0.79477

Table B.6-9 Sensitivity Study – Package Pitch

Package Pitch (cm)	k_{keno}	σ	k_{eff}
0	**0.83761**	**0.00055**	**0.83871**
0.5	0.83689	0.00057	0.83803
1.0	0.83732	0.00052	0.83836
2.0	0.83626	0.00056	0.83738
3.0	0.83626	0.00055	0.83736
4.0	0.83731	0.00053	0.83837
5.0	0.83622	0.00058	0.83738

Table B.6-10 USL Evaluation

USL Parameter	**Limiting Value**	**USL**
EALF in eV	0.056	0.9414
U-235 Enrichment in wt. %	5.0	0.9402
H/X	533	0.9397

Figure B.6-1 Simplified Packaging Model

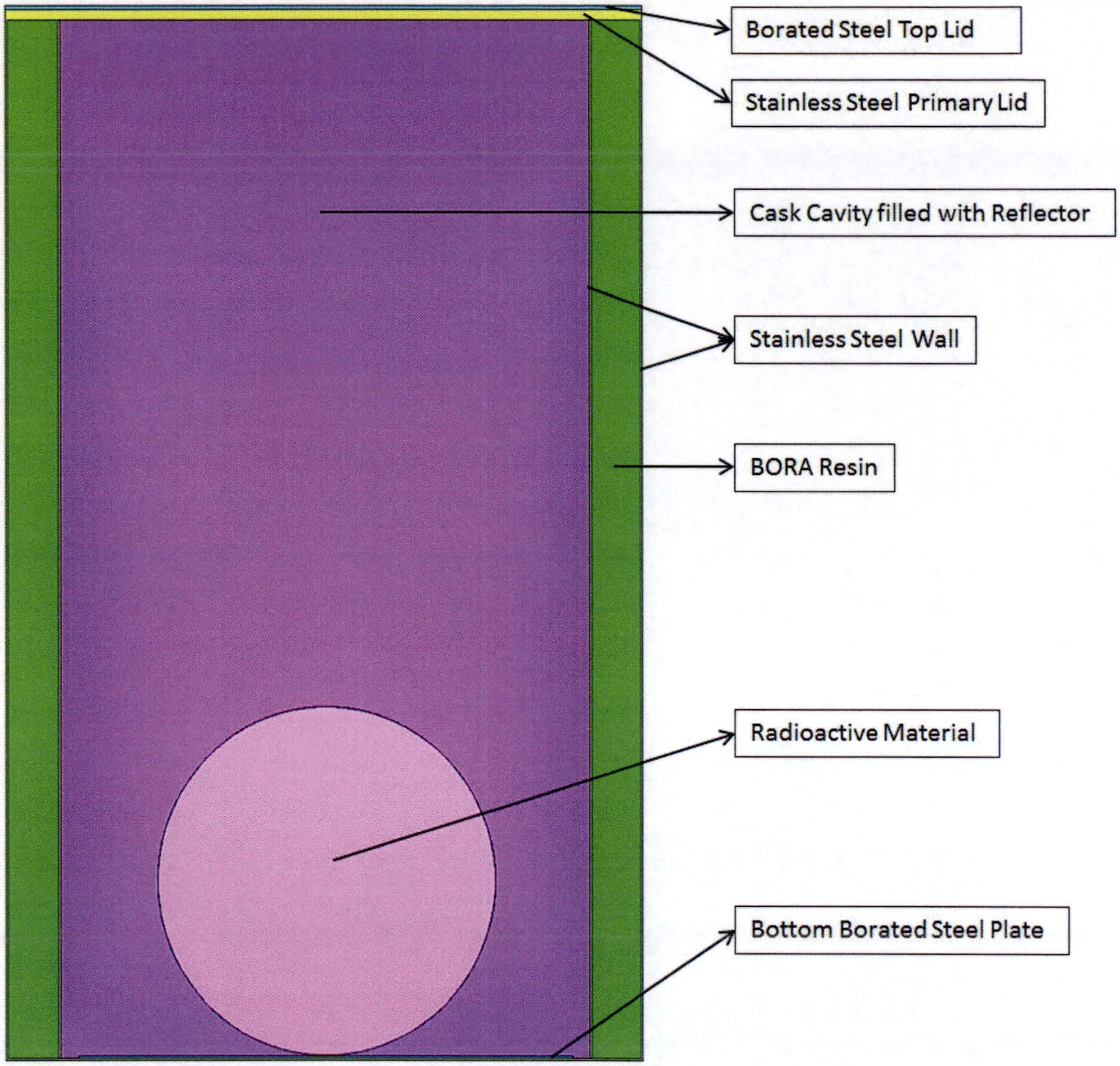

Figure B.6-2 KENO V.a Simplified Model of the TNF-XI Package

7.0 OPERATING PROCEDURES

7.1 Introduction

This section delineates the procedures for loading a payload into the TNF-XI packaging. Reference to specific TNF-XI packaging components *(items)* may be found in Appendix 1.3.1, *Packaging General Arrangement Drawings, specifically on the List of Material table.*

