Enclosure 5

Transnuclear, Inc. Calculation No. ANF250-0602, Revision 0

AREVA TRANSNUCLEAR INC.	Form 3.2-1 Calculation Cover Sheet TIP 3.2 (Revision 3)	Calculation No.:	ANF250-0602
		Revision No.:	0
		Page: 1 of 42	

DCR NO (if applicable) : N/A	PROJECT NAME: ANF-250
PROJECT NO: 29250	CLIENT: Transnuclear Inc.

CALCULATION TITLE:

ANF-250 Pellet Criticality Analysis

SUMMARY DESCRIPTION:

1) Calculation Summary

A criticality analysis for the ANF-250 package is performed for UO_2 fuel pellets enriched to 5.0% U-235. The analysis is performed for two different lattice configurations of the fuel pellets; square pitch and triangular pitch. The analysis is performed for both the Normal Conditions of Transport (NCT) and the Hypothetical Accident Conditions (HAC). The analyses are performed for masses of U from 70 kg to 120 kg per package. A criticality safety index of 0.9 is justified for all configurations.

2) Storage Media Description

Secure network server initially, then redundant tape backup

If original issue, is licensing review per TIP 3.5 required?

Yes ☐ **No** ☒ **(explain below)** **Licensing Review No.:**

This calculation is one of the design basis calculations to support the current licensing submittal for the ANF-250 Packaging. Therefore, a 72.48 review by Transnuclear is not necessary.

Software Utilized:	**Version:**
SCALE6 PC	C00750MNYCP01
Calculation is complete: Originator Name and Signature: M. Mason	Date: 11/19/2009
Calculation has been checked for consistency, completeness and correctness: Checker Name and Signature: Rick Migliore	Date: 12/22/09
Calculation is approved for use: Project Engineer Name and Signature: S.R. STREUTHER	Date: 12/23/09

REVISION SUMMARY

REV.	DATE	DESCRIPTION	AFFECTED PAGES	AFFECTED DISKS
0	12/23/09	Initial Issue	ALL	

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1.0 PURPOSE

The purpose of this calculation is to perform a criticality evaluation for the ANF-250 package containing UO_2 fuel pellets enriched to 1.0 wt% and 5.0 wt% U-235. The objective of the analysis is to determine the maximum mass of U and the maximum number of packages that may be transported in accordance with 10CFR71 criticality requirements.

2.0 DESCRIPTION OF CRITICALITY DESIGN

2.1 Design Features

The primary criticality control design feature of the ANF-250 packaging is the pellet shipping suitcase. The pellet suitcase is a flanged steel container that utilizes a flange and bolted closure containing a gasket. The fuel pellets are placed into polystyrene trays which are placed inside the suitcase. The suitcases (2 per packaging) are placed inside a steel containment vessel. The containment vessel has a flanged and bolted closure with a silicone gasket. The containment vessel is enclosed in a outer container fabricated from two 55 gallon drums. Steel springs attached to the vessel locate it in the drum. Vermiculite fills the space between the containment vessel OD and the outer container ID. Vermiculite also fills the space above the containment vessel lid/closure and the drum lid. The gasketed suitcase and containment vessel are designed to prevent water from entering the suitcase during transport. The multiple containers utilized in the packaging control/maintain the geometry of the suitcases to minimize neutronic interaction between packages during transport conditions.

An additional design feature of the packaging is to limit the hydrogen content in the suitcase to 574.5g hydrogen (1149g total), this maintains an under-moderated condition for the UO_2 pellets during transport.

2.2 Summary Table of Criticality Evaluation

The upper subcritical limit (USL) for ensuring that the ANF-250 (single package or package array) is acceptably subcritical, is:

USL = 0.9406 for 5 wt% enriched pellets and

USL = 0.937 for 1.0 wt% enriched pellets

The package is considered to be acceptably subcritical if the computed k_{safe} (k_s), which is defined as $k_{effective}$ (k_{eff}) plus twice the statistical uncertainty (σ), is less than or equal to the USL, or:

$$k_s = k_{eff} + 2\sigma \leq USL$$

The USL is determined on the basis of a benchmark analysis and incorporates the combined effects of code computational bias, the uncertainty in the bias based on both

benchmark-model and computational uncertainties, and an administrative margin. The results of the benchmark analysis indicate that the USL is adequate to ensure subcriticality of the package.

The packaging design is shown to meet the requirements of 10 CFR 71.55(b) and for the array requirements of 10CFR71.59. Moderation by water in the most reactive credible extent is utilized in the HAC analyses. In all models, the fuel is conservatively homogenized with cell weighted cross sections based on both a square and a triangular lattice pitch, which represents a heterogeneous fuel model (pellet and moderator cell). In both the normal conditions of transport (NCT) and HAC array models, a 3-D array is utilized with 12-in (30.48 cm) of water reflection all around.

The maximum results of the criticality calculations are summarized in Table 1. The analyses were performed for uranium mass from 60 kg to 120 kg, (UO_2 pellets enriched to 1.0 wt% and 5.0 wt% U-235). The HAC array is bounding and the mass limit for transport is 120 kg U.

Table 1. Summary of Criticality Evaluation

Normal Conditions of Transport (NCT)	
Case	k_s
Single Package Maximum (5.0 wt%)	0.6300
10x11x3 Package Array Maximum (5.0wt%)	0.8133
13x13x4 Package Array Maximum (1.0 wt%)	0.5547
Hypothetical Accident Condition (HAC)	
Case	k_s
Single Package Maximum (5.0 wt%)	0.7727
7x8x2 Package Array Maximum (1.0 wt%)	0.9338
11x12x2 Package Array Maximum (1.0 wt%)	0.6062

2.3 Criticality Safety Index

As expected the HAC is the limiting condition. For the 5.0 wt% enriched fuel, N = 112/2 = 56 and the criticality safety index, which is defined as 50/N, is equal to 0.9. For the 1.0 wt% enriched fuel, N =264/2 = 132 and the CSI = 0.4.

3.0 METHODOLOGY

The fuel pellets are placed into a polystyrene tray before placement into the ANF-250; therefore, for NCT evaluations, a discrete model of the package is developed utilizing a cell pitch based on the spacing in the tray. Additionally, the heterogeneous fuel cell, (UO_2 fuel

pellets and moderator), is modeled as a homogenized fuel mixture over the full cross section of the fuel pellet suitcase for NCT and HAC evaluations.

The CSAS5 module of the SCALE code [2] is utilized to perform the criticality analyses.

The cylindrical fuel pellet with a specified pitch is modeled (1-D) in the CSAS5 module using the *celldata* input option with parm=nitawl. For the homogenized fuel modeling, a cell weighted homogenized fuel mixture using the NITAWL and XSDRNPM codes is created by specifying a *cellmix=500* input option. This fuel mixture (designated as material 500) is modeled in the suitcase(s) of the KENO model along with the other components/materials in the ANF-250 package. Both a square pitch lattice and a triangular pitch lattice fuel cells are evaluated to determine the most reactive configuration. A single package is evaluated to meet the requirements of 10CFR71.55 and closely packed arrays of packages are evaluated to meet the requirements of 10CFR71.59. Pellet OD, pitch, interspersed water moderation, suitcase tolerance dimensions, UO_2 mass, moderation between packages in an array, and vermiculite composition are variables utilized in the analyses to determine the limiting condition for both NCT and HAC.

Given a mass of UO_2, a pellet OD, and a known volume V_T (=suitcase cross section area*height, where height is a variable) over which to homogenize, the lattice pitch can be determined.

The reactivity of the package is mainly controlled by the amount of moderation in the fuel pellet suitcase. For the NCT cases, no water leaks into the suitcases [1]. The current COC for the ANF-250, limits the mass of hydrogen to 1149 grams in the package (2 suitcases). This limit is used in the analysis presented herein by selecting an appropriate height for the homogenized fuel mixture in the suitcase, and an appropriate density factor for the polystyrene in the discrete model. For the HAC, water is assumed to flood the suitcase.

4.0 GENERAL CONSIDERATIONS

4.1 Model Configuration

The ANF-250 model is based upon Siemens Power Corporation drawings EMF-304, 306, Rev.8 [3] and EMF-306,175, Rev. 16 [4] . The ANF-250 package consists of a 16-gauge steel inner container approximately 295 mm (11-5/8 in) outer diameter by 1461 mm (57-1/2 in) long with a bolted and gasketed top flange closure and steel welded bottom plate. The inner container is centered and supported in an approximately 571.5 mm (22-1/2 in) inner diameter by 1737 mm (68-3/8 in) long, 16-gauge steel drum by twelve 6.4 mm (1/4 in) diameter steel springs welded to the outside of the inner container near the top flange and near the bottom of the vessel. The springs are not included in the criticality model. The space between the inner and outer containers is filled with vermiculite. Closure of the inner container is maintained by a lid, gasket and six hex-head bolts. The outer container closure is made with a lid, and a 12-gauge bolt locking ring.