7.1.1 Preparation of the TNF-XI for Loading

1. TNF-XI body – Visually inspect all the bayonets mating with the primary lid in each well for damage.
2. TNF-XI body – Visually inspect all the bayonets mating with the upper plug in each well for damage.
3. TNF-XI body – Visually inspect all external surfaces for damage. The maximum acceptable dent is 1/2-inch deep.
4. TNF-XI body – Visually verify that the fusible plugs on each container side (8 total) and on the upper surface (6) are in place.
5. TNF-XI body – Visually verify that the stacking pins (2) on the upper surface are in place and tightly secured.
6. Upper Plug – Visually inspect the external surfaces of the lid for handling damage. Maximum acceptable dent is 1/2-inch deep.
7. Upper Plug – Visually verify the 2 fusible plugs located on the upper surface of each plug are in place.
8. Upper plug – Visually verify the foam rubber gasket in the lid is clean, in good condition with no tears or cuts, and is tightly adhering.
9. Primary lid and Upper plug – Visually verify the sealing surfaces and the locking bayonets are clean and undamaged.
10. TNF-XI packaging wells – Visually verify the proper installation of the primary lid gasket in each well.
11. Packaging wells – Visually verify that the interior of each well is clean and dry.
12. When deviations to items 1, 5 and 13 are found, the item is corrected before release to loading.
13. When deviations to items 2, 3, 4, 6, 7, 8, 9, 10, 11, 12 and 14 are identified, the package or packaging component is immediately removed from service, identified as non-conforming material, and dispositioned in accord with written procedures including the10 CFR 71, Subpart approved QA Plan.

7.1.2 Loading the Payload into the TNF-XI

1. The uranium oxide payload will be contained in pails. Prior to the loading of the payload into the pails, visually verify that an undamaged boronated ring is correctly installed in each pail as shown in the drawings of Section 1.3.
2. A maximum of three pails may be loaded into a single well and the pails shall be placed so that the total mass of the payload material is distributed as evenly as practical among the four wells of the packaging. The maximum loading of any one well shall not exceed 25% of the maximum loading mass for the specific enrichment and type of content *as presented in the Certificate of Compliance for either* Homogeneous UO_2 powder or Heterogeneous UO_2 material.
3. After loading the pails into each well, the primary lid shall be placed into the well and rotated to engage the bayonets.
4. Secure the primary lid locker for each primary lid.
5. Lower each upper plug into position and rotate to engage the bayonets.
6. Install the securing plate after all upper plugs are in place.
7. Install safety cover.

7.1.3 Final Package Preparations for Transport

1. Install the tamper-indicating seal.
2. Not Used.
3. Monitor external radiation for each package per 49CFR §173.441[1].
4. Determine the surface contamination levels for each TNF-XI package per 49CFR §173.443.
5. Determine the criticality safety index for the loaded TNF-XI package per 49 CFR §173.403.

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[1] Title 49, Code of Federal regulations Part 173 (49CFR 173), *Shippers – General Requirements for Shipments and Packagings*, current Edition

6. Complete all necessary shipping papers in accordance with Subpart C of 49 CFR 172[2].
7. TNF-XI package marking shall be in accordance with 10 CFR §71.85(c) and Subpart D of 49 CFR 172. Package labeling shall be in accordance with Subpart E of 49 CFR 172. Packaging placarding shall be in accordance with Subpart F of 49 CFR 172.

7.2 Procedures for Unloading the Package

This section delineates the procedures for unloading a payload *(items)* out of the TNF-XI packaging. Reference to specific TNF-XI packaging components may be found in Appendix 1.3.1, *Packaging General Arrangement Drawings, specifically on the List of Material table.*

7.2.1 Unloading the Transport Vehicle

1. *Position the vehicle for unloading.*
2. Check shipment conformity with the label on the container and the packages.
3. Open the doors of the transport container (if the packages are shipped in a container).
4. Extract the packages.
5. Visually inspect the packaging.

7.2.2 Removal of the Payload from the TNF-XI

1. Remove the tamper safe seal.
2. Remove the safety cover.
3. Remove the securing plate.
4. Remove the upper plug from each well.
5. Lift the primary lid locker and remove the primary lid from each well.
6. Remove the pails containing the uranium oxide payload using an appropriate extraction device (gripper or sucker).

7.2.3 Final Package Preparations for Transport of Unloaded TNF-XI

1. Complete all required shipping papers in accordance with Subpart C of 49 CFR 172.

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[2] Title 49, Code of Federal Regulations, Part 172 (49 CFR 172), *Hazardous Materials Tables and Hazardous Communications Regulations, current* Edition.

2. TNF-XI package marking shall be in accordance with 10 CFR §71.85(c) and Subpart D of 49 CFR 172. Package labeling shall be in accordance with Subpart E of 49 CFR 172. Packaging placarding shall be in accordance with Subpart F of 49 CFR 172.

7.3 Preparation of an Empty Package for Transport

Previously used and empty TNF-XI packages shall be prepared and transported per the requirements of 49 CFR §173.428 and 49 CFR §173.433.

8.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

8.1 Acceptance Tests

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 TNF-XI package.

8.1.1 Visual Inspections

All TNF-XI packaging materials of construction and welds 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).

8.1.2 Structural and Pressure Tests

8.1.2.1 Lift/Tie-down Device Load Testing

The TNF-XI packaging does not contain any lifting/tiedown devices that require load testing.

8.1.2.2 Containment Vessel Pressure Testing

Per the requirements of 10 CFR §71.85(b), no pressure testing is required because the maximum normal operating pressure is less than 35 kPa. (See paragraph 3.4.1).

8.1.3 Fabrication Verification Leak Tests

The TNF-XI packaging does not contain any seals or containment boundaries that require leak testing.

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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.

8.1.4 Component Tests

8.1.4.1 Phenolic Foam

This section establishes the requirements and acceptance criteria for production, installation, inspection, and testing of the rigid, open-celled, phenolic foam utilized within the TNF-XI packaging. The detailed procedures for production and testing of the phenolic foam are given the Transnucleaire specification contained in Section 8.3. These procedures ensure that the foam has the specified physical, chemical, thermal, mechanical, and dimensional properties summarized as follows:

- All foam items are M1-F1 phenolic foam. The chemical composition is **[ ]** water and **[ ]** dry foam. The minimum content of Hydrogen is **[ ]** by mass. The other constituents are Carbon (**[ ]** by mass) and oxygen (**[ ]** by mass).
- Foam densities are summarized in the table below and are calculated from the sample mass and the displaced volume after placing it in water. The density includes at least **[ ]** water.
- Compressive strengths are summarized in the table below and are verified per ISO 844.
- To protect against corrosion of the package's structural components, all foam items must have a leachable chloride content less than 20 ppm as per the CNRS/WICKBOLD method.
- All foam has a thermal conductivity of **[ ]** W/m/K at 20°C, dry.
- All foam is classified as M1 fire-resistant per NF P 92-501 meaning that the foam self-extinguishes after undergoing an oven test.
- All steel surfaces are brushed, cleaned, and degreased prior to installation or pouring of foam.

Table 8-1 Properties of Foam Items

Item No.	Foam Density (kg/m^3) at 20°C	Compressive Strength at 50% Crushing at 20°C (MPa)	Fabrication Techniques (See Appendix 8.3)
15	[ ] (type3)	[	molded
23	[ ] (type1)		molded
24	[ ] (type1)*		poured
22	[ ] (type2)		molded
44**	[ ] (type2)	]	molded

Notes:

* Because item 24 is poured, during fabrication its density is verified indirectly by measuring its mass [ ] and comparing it to the volume of the foamed space (487 liters).

** Item 44 is referred to as Item 24-1 in Appendix 8.3

Qualification of the foam:

The qualification test of the foam parts is described in Section 8.3.

8.1.4.2 Neutron Poison

This section establishes the requirements and acceptance criteria for inspection and testing of neutron poison utilized within the TNF-XI packaging. Two neutron poisons are utilized for this package, borated stainless steel and BORA resin. For both neutron poison materials, the criticality analysis in Chapter 6 assumes that the Boron credit is 75% of the minimum Boron concentration stipulated on the design drawings.

8.1.4.2.1 Borated Stainless Steel

All borated stainless steel meets the requirements of ASTM A 887-89 Type 304B4 Grade B. The borated stainless steel disks in the cavity and in the shield plugs are fabricated to Böhler Bleche specification A976SC. Because all borated stainless steel is supplied, the supplier of this material performs all qualification and acceptance testing of this material. The fabricator receives only material that has been certified according to the applicable standards. For completeness, the acceptance testing used by the supplier for the borated stainless steel is provided below.

Borated stainless steel disk acceptance tests (performed by supplier):

Stainless steel disks will be cut from "parent–plates" which are manufactured according to ASTM A 887-89 for type 304B4 material. Additionally, each "parent-plate" will undergo an acceptance test to demonstrate the desired neutron absorption capability of the sheets.

The principle of the test is to measure the reduction of the neutron flux caused by the Boron alloyed in the material. The test device containing a neutron source is placed on the test article, which is situated on a reflector table. An impulse counter in the test device measures the count rate for a period of time depending on the Boron content, thickness of the material, and the power of the neutron source. The supplied plates will be tested such that:

- 2.5% of the "parent-plates" from which stainless steel disks are cut will be tested using multiple points on a grid, to demonstrate the Boron uniformity.
- 97.5% of the "parent-plates" will be tested at one random location on the plate.

Rejection of a parent-plate will occur if it does not meet the specified criteria. Only conforming plate material will be supplied to the fabricator.

The acceptance criteria for testing of the borated stainless steel plate is based on the minimum Boron content of the plate (B_{min}) and the plate's minimum thickness (th_{min}).