The fuel pellets are placed into polystyrene trays [7] for transport. A tray is about 610 mm (24.0") long by 190 mm (7.5") wide by 6.6 mm (0.26") in height. There are 15 columns of pellets on a tray with a pitch of 11.91 mm (0.469"). For the shipment, the pellet trays will be packed in pellet shipping suitcases (drawing EMF-304,306) with up to 9 trays per suitcase.

The pellet suitcase consists of two components; a 16 gauge stainless steel cover and a base to which the cover is attached. Foam is bonded to the inside of the cover; however, this is conservatively not included in the model which allows more water to fill the suitcase in the HAC. Ignoring the foam, the nominal inside dimensions of the cover are 121 mm (4.75 in) by 197 mm (7.75 in) by 632 mm (24.88 in).

The base is formed from 1"x1/16" square steel tubing covered with a 12 gauge steel plate (0.1046"). The cover is attached to the base using threaded fasteners with a gasket. The exact geometry of the base is not modeled, only the 12 gauge plate. Two suitcases are placed inside the inner container described above. The suitcases are located in a pellet box frame [8] which is inserted into the inner container. The pellet box frame is utilized to locate/center the suitcases in the container. The frame is not included in the analysis model(s).

For the pellet suitcase, nominal, minimum and maximum tolerance dimensions are evaluated. The inner vessel and outer container minimum tolerance dimensions are utilized in all the models.

The ANF-250 package geometry for the homogenized fuel mixture model is shown in Figure 1 and Figure 2 assuming the fissile mixture occupies the complete volume of the suitcases.

For the NCT homogenized model, the height of the homogenized fuel mixture is a function of the mass of UO_2 and the ratio of moderator volume to fuel volume (V_m/V_f). For the partial height fuel mixture model, the gap between the top of the fuel mixture and the top of the suitcase is assumed a void. The HAC model assumes a fully flooded suitcase and therefore, the homogenized fuel mixture fills the entire suitcase inside volume. The HAC model also assumes the outer container has its length and diameter reduced by 2.0" due to the drop accident [1].

A finite square lattice of packages is modeled for both the NCT and HAC (see Figure 3 and Figure 4). Water moderation between packages (HAC only) and interspersed within the package is varied to determine the most reactive condition. The array of packages is surrounded by a 30 cm water reflector (KENO water albedo).

The NCT single package model discreetly models the fuel pellets as a continuous column of fuel. Nine polystyrene trays are assumed in the model with each tray holding 15 columns of fuel pellets. Therefore an "assembly" of fuel rods in a 15x9 array is modeled inside each suitcase. A cross section of the discrete model is shown in Figure 5.