- A reference test piece is cut from one sheet of the order, and the Boron content of the reference test piece is measured by chemical analysis (Bref).
- The absolute minimum of the Boron content in the reference test piece (Bref_min) is calculated by subtracting twice the standard deviation of boron homogeneity from the boron content measured above. The standard deviation of boron homogeneity is provided by the material supplier and is based on historical data. Thus, the absolute minimum of the Boron content corresponds to the lower bound of Boron content with 95% probability.
- The reference thickness is determined by the equation:

  $$th_{ref} = B_{min} \times th_{min} / B_{ref\_min}$$

- The reference piece is then machined is grounded to the reference thickness.
- The neutron absorption capacity of the reference piece is then analyzed by measuring the count rate (CR) with the same test equipment and procedure used to measure the CR in the acceptance tests. However, 50 measurements are to be taken at one location so that an average value (CRref_mean) and the standard deviation (SCR_ref) can be calculated.
- The acceptance limit for the count rate during acceptance testing must be less than or equal to:

  $$CR \leq CR_{ref\_mean} - 2\ S_{CR\_ref}$$

  Thus, the acceptance limit corresponds to the lower bound of the count rate with 95% confidence in the acquisition of the count rate data.

8.1.4.2.2 BORA Resin

BORA resin is a rigid polyester based compound with a high natural boron content having a minimum density of **[ ]** g/cm^3. The mass percentage of the compounds used to make the resin is listed in Table 8-2. Additionally, small amounts of catalyst and accelerator are used to initiate and accelerate the polymerization.

Table 8-2 BORA Resin Composition

Component	Mass Percentage

For the boron carbide, the particles are between **[ ]** µm and **[ ]** µm in size. For the zinc borate, the average particles size is **[ ]** µm, and the maximum size **[ ]** µm. The discussion below regarding qualification testing of the resin shows that the particle concentration is uniform in the shell.

Material properties are documented in Section 8.4. The resin is mixed in a liquid form before pouring it into special molds. After polymerization, the shell is mounted onto the identified cavity.

<u>BORA resin qualification process:</u>

During the development of the product, material properties were characterized as a function of temperature, including the effect of temperature on material durability (see Section 8.4). Because this package is designed to handle fresh powder, the radiation environment is not severe enough to affect the material properties. For this reason, the effects of the radiation environment on the materials were not considered.

The qualification of the pouring of BORA resin is performed with the mold intended for use in the manufacturing process and by qualified operators, prior commencing manufacturing. In addition, a separate "test sample" is poured for each shell that is fabricated. Each shell/test sample is poured from a unique batch so that non-conformity in a shell does not impact other shells.

Qualification of BORA resin manufacturing process will occur if:

- The mass of each compound used in making the resin is within ±0.5% of its nominal mass.

- The BORA resin shell meets the dimensional inspection criteria (thickness and height).

- The BORA resin shell meets the density criteria.

- Samples are taken at multiple locations in the top, middle, and bottom of the shells as well as the "test sample" that is made at the end of the pour. The "test sample" corresponds to the sample that will be used for conducting the acceptance test. All specimens must meet the minimum density requirement (**[ ]** g/cm^3) in order for qualification to occur. Qualification test data is provided in Table 8-3.

- The BORA resin shell meets the Boron content requirements as measured by mass spectroscopy given that the concentration of B-10 in natural Boron is 19.9 atom-percent (18.43 wt-%).

- Test specimens are cut from a qualification test shell at multiple locations. First, the density of each test specimen is measured. Next, the percentage of Boron content is measured by mass spectroscopy. All test specimens must meet the minimum resin density (**[ ]** g/ cm^3) and minimum Boron percentage **[ ]** requirements in order for qualification to occur. Qualification test data are provided in Table 8-4.

- The BORA resin shell meets the minimum Boron content determined by calculation.

The above tests show that:

- The proper amount of natural boron (and B-10) is in each pour.

- The resin density and the natural boron (and B-10) content is uniform in each shell.

Thus, ensuring the minimum resin density, proper material dimensions, the minimum Boron content, and homogeneity of the Boron, guarantee that the resin will have the proper B-10 number density of **[ ]** B^{10}/b-cm.

Additionally, the tests show that the test sample is appropriate to use for the verification of density during acceptance testing.

Table 8-3 Qualification Test Data

Qualification Test Article	Calculated % Boron*	Measured Average Density**	
24	[ ]	Top	
		Middle	
		Bottom	
		Test Sample	
25	[ ]	Top	
		Middle	
		Bottom	
		Test Sample	
26	[ ]	Top	
		Middle	
		Bottom	
		Test Sample	

* Natural Boron content. Calculated from the masses of the compounds used to mix the resin. The B-10 content is equal to 18.43% of natural Boron content.

** average density is the average of 3 samples at shell location and 1 sample for the casting sample

Table 8-4 Mass Spectroscopy Qualification Test Results (from Test Report 12986-R-10, Rev 0, see Section 8.5)

Base Sample	B-nat* (%)	Measured Density (g/cm^3)	Middle Sample	B-nat* (%)	Measured Density (g/cm^3)	Top Sample	B-nat* (%)	Measured Density (g/cm^3)
B1a			M1a			H1a		
B1b			M1b			H1b		
B2a			M2a			H2a		
B2b			M2b			H2b		
B3a			M3a			H3a		
B3b			M3b			H3b		
B4a			M4a			H4a		
B4b			M4b			H4b		
Average			Average			Average		

* The B-10 content is equal to 18.43% of natural Boron content.

BORA resin qualification at low temperature conditions:

The chemical properties of the BORA resin do not change under cold temperature, only the mechanical characteristics such as the compression modulus which increases in cold conditions. Thus, it has no impact on the TNF-XI package design.