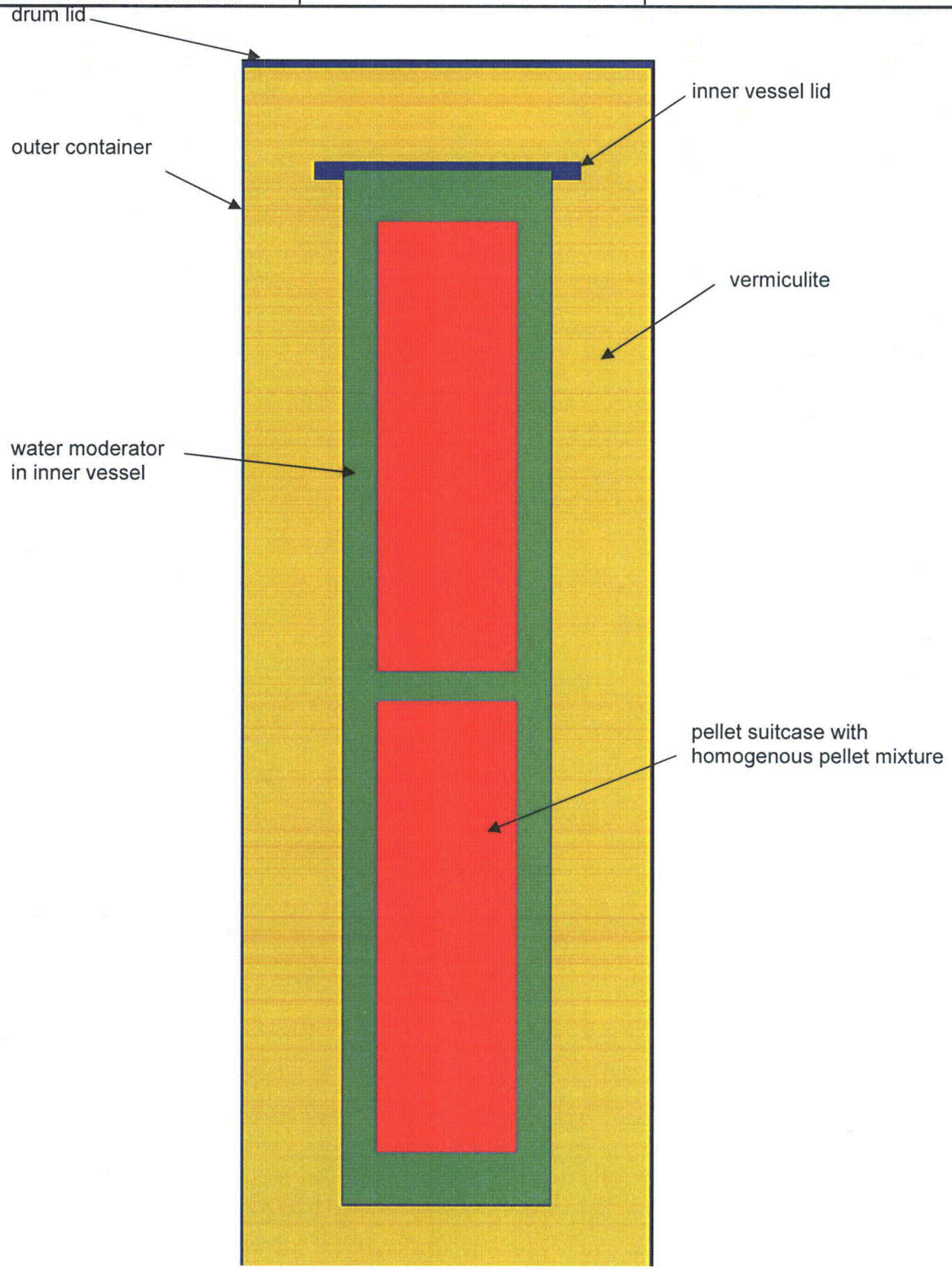


Figure 1. ANF-250 Homogenized Fuel Model, Longitudinal Section

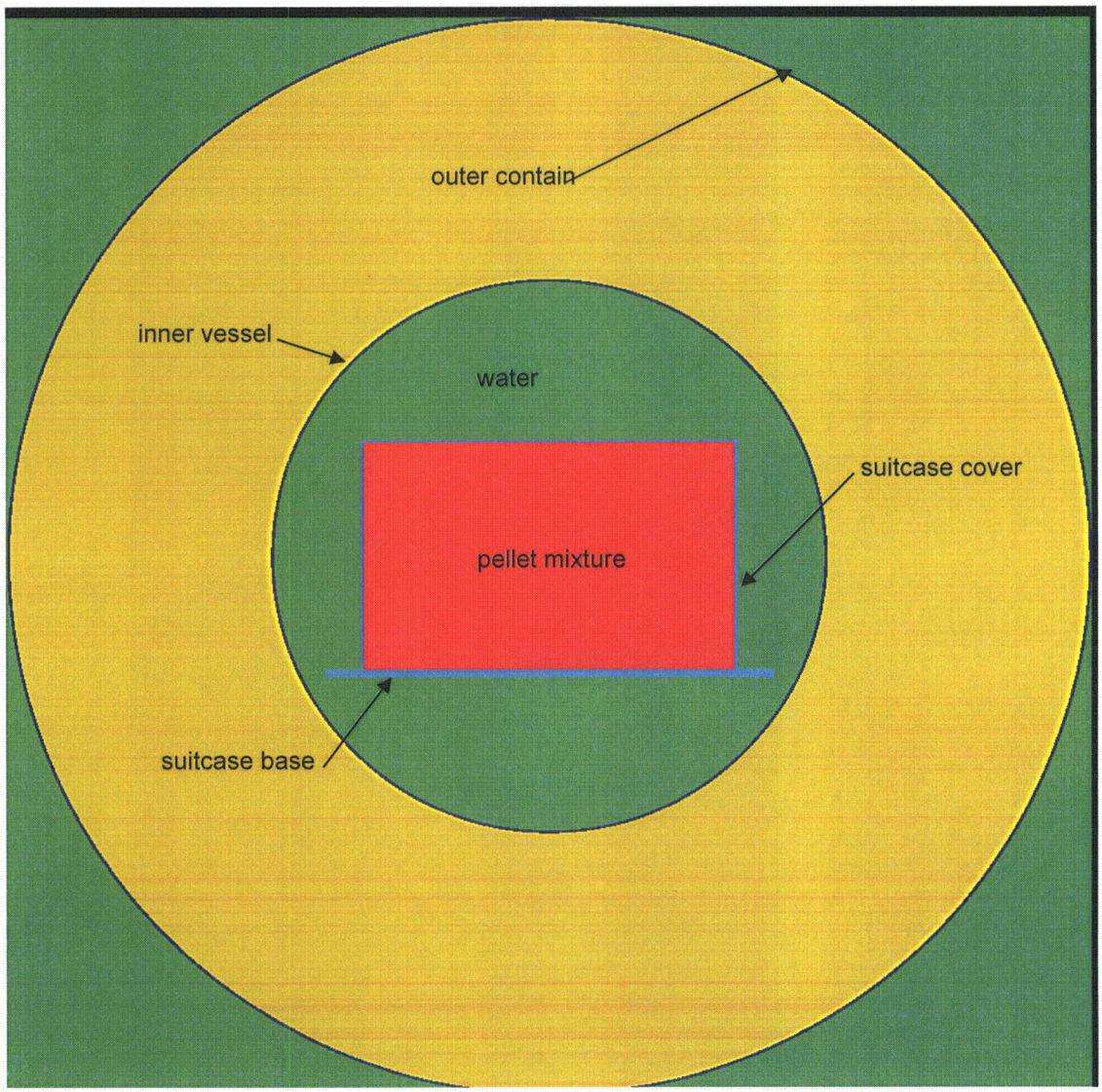
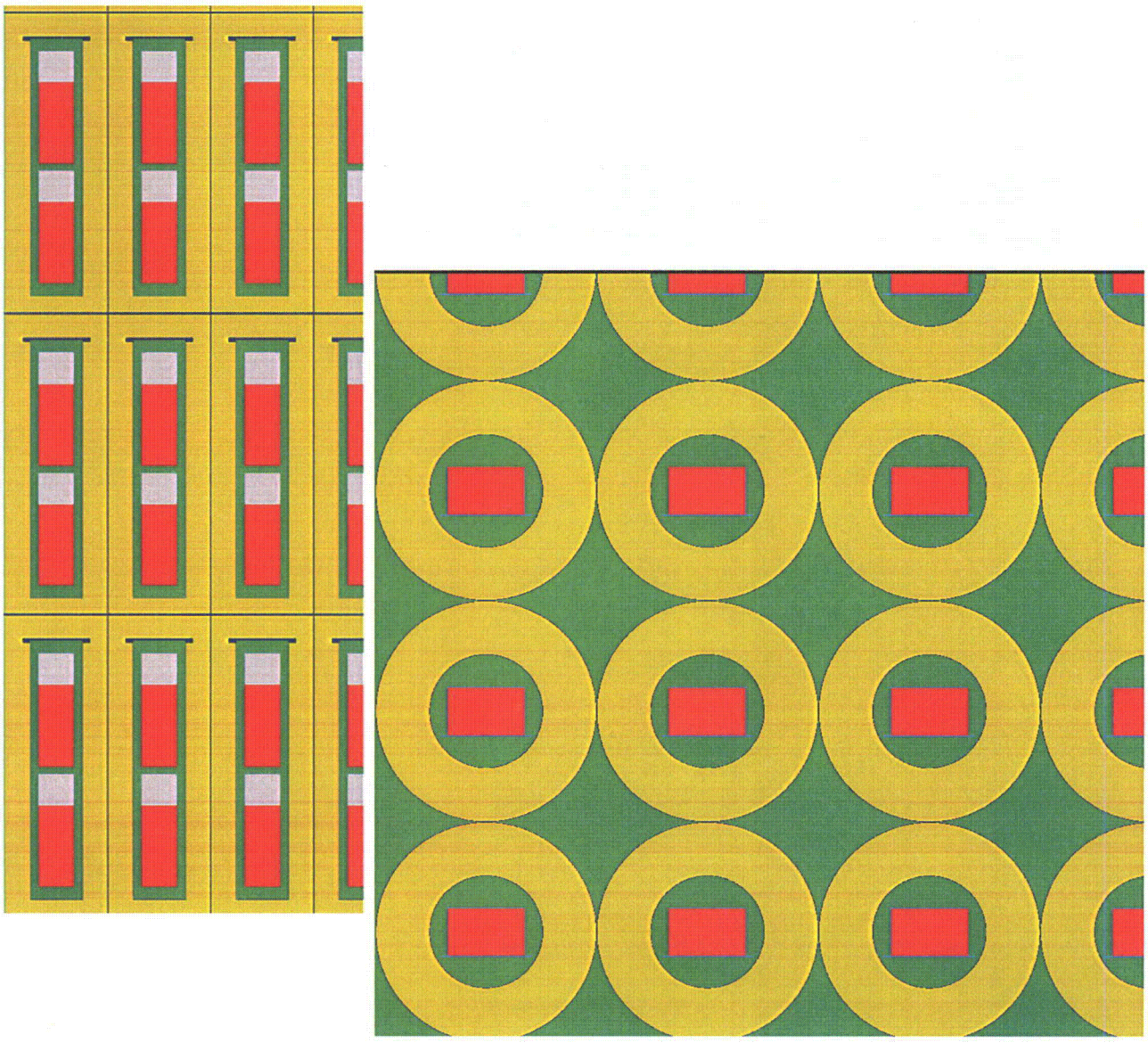
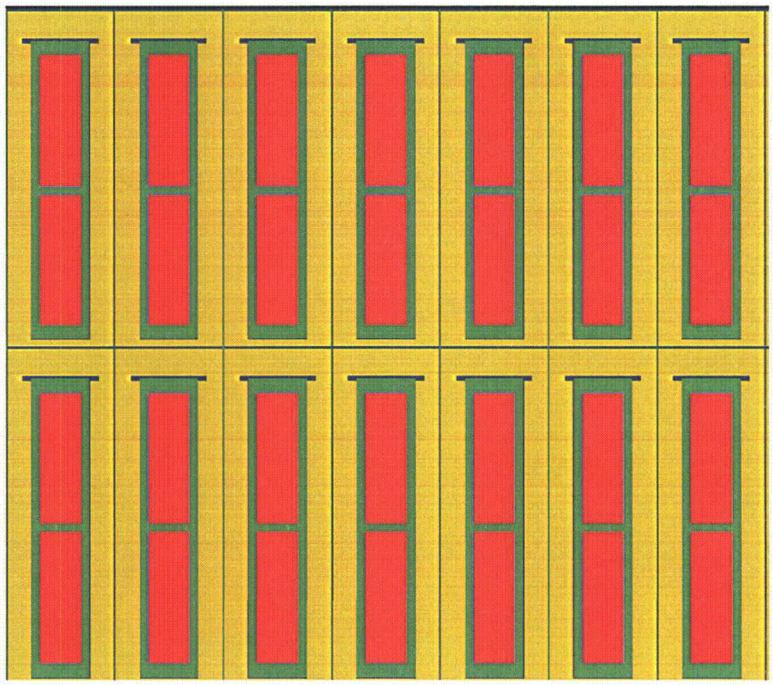