Additionally, the thermal expansion of the BORA resin material is [ ] K^{-1}. The change in thickness of the shell (34 mm thick) in cold conditions is equal to:

h = [ ] mm

This small change in thickness will not change the B-10 areal density in the shell.

BORA resin qualification at normal conditions:

The maximum temperature of the BORA resin shell in normal conditions of transport is 62°C (Section 3.6.2, Figure 5) including the effects of insolation.

During the qualification of the resin, a resin sample (25×35×100 mm) was weighed after being heated to a temperature of 50°C for 4032 hours (168 days).

The loss of mass measured after the heating period was approximately [ ]

Conservatively it is assumed that this loss of mass is due to water evaporation. The atomic mass ratio of hydrogen in water is :

Hydrogen : 2 / 18 = 11.11 %

Then, the loss of hydrogen is equal to:

[ ]

This means that the hydrogen content in the BORA resin, at minimum equal to [ ] (according to Section 1.2.1.3), is reduced to [ ] which is negligible. Recall that in manufacturing, the density is at least [ ] g/cm^3 whereas criticality calculations were performed with [ ] g/cm^3.

The minimum density requirement allows a decrease in hydrogen to:
[ ] Thus, conservatively assuming a maximum loss in hydrogen content, the required hydrogen concentration will be present in the resin.

BORA resin acceptance tests:

The quantity of Boron in the resin are checked to ensure that the concentrations exceed those used in the criticality studies (see chapter 6 of this Safety Analysis Report). Shells that do not conform to prescribed mass, density, or dimensional requirements are rejected.

Each BORA resin shell will be manufactured with qualified molds and each shell will be verified for:

- Component mass: Each component mass must be within ±0.5% of its nominal mass

- Dimensional requirements: minimum thickness, as well as height, to ensure complete coverage when the shell is placed between the inner and outer shells of the inner well.
- Density: direct measuring of the resin density of 3 specimens is taken from the test sample. The minimum acceptable density from acceptance testing (**[ ]** g/cm^3) is greater than the minimum density assumed for the material (**[ ]** g/cm^3). Density measurements cannot be made on the shell itself because the test is destructive. Qualification test data indicates homogeneity between test sample and the corresponding shell.
- Natural Boron content: calculated from measuring the mass of the components used in making the resin. Given the percentage of natural Boron in the sample, the amount of B-10 can be determined given there is 19.9 atom-percent (18.43 wt-%) of B-10 in natural Boron.

The satisfaction of these requirements guarantee that the BORA resin shell has the proper B-10 density of **[ ]** B^{10}/b-cm. Each resin shell is fabricated from a unique batch of resin. Thus, failure of the shell to meet the specified criteria results in the rejection of only that particular shell.

A sampling of data from existing shell acceptance tests is provided in Table 8-5 for verification with 95% confidence that the calculated Boron concentration and the minimum resin density specified in the acceptance test procedure are greater than the required minimum values. The 36 data points are taken from shells made both early (casting number from 96 to 115) and later (casting number from 1179 to 1235) in the manufacturing process. This shows that the 95% confidence is valid over time.

Table 8-5 BORA Resin Acceptance Test Data

	Casting No	Calculated % Boron-natural	Measured Average Density (g/cm^3)
1	96	[	]
2	98		
3	100		
4	103		
5	97		
6	99		
7	95		
8	91		
9	105		
10	107		
11	111		
12	112		
Sample Size (n)		12	12
Average		[	]
Standard Deviation (σ)			
95% Probability (2σ)			
95% Lower Bound**			
Minimum allowable			

Table 8-5 (continued) BORA Resin Acceptance Test Data

	Casting No	Calculated % Boron-natural	Measured Average Density (g/cm^3)
13	146		
14	144		
15	143		
16	139		
17	129		
18	120		
19	113		
20	119		
21	135		
22	134		
23	118		
24	115		
Sample Size (n)		12	12
Average			
Standard Deviation (σ)			
95% Probability (2σ)			
95% Lower Bound**			
Minimum allowable			
25	1205		
26	1211		
27	1212		
28	1214		
29	1204		
30	1229		
31	1228		
32	1235		
33	1213		
34	1208		
35	1199		
36	1179		
Sample Size (n)		12	12
Average			
Standard Deviation (σ)			
95% Probability (2σ)			
95% Lower Bound**			
Minimum allowable			

* Each density is the average of that measured from three specimen from each casting sample

** The lower bound determined from acceptance test data is greater than the larger of the two lower bounds determined during qualification testing [ ] Thus, the qualification tests bound the acceptance test data.

8.1.5 Test for Shielding Integrity

The TNF-XI package does not contain any biological shielding.

8.1.6 Thermal Acceptance Tests

The material properties utilized in Chapter 3.0, *Thermal*, are consistently conservative for the Normal Conditions of Transport (NCT) thermal analysis performed. The Hypothetical Accident Condition (HAC) fire certification testing of the TNF-XI package (see Section 2.10.1, *Certification Tests*) served to verify material performance in the HAC thermal environment. As such, with the exception of the tests required for specific packaging components, as discussed in Section 8.1.4, *Component Tests*, specific acceptance tests for material thermal properties are not required or performed.

8.2 MAINTENANCE PROGRAM

8.2.1 Structural and Pressure Tests

8.2.1.1 Weight Verification

Verification of the package's empty mass must occur within three years prior to a shipment or within the last 15 transports (whichever is in a shorter amount of time), to ensure that no water in-leakage has occurred in the foam region of the package.

8.2.1.2 Surface Inspection

Visual inspection shall be performed on the visible surfaces of the package exterior, plugs, lids, and cavities for indications of chemically induced corrosion, within three years of a shipment or within the last 15 transports (whichever is in a shorter amount of time). This ensures that degradation such as pitting or through wall corrosion has not taken place.

8.2.1.3 Lifting/Tie-down Device Load Testing

The TNF-XI package does not contain any lifting/tie-down devices that require load testing.

8.2.1.4 Containment Boundary Pressure Testing

No pressure tests are necessary to ensure continued performance of the TNF-XI packaging.

8.2.2 Leak Tests

No leak tests are necessary to ensure continued performance of the TNF-XI packaging.

8.2.3 Subsystem Maintenance

8.2.3.1 Fasteners

The TNF-XI package does not contain any fasteners that require maintenance.

8.2.3.2 Seals

Seals are to be replaced every 3 years if necessary.

8.2.4 Valves, Rupture Disks and Gaskets on Containment Vessel

8.2.4.1 Valves

The TNF-XI package does not contain any valves.

8.2.4.2 Rupture Disks

The TNF-XI package does not contain any rupture disks.

8.2.4.3 Gaskets

The TNF-XI package does not contain any containment vessel gaskets.

8.2.5 Shielding

The TNF-XI package does not contain any biological shielding.

8.2.6 Thermal

No thermal tests are necessary to ensure continued performance of the TNF-XI packaging.

8.3 Appendix A

Transnucleaire Specification 12986-A-7E issue 6

Specification for Series Production of Phenolic Foam Components

Note: This specification contains proprietary information and is exempt from public disclosure per 10 CFR 2.390.

8.4 Appendix B

Transnucleaire BORA Resin Data Sheet

12986-R-08, Revision 2, 28/5/2002

Note: This data sheet contains proprietary information and is exempt from public disclosure per 10 CFR 2.390.

8.5 Appendix C

Transnucleaire BORA Resin: Homogeneity of Components

TNF-XI Test Procedure

12986-R-10, Revision 0, 3/2002

Note: This test procedure contains proprietary information and is exempt from public disclosure per 10 CFR 2.390.

Enclosure 4 to E-45372

Proposed Changes to
CoC 9301 Revision 8

Enclosure 4- Proposed Changes to CoC 9301 Revision 8

NRC FORM 618
(8-2000)
10 CFR 71

U.S. NUCLEAR REGULATORY COMMISSION

CERTIFICATE OF COMPLIANCE
FOR RADIOACTIVE MATERIAL PACKAGES

1. a. CERTIFICATE NUMBER	b. REVISION NUMBER	c. DOCKET NUMBER	d. PACKAGE IDENTIFICATION NUMBER	PAGE		PAGES
9301	~~8~~ 9	71-9301	USA/9301/AF-96	1	OF	7

2. PREAMBLE

a. This certificate is issued to certify that the package (packaging and contents) described in Item 5 below meets the applicable safety standards set forth in Title 10, Code of Federal Regulations, Part 71, "Packaging and Transportation of Radioactive Material."

b. This certificate does not relieve the consignor from compliance with any requirement of the regulations of the U.S. Department of Transportation or other applicable regulatory agencies, including the government of any country through or into which the package will be transported.

3. THIS CERTIFICATE IS ISSUED ON THE BASIS OF A SAFETY ANALYSIS REPORT OF THE PACKAGE DESIGN OR APPLICATION

a. ISSUED TO *(Name and Address)*

AREVA Inc.
7135 Minstrel Way
Columbia, MD 21045

b. TITLE AND IDENTIFICATION OF REPORT OR APPLICATION

~~Packaging Technology, Inc., application~~
~~dated July 24, 2002, as supplemented.~~
TBD

4. CONDITIONS

This certificate is conditional upon fulfilling the requirements of 10 CFR Part 71, as applicable, and the conditions specified below.

5.

(a) Packaging

(1) Model No.: TNF-XI

(2) Description

A shipping container for unirradiated enriched forms of homogenous and heterogeneous uranium oxides. The packaging body is a parallelepiped and is approximately 44 inches x 44 inches x 37 inches. The package contents are enclosed in pails which each have a borated stainless steel ring. Three pails are stacked inside four inner wells of the packaging body. Each inner well is closed by a primary lid and an upper plug.

The packaging body is constructed of an outer stainless steel envelope which is 0.08 inches thick. The space between the outer shell and the inner wells is filled with fire-retardant, open cell phenolic foam.