Figure 2. ANF-250 Homogenized Fuel Model, Cross Section

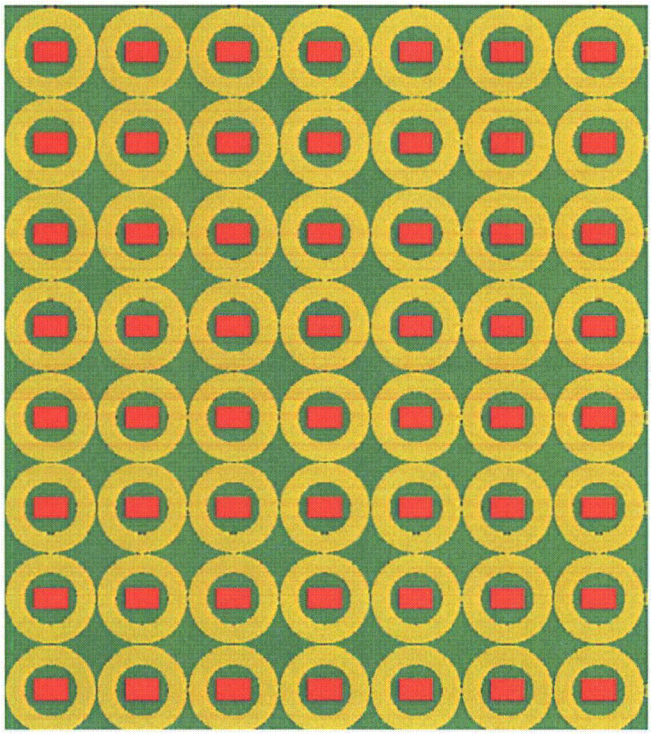


Longitudinal Section Cross Section

Figure 3. ANF-250 NCT Models, 10x11x3 Array



Longitudinal Section



Cross Section

Figure 4. ANF-250 HAC Array, 7x8x2

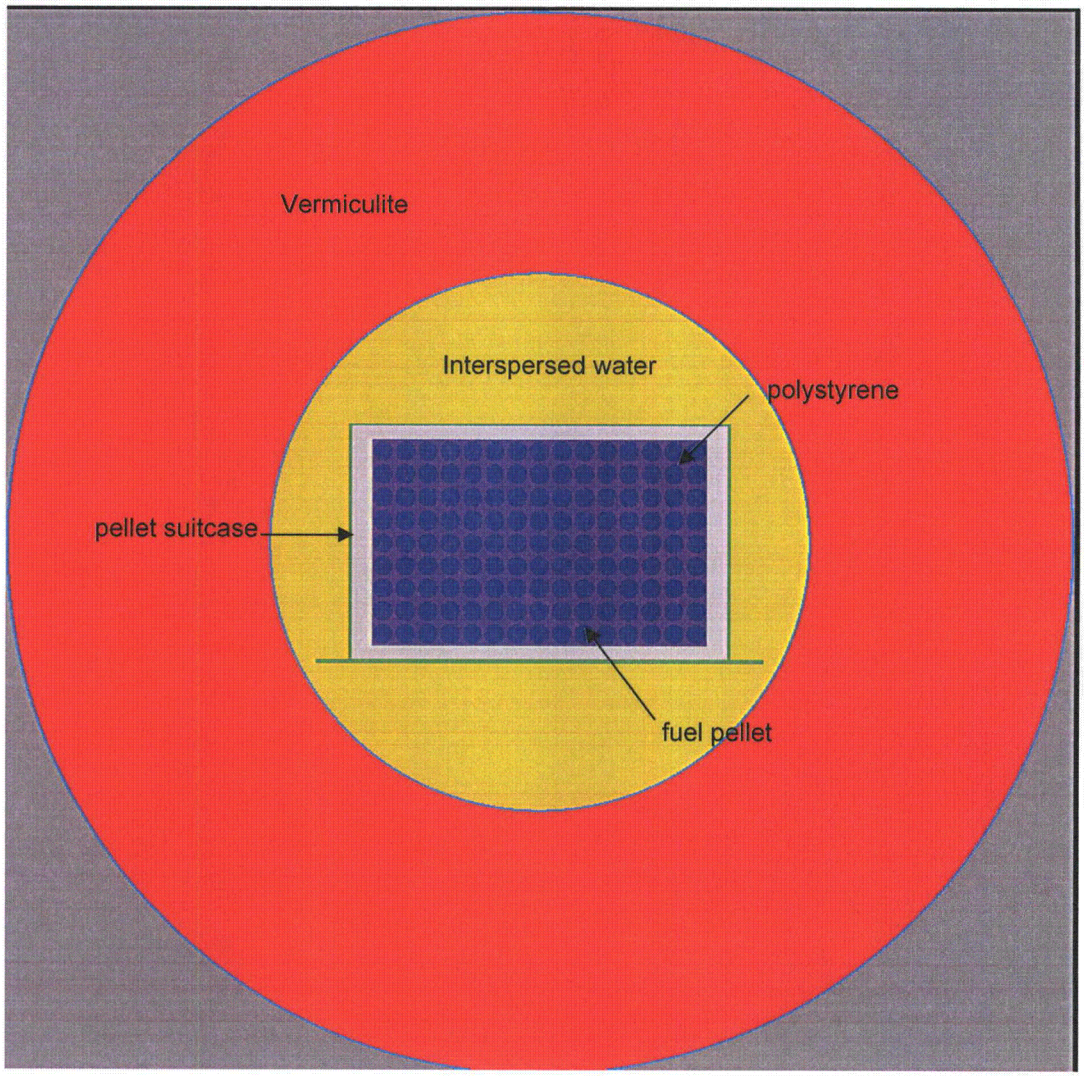


Figure 5. ANF-250 Discrete Model Cross Section

4.2 Material Properties

The material properties for the CSAS5 evaluations are taken directly from the SCALE6 standard compositions. The fuel pellets are conservatively modeled at full theoretical density, 10.96 g/cc UO_2 and 5.0 wt% U-235.

The stainless steel used for the suitcase cover and base is the SCALE standard composition *SS304* material with a density of 7.94 g/cc. Carbon steel used for the inner vessel and the outer container is the SCALE standard composition *carbonsteel* with a density of 7.821 g/cc.

Water is the SCALE standard composition with a density ranging from 0 to 0.9982 g/cc.

The vermiculite specification is indicated on license drawing EMF-306,175, Revision 16 which is a condition of the NRC Certificate of Compliance USA/9217/AF. The vermiculite is purchased to ASTM C516-80 Type 1 Grade 1. Vermiculite is a naturally occurring substance such that its exact composition may vary from sample to sample. The typical chemical analysis by weight percent is provided in Table 2. A density value of 0.068 g/cc is used with the minimum composition and a density of 0.0805 with the maximum composition material. Maximum composition and maximum density vermiculite is used except where noted. The quantity of water in the vermiculite was varied between 0 and 29 wt% (50/(140-16+50)) and modeled in CSAS5 using the arbitrary material descriptions. Note, the max and min wt% total to more than 100% and less than 100%, thus, the effective densities utilized in the KENO V.a code runs may be more or less than the densities listed above according to the total wt% input. Polystyrene was also input using the arbitrary material description. The density of polystyrene is 1.06 g/cc and has 8 carbon and 8 hydrogen atoms per molecule; $(C_8H_8)_n$.

Table 2. Vermiculite Composition (ASTM C-516-80 Type 1 Grade 1)

Compound within Mixture	Wt.% Minimum	Wt.% Maximum
SiO_2	38	46
Al_2O_3	10	16
MgO	16	35
CaO	1	5
K_2O	1	6
Fe_2O_3	6	13
TiO_2	1	3
H_2O	8	16
Other (not used)	0.2	1.2
Total	81.2	141.2

4.3 Computer Codes and Cross-Section Libraries

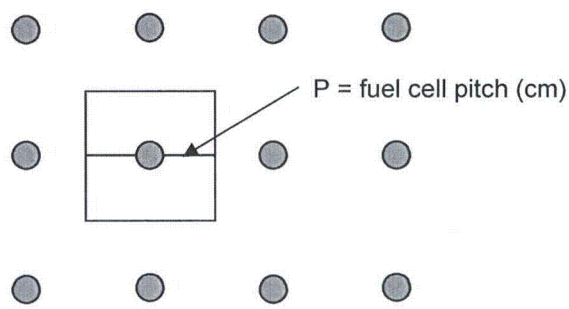
The CSAS5 module of the SCALE6 code is used for the criticality analysis [2]. The 238groupndf5 cross section library is utilized with all cross sections at room temperature (293.6 K). The CSAS5 module using the *celldata* option prepares a cell weighted homogenized fuel mixture for used in the KENOVa criticality code in SCALE6. The NITAWL code is used to process the cross sections thru the *parm=nitawl* card in the CSAS5 input.

All cases are run with 1000 neutrons per generation for 805 generations. The 1 sigma uncertainty is less than 0.0011 for all cases.

4.4 Lattice Cell Modeling for CSAS5

For the CSAS5 calculation, a homogenized cell weighted cross section fuel mixture is created as a material input for the KENO criticality calculation. The pellet analysis utilizes a lattice cell configuration. The cell is modeled as a cylindrical fuel pellet surrounded by a moderator. The cell is described by defining a diameter for the fuel pellet and a cell (lattice) pitch with the moderator material identified. For the pellet analyses, both a square lattice and a triangular lattice are evaluated. The following defines the relationship between the mass of fuel, pellet diameter, lattice pitch and the ratio of moderator volume to fuel volume (V_m/V_f)

<u>Square Pitch Lattice</u>



1) $A_{cell} = P^2$

2) $A_T = N*A_{cell} = NP^2$ Area of pellet container where N= # of cells in container

3) $m = \pi r^2 h\rho$ mass of pellet in cell where h= pellet stack height
ρ = pellet density and r = pellet radius

4) $M = N * \pi r^2 h\rho = A_T \pi r^2 h\rho / P^2$ (using equations #1 & #3) mass of fuel in container

rearranging equation #4 where $A_T h = V_T$ (container volume)

5) $P^2 = V_T \pi r^2 \rho / M$ $V_T = A_T h'$ where h' is height of fuel mixture

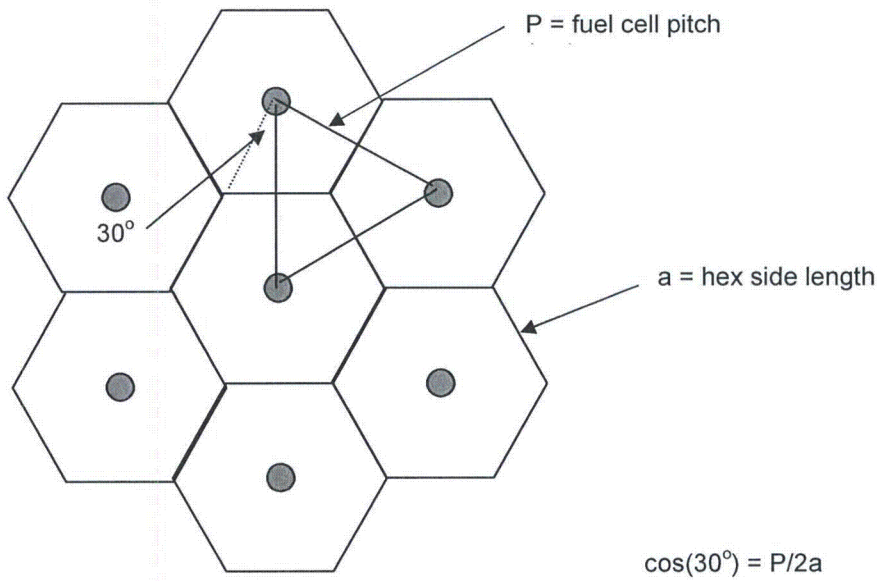
6) $P^2 = V_T \pi r^2 / V_f$ where $\rho/M = 1/V_f$ V_f & V_m are volumes of fuel and moderator

7) $V_T = V_f + V_m$ and $V_T / V_f = 1 + V_m / V_f$

8) $P^2 = \pi r^2 * (1 + V_m / V_f)$ (using equation #7)

9) $P = r * [\pi(1+ V_m / V_f)]^{(0.5)}$

Triangular Pitch Lattice



$\cos(30^\circ) = P/2a$

$a=P/2*0.866025 = P/1.732$

1) $A_{cell} = 2.59808a^2=0.866025P^2$

2) $A_T = N^* A_{cell} = 0.866025N P^2$ Area of pellet container where N= # of cells in container

ρ = pellet density and r = pellet radius

3) $m = \pi r^2 h\rho$ mass of pellet in cell where h= pellet stack height

4) $M = N * \pi r^2 h\rho = A_T\pi r^2 h\rho/0.866025 P^2$ (using equations #1 & #3) mass of fuel in container

rearranging equation #4 where $A_T h = V_T$ (container volume)

5) $P^2 = V_T\pi r^2\rho/0.866025M$ $V_T = A_T h'$ where h' is height of fuel mixture

6) $P^2 = V_T\pi r^2/0.866025V_f$ where $\rho/M = 1/ V_f$ V_f & V_m are volumes of fuel and moderator

7) $V_T = V_f + V_m$ and $V_T/ V_f = 1 + V_m/ V_f$

8) $P^2 = (\pi r^2/0.866025) * (1 + V_m/ V_f)$ (using equation #7)

9) $P = r * [1.1547\pi(1+ V_m/ V_f)]^{(0.5)}$

The pellet diameter, UO_2 density, pitch are input parameters for CSAS5. For the NCT analyses, the current CoC limits the grams of hydrogen moderator in the suitcase to a total of 1149 grams (574.5 g each). The mass of hydrogen can be calculated from the mass of UO_2 in the suitcase and the V_m/V_f ratio as follows:

H (g/suitcase) = UO_2 (g) /ρ_{UO2} (g/cc) * (V_m/V_f) * ρ_{mod} * wt% H in moderator

H (g/suitcase) = UO_2(g)/10.96 *(V_m/V_f)*0.9982*(1.0077*2/18.0058) for water moderator

H (g/suitcase) = UO_2(g)/10.96 *(V_m/V_f)*(1.06*0.0774) for polystyrene

The height (h') of the homogenized fuel mixture in the suitcase is selected to obtain the proper mass of hydrogen in the suitcase.

Discrete Fuel Model Lattice

As previously mentioned above, the fuel pellets are placed in a polystyrene tray. The tray contains 15 columns of pellets with a planar (X) pitch of 11.9 mm (0.469"). The base of the tray has a max thickness of 1.98 mm (0.078"). The trays are stacked together (max 9) and placed into a suitcase. Therefore, the pitch in the axial (Y) direction is 1.98 + pellet OD. For the pellet ODs evaluated; 0.28", 0.35" and 0.40", the "axial" pitch is 9.09 mm (0.358"), 10.9 mm (0.428"), and 12.1 mm (0.478"), respectively. However, to calculate the resonance corrections in CSAS5, only a single pitch can be input. An effective pitch is calculated by using the square root of the rectangular fuel cell area formed by the X pitch and Y pitch dimensions, 1.0408 cm, 1.1380 cm, and 1.2026 cm respectively.

Since a fuel cell, fuel pellet(rod) surrounded with polystyrene (PS), is being modeled, the PS density needs to be adjusted to reflect the actual tray/pellet configuration. The PS pellet trays have a mass of 300 grams and there are 9 trays per suitcase, so a suitcase contains a total mass of 2.70 kg PS. PS contains 7.74 wt% hydrogen; therefore, there are 209g H in a suitcase. The length of the pellet column is modeled as 596.9 mm (23.5") [7].The adjusted/effective PS density can be calculated as follows:

For a 0.35" pellet OD, the unit fuel cell is 1.19 cm x 1.09 cm for an area of 1.295 cm^2. The mass of (full density) PS in the cell = $(1.295 - \pi*0.4445^2)*1.06$ = 0.7148 g. There are 2,700g of PS in the suitcase, which gives 209.0 g H per suitcase. There are 135 (15x9) fuel cells in the suitcase, each one 59.69 cm in length. Therefore, the true mass of H in the unit fuel cell = 209.0/135/59.69 = 0.02593 g H. The density adjustment factor = 0.02593/(0.7148*0.0774) = 0.4688 which is input with the arbitrary material input for PS. Similar calculations for the 0.28" pellet and the 0.40" pellet yield factors of 0.4608 and 0.4973, respectively. These factors are for the true "normal" case. The CoC allows a maximum hydrogen content of 1149g for the package (574.5g H per suitcase). For conservatism, evaluations are performed using this limit. Calculations based on the methodology shown above yield the following density factors for the 574.5 g H in each suitcase: 0.28" pellet – 1.2668, 0.35" pellet – 1.2887, and 0.40" pellet – 1.3672.

Calculations based on the equations shown above are performed in the spreadsheet *ANF250_ pellet-scale6.xls*. The criticality calculation results are also in this spreadsheet. The homogenized fuel mixture height (h') is entered in the KENO model section of the CSAS5 input for the homogenized fuel model.

5.0 SINGLE PACKAGE EVALUATION

5.1 NCT Configuration

A single package analysis is performed for the NCT. In the NCT analysis, the pellet suitcase interior remains leak-tight; however, the inner vessel is allowed to fill with water (interspersed water), the vermiculite to become water saturated or replaced by water, and the package is closely reflected all around with 12" (30.48 cm) of full density water, (water albedo). The suitcase is modeled with maximum tolerance dimensions.

Discrete Model

The fuel pellets and PS pellet trays are modeled as a discrete 15x9 array of UO_2 rods. For the first discrete model, the PS density is modified to achieve the correct H density in the fuel cell based on the normal mass of 300 grams for a PS tray (2.70 kg in suitcase). To accommodate other equivalent PS trays and allow for other sources of hydrogen in the suitcase, the second model conservatively uses the COC limit of 574.5 grams H in the suitcase (7.42 kg PS in suitcase). The PS density is modified to achieve this limit. Three pellet diameters and associated uranium masses were evaluated for each of the two models: 0.28"- 62 kg U, 0.35" – 97 kg U, and 0.40" – 126 kg U.

As expected, the second model with the package hydrogen mass limit is clearly the most reactive as shown in Table 3 with the 126 kg U case being bounding. Variations on the density of the interspersed water and the water in the vermiculite, including replacement of the vermiculite by full density water were evaluated to find the optimum moderation for the package. As shown in Table 3, full density interspersed water and full density water displacement of the vermiculite is the bounding condition with k_s = 0.6300 (u126-pd4-pt120-s-im100-rf100-vr100-tolp-traym) which is significantly less than the USL.