The four inner wells each have an inside diameter of 14 inches and height of 27 inches. The inner wells are constructed of (1) and outer shell of stainless steel sheet 0.04 inches thick, with a diameter of 17 inches, (2) and inner shell of stainless steel sheet 0.04 inches thick with a diameter of 14 inches, and (3) a flat bottom of 0.04 inch thick stainless steel sheet with a 0.08 inch thick borated stainless steel plate glued to it. A molded annular layer of neutron-poison BORA resin is inserted between the inner and outer steel shells of the inner well.

Each upper plug consists of two thermal insulating disks of phenolic foam, with an internal stiffener disk made of aluminum alloy. The upper plug assembly is encapsulated inside a 0.03 inch thick stainless steel envelope.

5.(a) (2) Description (continued)

The four primary lids closing off the inner wells are stainless steel circular plates 0.2 inches thick on the center part, and 0.4 inches thick on the periphery. Four bayonet teeth are welded to the primary lid to lock in the well flanges. A primary lid locker is located between the well flange and the primary lid to prevent the rotation of the primary lid during transport. The primary lid and the inner well are sealed by an elastomer gasket set in a rectangular groove machined on the inner face of the primary lid.

The approximate dimensions and weights of the package are as follows:

Inner well inside diameter	14 inches
Overall package dimensions	
Width	44 inches
Length	44 inches
Height	41 inches
Maximum weight of contents in any pail	25 kg
Maximum content weight	300 kg
Maximum package weight (including contents)	1050 kg

(3) Drawings

The packaging is constructed in accordance with the Packaging Technology, Inc., Drawing No. 10799-SAR, Rev. 3, Sheets 1 through 7.

(b) Contents

(1) Type and form of material

The following provides a description of the ~~three~~ four types of material authorized in 5.(b)(1)(i), 5.(b)(1)(ii), ~~and~~ 5.(b)(1)(iii), and 5.(b)(1)(iv):

Homogeneous UO_2 powder: Powders, such as fine powder, are those materials that were not subjected to any treatment that would lead to agglomeration.

Heterogeneous UO_2 material: Heterogeneous materials, such as coarse powder, granulated powders, pellets, and scrap, are those materials that do not meet the definition of homogeneous powders.

In case of a mix of several forms of fissile material, the mix shall be considered heterogeneous material.

(i) The uranium oxide pellets, powder, and scrap meets the requirements of Enriched Commercial Grade Uranium, as defined in ASTM C996-10. U_3O_8 or $UO_{x,\ x>2}$ are authorized provided that the equivalent UO_2 mass is less than the limits specified below:

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5.(b)(1)(i) Type and Form of Material (continued)

Max ^{235}U Enrichment (weight %)	Homogenous UO_2 Powder Maximum Loading (kg)	Heterogeneous UO_2 Material (Pellet and Scrap) Maximum Loading (kg)
≤ 4.05	300	300
4.1	300	293
4.15	300	287
4.25	300	271
4.35	300	259
4.45	300	247
4.55	294	238
4.65	281	228
4.75	265	219
4.85	255	208
4.95	244	202
5.0	239	197

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(ii) The uranium oxide pellets, powder, and scrap meets the requirements of Enriched Commercial Grade Uranium, as defined in ASTM C996-10. U_30_8 or $UO_{x,\, x>2}$ are authorized provided that the equivalent UO_2 mass is less than the limits specified below:

Max ^{235}U Enrichment (weight %)	Homogenous UO_2 Powder Maximum Loading (kg)	Heterogeneous UO_2 Material (Pellet and Scrap) Maximum Loading (kg)
≤ 4.05	300	300
4.15	300	284
4.25	300	271
4.35	300	256
4.45	300	247
4.55	286	236
4.65	271	224
4.75	259	216
4.85	248	208
4.95	238	202
5.0	232	196

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(iii) The uranium oxide powder scrap, which may contain impurities, meets the requirements of Enriched Commercial Grade Uranium, as defined in ASTM C996-10. The impurities aluminum and carbon shall not exceed 5,000 ppm and 10,000 ppm, respectively. U_3O_8 or $UO_x.x_{>2}$ are authorized provided that the equivalent UO_2 mass is less than the limits specified below:

Max ^{235}U Enrichment (weight %)	Homogenous UO_2 Powder Maximum Loading (kg)
≤ 4.05	300
4.15	300
4.25	300
4.35	300
4.45	300
4.55	286
4.65	271
4.75	259
4.85	248
4.95	238
5.0	232

Insert 1

(2) Maximum quantity of material per package

(i) For the contents described in 5.(b)(1)(i), no more than 25 kg of contents per pail. No more than 300 kg of contents per package. Presence of hydrogenated materials (with a hydrogen concentration less than hydrogen concentration in water) or water inside cavities and pails is allowed.

The auto-ignition temperature of the hydrogenated materials (with a hydrogen concentration less than hydrogen concentration in water) shall be greater than 140°C (284°F).

The presence of materials containing more hydrogen than water is not allowed in the package.

(ii) For the contents described in 5.(b)(1)(ii), no more than 25 kg of contents per pail. No more than 300 kg of contents per package. In each pail, the contents can be put in a polyethylene bag (CH_2) or in a bag made of a material with a hydrogen concentration less than that of polyethylene. The maximum hydrogen content of the bags within each cavity is a mass of 56 g H, which is equivalent to a maximum mass of 390 g polyethylene, considering all sources of hydrogenous material within each cavity.