Two cases were run (-vrmn & -vrmx), using the single package model, to determine whether the min density or max density vermiculite (see Table 2) would produce the larger reactivity and thus be appropriate to use for the ANF-250 evaluations. As shown in the first two cases in Table 3, the reactivity from the maximum density vermiculite case (-vrmx) was marginally larger than the minimum density reactivity and thus the maximum density will be used in all the analyses.

5.2 NCT Results

Results for the single package evaluation are summarized in Table 3. The most reactive case is in bold.

Table 3. Single ANF-250 Discrete Model Results

Run ID	Pellet OD (cm)	Equiv Pitch (cm)	U (kg)	Interspersed Water (vol fraction)	Vermiculite Water (%wt)	Hydrogen (grams per suitcase)	V^5_m/V_f	k_s ($k_{eff}+2\sigma$)
u126-pd4-pt120-s-im100-rf100-vrmx-tolp-tray	1.016	1.203	126	1.00	16.0	209.0	0.390	0.4557
u126-pd4-pt120-s-im100-rf100-vrmn-tolp-tray	1.016	1.203	126	1.00	8.0	209.0	0.390	0.4536
u62-pd28-pt104-s-im100-rf100-vr6-tolp-tray	0.711	1.041	62	1.00	6.0[1]	209.0	0.796	0.3755
u97-pd35-pt114-s-im100-rf100-vr6-tolp-tray	0.889	1.138	97	1.00	6.0	209.0	0.509	0.4238
u126-pd4-pt120-s-im100-rf100-vr6-tolp-tray	1.016	1.203	126	1.00	6.0	209.0	0.390	0.4541
u62-pd28-pt104-s-im100-rf100-vr6-tolp-traym	0.711	1.041	62	1.00	6.0	574.5	2.187	0.5428
u97-pd35-pt114-s-im100-rf100-vr6-tolp-traym	0.889	1.138	97	1.00	6.0	574.5	1.400	0.5843
u126-pd4-pt120-s-im100-rf100-vr6-tolp-traym	1.016	1.203	126	1.00	6.0	574.5	1.072	0.6076
u126-pd4-pt120-s-im90-rf100-vr6-tolp-traym	1.016	1.203	126	0.90	6.0	574.5	1.400	0.5978
u126-pd4-pt120-s-im70-rf100-vr6-tolp-traym	1.016	1.203	126	0.70	6.0	574.5	1.400	0.5710
u126-pd4-pt120-s-im50-rf100-vr6-tolp-traym	1.016	1.203	126	0.50	6.0	574.5	1.400	0.5330
u126-pd4-pt120-s-im100-rf100-vr18-tolp-traym	1.016	1.203	126	1.00	18.0[2]	574.5	1.400	0.6091
u126-pd4-pt120-s-im100-rf100-vr50-tolp-traym	1.016	1.203	126	1.00	50.0[3]	574.5	1.400	0.6106
u126-pd4-pt120-s-im100-rf100-vr100-tolp-traym	1.016	1.203	126	**1.00**	**100[4]**	**574.5**	**1.400**	**0.6300**

1. Nominal 6.0 %wt water. Actual is nominal*100/(∑component wt% (table 2) = 6.0*100/(140-16+10) = 4.48 wt%
2. Nominal 18.0%wt water. Actual is nominal*100/(∑component wt% (table 2) = 18.0*100/(140-16+18) = 13.0 wt%
3. Nominal 50.0%wt water. Actual is nominal*100/(∑component wt% (table 2) = 50.0*100/(140-16+50) = 28.7 wt%
4. 100 % water replaces vermiculite volume.
5. V_m is the volume of PS at the normal density of 1.06 g/cc

5.3 HAC Configuration

In the HAC analysis, the suitcases are fully flooded and are modeled with maximum tolerance dimensions. The outer container is assumed to have its diameter and length reduced by 2" each as a results of the accident conditions [1]. The cylindrical package is closely reflected all around with 12" (30.48 cm) of full density water, (water albedo).

Because the fuel pellets may be dislodged from the pellet trays in the HAC, the fuel and moderator are modeled as a homogeneous mixture inside the suitcase. As described in Section 4.4, there is a relationship between the pellet OD, pellet pitch, and height of the homogeneous mixture in the suitcase. For the HAC, the suitcase is assumed to be flooded; therefore, the homogenized fuel mixture (UO_2 and water) fills the full height of the suitcase.

Initial runs were made using the 0.28" pellet OD. Based on the results for the NCT single package, full density water moderation inside the package, (interspersed water), and water replacement of the vermiculite were modeled. The volume of moderator to volume of fuel ratio (V_m/V_f) was varied by evaluating fuel masses ranging from 60 kg to 120 kg U. The results for these evaluations are shown in Table 4 and the reactivity (k_s) as a function of V_m/V_f is shown in Figure 6. The reactivity curve shown in the figure represents the "U" or bell shaped reactivity vs H/U curve typical for a low enriched UO_2 water moderated system. The reactivity peaks around 80 to 90 kg U, (V_m/V_f =2.4 -2.8).

To further investigate the maximum reactivity, the 70 kg U case was modified to decrease the V_m/V_f ratio to values around the peak reactivity range. This was accomplished by reducing the height of the fuel mixture in the suitcase,(less water with a void above). Three cases were evaluated, V_m/V_f =2.5, 2.8 and 3.1. These results are also shown in Table 4 and all are less than the maximum previously calculated.

Four additional runs were made to evaluate reactivity as a function of the pellet OD. The maximum reactivity case, previously determined as 80 kg U, was evaluated with pellet ODs of 0.35", 0.40", 0.45" and 0.50". The results of this evaluation are shown in Table 4 and confirm that the 0.28" pellet OD is bounding.

The bounding HAC single package condition was determined to be 80 kg U with full flooding in and around the suitcases, and the vermiculite replaced by water. The calculated reactivity, k_s = 0.7727 (hau80-pd28-pt121-single-im100-vr100-tolp), is significantly less than the USL.

5.4 HAC Results

Results for the single package evaluation are summarized in Table 4. The most reactive case is in bold

Table 4. HAC Single Package Results

Run ID	Pellet OD (cm)	Pitch (cm)	U (kg)	Interspersed Water (vol fraction)	Vermiculite Water (%wt)	Hydrogen (grams per suitcase)	V_m/V_f	k_s (k_{eff} +2σ)
hau60-pd28-pt140-single-im100-vr100-tolp	0.700	1.397	60	1.00	100[1]	1413	4.073	0.7579
hau70-pd28-pt129-single-im100-vr100-tolp	0.700	1.294	70	1.00	100	1355	3.349	0.7700
hau80-pd28-pt121-single-im100-vr100-tolp	**0.700**	**1.210**	**80**	**1.00**	**100**	**1298**	**2.805**	**0.7727**
hau90-pd28-pt114-single-im100-vr100-tolp	0.700	1.141	90	1.00	100	1240	2.382	0.7721
hau100-pd28-pt108-single-im100-vr100-tolp	0.700	1.082	100	1.00	100	1182	2.044	0.7667
hau120-pd28-pt099-single-im100-vr100-tolp	0.700	0.988	120	1.00	100	1066	1.537	0.7493
hau70-pd28-pt125-single-im100-vr100-tolp	0.700	1.254	70	1.00	100	1250	3.088	0.7636
hau70-pd28-pt121-single-im100-vr100-tolp	0.700	1.214	70	1.00	100	1144	2.827	0.7563
hau70-pd28-pt116-single-im100-vr100-tolp	0.700	1.157	70	1.00	100	1003	2.479	0.7507
hau80-pd35-pt154-single-im100-vr100-tolp	0.889	1.537	80	1.00	100	1298	2.805	0.7671
hau80-pd4-pt175-single-im100-vr100-tolp	1.016	1.756	80	1.00	100	1298	2.805	0.7639
hau80-pd45-pt197-single-im100-vr100-tolp	1.143	1.976	80	1.00	100	1298	2.805	0.7615
hau80-pd5-pt219-single-im100-vr100-tolp	1.270	2.196	80	1.00	100	1298	2.805	0.7572

1. 100 % water replaces vermiculite volume.

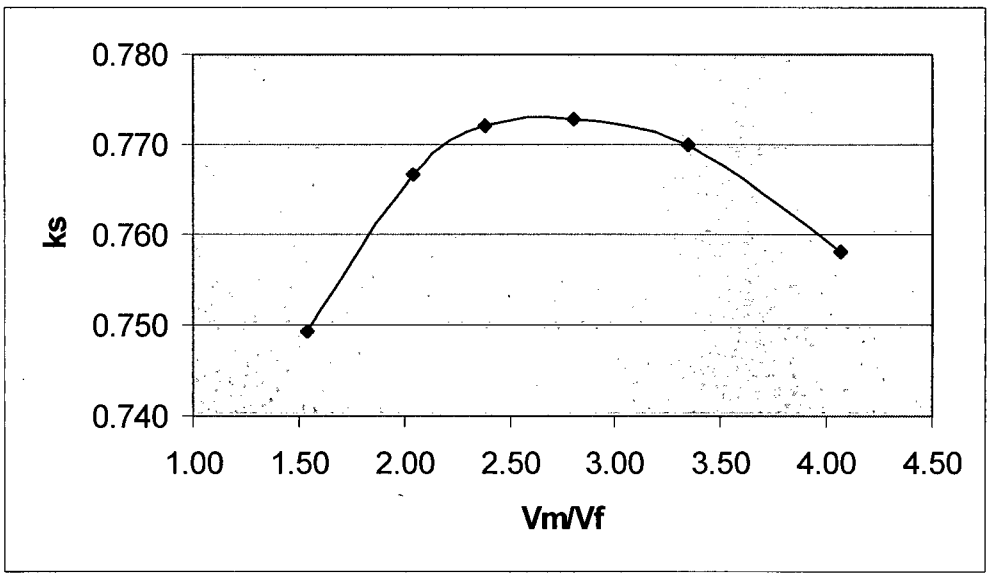


Figure 6. ANF-250 HAC Single Package Reactivity

6.0 EVALUATION OF PACKAGE ARRAYS UNDER NORMAL CONDITIONS OF TRANSPORT

6.1 Configuration

Discrete Model

The fuel pellet/PS pellet tray model described in section 5.0 is utilized as the basis for the NCT array evaluation. Based on the single package analyses, the 126 kg U with 0.40" pellet OD is the basic model utilized. The model has the COC limit of 1149 g H moderator (PS) in the package (suitcase). A 10x11x3 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 (void) between the packages.

Calculations were performed varying the interspersed water (around the suitcases) and the water content in the vermiculite to determine the optimum moderation condition. The results of these calculations are shown in Table 5. As can be seen in the table, the case (u126-pd4-pt120-a10113-im10-rf0-vr0-tolp-traym) with 10% interspersed water density and no water in the vermiculite is the most reactive configuration, k_s = 0.8095. The reactivity is significantly less than the USL.

Homogenized Fuel Model

As discussed in Section 5.3, a homogenized fuel/moderator model may be utilized to evaluate the package. The PS pellet trays modeled in the discrete model may be subject to minor changes and since the mass of hydrogen is the main concern, a homogenized fuel/PS mixture does not require a specific pellet tray design. Therefore, the NCT array is also evaluated using a homogenized model with the COC limit of 1149 g H in the suitcases. A square lattice cell pitch is used for the cell weighting.

The evaluation for the NCT is a 10x11x3 array with each packaging containing 120kg U and a pellet OD of 0.5". Each cylindrical package was enclosed in a void cuboid and the packages are placed in a closely packed square lattice array. The array is closely reflected all around with 12" (30.48 cm) of full density water. To replicate the discrete model, the interspersed water was modeled at 10% density and there was no water content in the vermiculite.

As a result of the relationship between fuel mass, pellet OD and pitch (Section 4.4), the height of the homogeneous fuel/PS mixture does not fill the suitcase when the hydrogen gram limit of 1149 g is met. This condition could be modeled with the fuel mixture in the bottom part of the suitcase and a void above the mixture. Modeling in this manner, places a void between the fuel mixtures in the top and bottom suitcase, (see Figure 3). To maximize the reactivity in the package/array, a model was prepared to locate the fuel mixture in the top part of the lower suitcase with the fuel mixture in the bottom part of the top suitcase for each package. This eliminates the void space between the mixtures as shown in Figure 7.

Table 6 shows the results of the homogenized fuel mixture model runs performed for U masses from 80 kg to 120 kg. Additional runs were made to evaluate the effect of the pellet OD on the array reactivity. The results for pellet ODs from 0.28" to 0.5" are also shown in Table 6. The most reactive configuration is the case with 120 kg U and 0.5" pellet OD (u120-pd5-pt164-a10113-im10pk0-vr0-tolp-p2-ps). Comparing the results of homogenized model to the discrete model (Table 6), one can see the homogenized model is slightly more reactive (0.8133 vs 0.8095); however, both are well below the USL.

The homogenized model was also evaluated using a triangular lattice cell pitch instead of the square lattice cell pitch. Section 4.4 describes the relationships developed for the triangular lattice pitch. The first, third, fifth, and seventh cases in Table 6 were reevaluated using the triangular lattice pitch. The results of these evaluations are also shown in Table 6, below their comparable square lattice case (run ID prefix tru120-...). Comparing the results of the square and triangular pitch results, one can see that the triangular pitch results are statistically similar to the square pitch results and utilizing either lattice description would likely provide equivalent results.

Also shown in Table 6 are results for an evaluation of the suitcase tolerance's affect on the array reactivity. Three cases were evaluated, nominal suitcase dimension, minus tolerance dimension and plus tolerance dimension. The results show the plus tolerance (-tolp) to be the most reactive, but the difference in reactivity between the cases is of minor significance. Using the plus tolerance dimension suitcase for the analyses is confirmed.

One case was run for 1.0 wt% U-235 enriched pellets with a 13x13x4 package array. The conditions were identical to the discrete model bounding case for 5.0 wt% enriched pellets.

6.2 Results

Results for the NCT array evaluation are shown in Tables 5 and 6. The most reactive cases are in bold. In accordance with 10CFR71.59, the evaluated array produces a value of N = 330/5 = 66 for 5 wt% U-235 pellets. This in turn produces a CSI of 50/66 = 0.8 for NCT (HAC may be more conservative and thus bounding). For the 1.0 wt% U-235 pellets, the evaluated array produces a value of N = 676/5 = 135 which produces a CSI of 0.4 for NCT.

Table 5. NCT Discrete Fuel Model 10x11x3 Array Results

Run ID	Pellet OD (cm)	Equiv Pitch (cm)	U (kg)	Interspersed Water (vol fraction)	Vermiculite Water (%wt)	Hydrogen (grams per suitcase)	V_m/V_f	k_s ($k_{eff}+2\sigma$)
u126-pd4-pt120-a10113-im100-rf0-vr100-tolp-traym	1.016	1.203	126	1.00	100.0[1]	574.5	1.400	0.6322
u126-pd4-pt120-a10113-im100-rf0-vr50-tolp-traym	1.016	1.203	126	1.00	50.0[2]	574.5	1.400	0.6841
u126-pd4-pt120-a10113-im100-rf0-vr25-tolp-traym	1.016	1.203	126	1.00	25.0[3]	574.5	1.400	0.6928
u126-pd4-pt120-a10113-im100-rf0-vr0-tolp-traym	1.016	1.203	126	1.00	0.0	574.5	1.400	0.7050
u126-pd4-pt120-a10113-im100-rf0-vr6-tolp-traym	1.016	1.203	126	1.00	6.0[4]	574.5	1.400	0.7019
u126-pd4-pt120-a10113-im50-rf0-vr0-tolp-traym	1.016	1.203	126	0.50	0.0	574.5	1.400	0.7657
u126-pd4-pt120-a10113-im25-rf0-vr0-tolp-traym	1.016	1.203	126	0.25	0.0	574.5	1.400	0.8069
u126-pd4-pt120-a10113-im10-rf0-vr0-tolp-traym	**1.016**	**1.203**	**126**	**0.10**	**0.0**	**574.5**	**1.400**	**0.8095**
u126-pd4-pt120-a10113-im1-rf0-vr0-tolp-traym	1.016	1.203	126	0.01	0.0	574.5	1.400	0.7802
u126-pd4-pt120-a10113-im5-rf0-vr0-tolp-traym	1.016	1.203	126	0.05	0.0	574.5	1.400	0.7964
u126-pd4e1-pt120-a13134-im10-rf0-vr0-tolp-traym	**1.016**	**1.203**	**126**	**0.10**	**0.0**	**574.5**	**1.400**	**0.5547[5]**

1. 100% water replaces vermiculite volume
2. Nominal 50. %wt water. Actual is nominal*100/(∑component wt% (table 2) = 50.*100/(140-16+50) = 28.7 wt%
3. Nominal 25. %wt water. Actual is 25*100/148 = 18.9 wt%
4. Nominal 6.0 %wt water. Actual is 6*100/130 = 4.6 wt% 5. 1% U-235 13x13x4 array