The auto-ignition temperature of the bag material shall be greater than 140°C (284°F).

The presence of materials containing more hydrogen than polyethylene is not allowed in the package.

(iii) For the content described in 5.(b)(1)(iii), no more than 25 kg of uranium oxide powder scrap contents per pail. No more than 300 kg of uranium oxide powder scrap contents per package. In each pail, the contents can be put in a polyethylene bag (CH_2) or in a bag made of a material with a hydrogen concentration less than that of polyethylene. The maximum hydrogen content of the bags within each cavity is a mass of 56 g H, which is equivalent to a maximum mass of 390 g polyethylene, considering all sources of hydrogenous material within each cavity.

The auto-ignition temperature of the bag material shall be greater than 140°C (284°F).

The presence of materials containing more hydrogen than polyethylene is not allowed in the package.

Insert 2

(c) Criticality Safety Index:

For the content described in 5.(b)(1)(i), 5.(b)(1)(ii), and 5.(b)(1)(iii)	0.5
For the content described in 5.(b)(1)(iv)	0.0

6. Transport by air is not authorized.

7. In addition to the requirements of Subpart G of 10 CFR Part 71:

(a) The package shall be prepared for shipment and operated in accordance with the operating procedures in Chapter 7 of the application, as supplemented;

(b) The package must by acceptance tested and maintained in accordance with the Acceptance Tests and Maintenance Program in Chapter 8 of the application, as supplemented; and,

(c) Prior to each shipment, the stainless steel components of the packaging must be visually inspected. Packagings in which stainless steel components show pitting corrosion, cracking, or pinholes are not authorized for transport.

Enclosure 4- Proposed Changes to CoC 9301 Revision 8

NRC FORM 618 (8-2000) 10 CFR 71

U.S. NUCLEAR REGULATORY COMMISSION

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8. The packaging authorized by this certificate is hereby approved for use under the general license provision of 10 CFR 71.17.

9. ~~Revision No. 7 of this certificate may be used until February 28, 2016.~~

10. Expiration date: November 30, 2018.

REFERENCES

~~Packaging Technology, Inc., application dated July 24, 2002.~~

~~Supplements provided by Packaging Technology, Inc., dated: October 29, 2002; March 7, April 3, May 6, June 26, July 21, 2003; November 26, 2007; and August 6, 2008.~~

~~Supplements provided by Transnuclear, Inc., dated: September 8, October 28 and December 23, 2011; January 6, 2012; June 27, 2013 and November 1, 2013; and January 27, 2014.~~

~~Supplement provided by AREVA Inc., dated December 9, 2014.~~

FOR THE U.S. NUCLEAR REGULATORY COMMISSION

Michele Sampson, Chief
Spent Fuel Licensing Branch
Division of Spent Fuel Management
Office of Nuclear Material Safety
and Safeguards

TBD

Date: ~~February 6, 2015~~

Insert 1 **(For Page 5 of 7 of CoC 9301 Revision** 8)

(iv) The uranium oxides in the form of powder and scraps, enriched up to a maximum of 5.0 wt.% U-235, may be mixed with residues consisting of incinerator ashes or earth, sand and residues from dissolution. U_3O_8 or $UO_{x,\ x>2}$, non-irradiated, are authorized when the uranium mass is less than 5 kg per well (each well containing three pails), or equivalent UO_2 mass less than 5.68 kg per well (each well containing three pails). The content is designated as Content #7.

Insert 2 **(For Page 6 of 7 of CoC 9301 Revision** 8)

(iv) For the content described in 5.(b)(1)(iv), Content #7, no more than 75 kg of uranium oxide powder and scraps mixed with residues, consisting of incinerator ashes or earth, sand and residues from dissolution, contents per well. No more than 300 kg uranium oxide powder and scraps mixed with residues, consisting of incinerator ashes or earth, sand and residues from dissolution, contents per package.

The incinerator ashes consist of mainly silica, alumina, alumina-silicates, metal oxides, phosphates, aluminum metal, charred wood, and charred plastic.

The earth, sand and dissolved residues consist of mainly silica, alumina, titanium, iron oxide and alumina-silicate. Other organic or inorganic compounds may be present in the form of trace amounts.

The residues are chemically stable and contain no liquid.

The radioactive material may be placed in plastic bags made of a material with a hydrogen concentration less than that of polyethylene.

The auto-ignition temperature of the bag material shall be greater than 140°C (284°F).

The presence of material containing more hydrogen than polyethylene is not allowed in the package.

Enclosure 5 to E-45372

Listing of Computer Files Contained in Enclosure 6

Listing of Computer Files Contained in Enclosure 6

(All files are Proprietary)

Disk ID No. (size)	Discipline	System/Content	File Series (topics)	Number of files
Enclosure 6 One DVD (62 MB)	Criticality	TNF-XI	1 sensitivity study on simplified packaging model	10
			2 sensitivity study on Content 7	54
			3 sensitivity study on in-cavity reflector	18
			4 sensitivity study on Content 7 scrap size	38
			5 sensitivity study on package pitch	14
			6 criticality evaluation	22