Table 6. NCT Homogenized Fuel Model Array 10x11x3 Results

Run ID	Pellet OD (cm)	Pitch (cm)	U (kg)	Interspersed Water (vol fraction)	Vermiculite Water (%wt)	Mixture Height (in)	V_m/V_f	k_s ($k_{eff}+2\sigma$)
u120-pd5-pt164-a10113-im10pk0-vr0-tolp-p2-ps	**1.270**	**1.642**	**120**	**0.10**	**0.0**	**20.97**	**1.127**	**0.8133**
tru120-pd5-pt176-a10113-im10pk0-vr0-tolp-p2-ps	1.270	1.764	120	0.10	0.0	20.97	1.127	0.8145
u100-pd5-pt173-a10113-im10pk0-vr0-tolp-p2-ps	1.270	1.726	100	0.10	0.0	19.33	1.353	0.8056
tru100-pd5-pt185-a10113-im10pk0-vr0-tolp-p2-ps	1.270	1.855	100	0.10	0.0	19.33	1.353	0.8065
u90-pd5-pt178-a10113-im10pk0-vr0-tolp-p2-ps	1.270	1.781	90	0.10	0.0	18.50	1.503	0.8039
tru90-pd5-pt191-a10113-im10pk0-vr0-tolp-p2-ps	1.270	1.914	90	0.10	0.0	18.50	1.503	0.8029
u80-pd5-pt185-a10113-im10pk0-vr0-tolp-p2-ps	1.270	1.846	80	0.10	0.0	17.68	1.691	0.7951
tru80-pd5-pt198-a10113-im10pk0-vr0-tolp-p2-ps	1.270	1.984	80	0.10	0.0	17.68	1.691	0.7982
u120-pd45-pt148-a10113-im10pk0-vr0-tolp-p2-ps	1.143	1.478	120	0.10	0.0	20.97	1.127	0.8115
u120-pd4-pt131-a10113-im10pk0-vr0-tolp-p2-ps	1.016	1.313	120	0.10	0.0	20.97	1.127	0.8101
u120-pd35-pt115-a10113-im10pk0-vr0-tolp-p2-ps	0.889	1.149	120	0.10	0.0	20.97	1.127	0.8077
u120-pd28-pt092-a10113-im10pk0-vr0-tolp-p2-ps	0.711	0.919	120	0.10	0.0	20.97	1.127	0.8047
u120-pd5-pt164-a10113-im0-vr3-ps (nominal)	1.270	1.642	120	0.00	3.0[1]	21.90	1.127	0.7804
u120-pd5-pt164-a10113-im0-vr3-tol-ps (-tolerance)	1.270	1.642	120	0.00	3.0	22.82	1.127	0.7833
u120-pd5-pt164-a10113-im0-vr3-tolp-ps (+tolerance)	1.270	1.642	120	0.00	3.0	20.97	1.127	0.7840

1. Nominal wt% water. Actual is 3.0*100/127 = 2.4 wt%

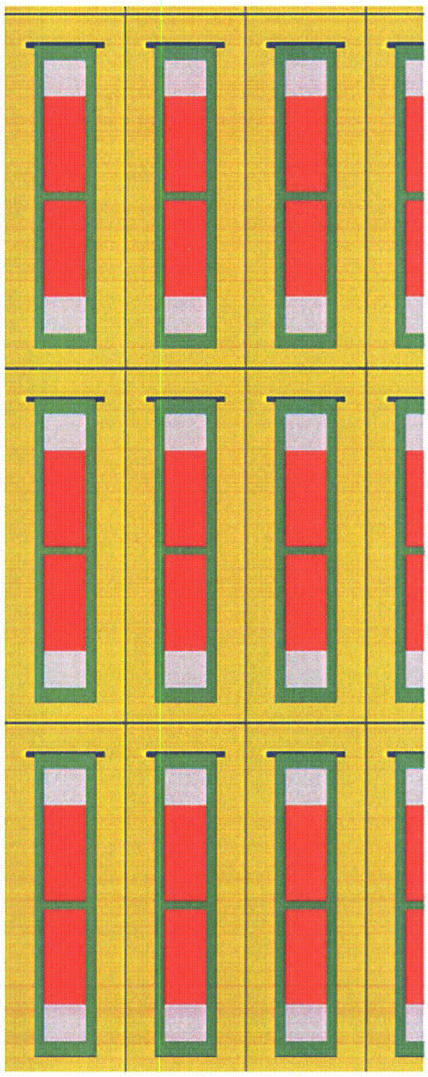


Figure 7. ANF-250 NCT Model, 10x11x3 Array, Adjacent Fuel Mixtures

7.0 PACKAGE ARRAYS UNDER HYPOTHETICAL ACCIDENT CONDITIONS

7.1 Configuration

In the HAC array analysis, the suitcases are fully flooded and are modeled with maximum tolerance dimensions. The outer container is assumed to have its diameter and length reduced by 2" each as a result of the accident conditions [1]. Each cylindrical package is enclosed in a cuboid containing water and the packages are placed in a closely packed square lattice array. The array is closely reflected all around with 12" (30.48 cm) of full density water. Interspersed water is assumed to fill the inner container, (see Figure 4). As in the HAC single package analysis, Section 5.3, a homogeneous fuel/moderator model is utilized with the homogenized fuel mixture filling the entire suitcase interior volume.

Since the %wt of hydrogen is almost 45% more in water than in polystyrene (11.19% vs 7.74%), water is a more effective moderator than PS. Therefore, in this HAC analysis, it is assumed that the PS trays are gone (melted, vaporized, etc.) and that their volume is replaced by water.

As in the NCT evaluation, runs were performed to determine the sensitivity of the array reactivity to the interspersed water and the water content of the vermiculite. Initial runs were made using an 8x8x2 array, with 70 kg U per package and a pellet OD of 0.28". The results of these three runs are shown in Table 7.

In the package model for the first three cases, the suitcases were located in the axial center of the inner vessel. A more reactive configuration for the two tier array would be to move the suitcases closer together (axially). Note, there is not much room for lateral movement of the suitcases, nor would it have much effect on the array reactivity because as the suitcase moves closer to one adjacent package, it moves away from another adjacent package. Therefore, the model was altered to have the suitcases located at the top of the inner vessel, for the bottom array layer, and for the top array layer, the suitcases are modeled at the bottom of the inner vessel. Figure 8 shows this configuration. The first case (hau70-pd28-pt129-a882-im1void-vr6-tolp-sp) with this model was a repeat of the first case in Table 7 to determine the reactivity change due to the relocated suitcases. As seen in Table 7, an increase occurred, k_s increased from 0.9306 to 0.9349. Additional cases were run using this model (non-centered suitcase) with 80 kg U and variations of interspersed water and vermiculite water content. The results for these cases (case ID suffix-sp) are also shown in Table 7.

The maximum reactivity case (hau80-pd28-pt121-a882-im6pk1-vr3-tolp-sp) occurred with interspersed water density (6%), water between packages (1%), and vermiculite water content (3%). However, k_s exceeds the USL, thus, the array size must be reduced. Additional, runs were performed with different uranium masses, and the moderation combination found for the 8x8x2 array; interspersed water density (6%), water between packages (1%), and vermiculite water content (3%), to find the maximum reactivity for 7x8x2 array. The results are shown in Table 8.

This table shows the reactivity peaking around 80 kg U. Additional cases were evaluated for different pellet ODs using 80 kg and 90 kg U. Results from these evaluations are also shown in Table 8.

As in the NCT evaluations, a triangular lattice pitch in place of the square lattice pitch evaluation was performed and the results are also shown in Table 8 (case ID prefix htru-...) directly below the comparable run with a square lattice. As in the NCT array evaluation, the results are basically the same for the triangular lattice and square lattice cases.

To assure the optimum moderation for the HAC array was identified, additional runs were performed for the 80 kg and 90 kg uranium cases. The vermiculite water content was reduced to 0, and the interspersed water in the package was increased to 10% density. With this combination and a void between the packages, the maximum reactivity for the HAC array was determined to be 0.9338 (hau80-pd28-pt121-a782-im10void-vr0-tolp-sp). The results for these additiona runs are also shown in Table 8.

Two additional runs were made using 80 kg U with the homogenized fuel water mixture at a reduced height in the suitcases. The remaining height/volume in the suitcase was filled with full density water. The reactivity of these cases was less than the maximum calculated giving evidence that modeling the flooding of the suitcase as a full height fuel mixture is conservative.

A HAC array evaluation was performed for 1.0 wt% U-235 fuel pellets in a 11x12x2 array of packages. The conditions were the same as the bounding HAC array case for 5.0 wt% U-235 fuel. The results are shown in Table 8.

7.2 Results

Results for the HAC array evaluation are summarized in Tables 7 and 8. The most reactive cases are in bold. In accordance with 10CFR71.59, the evaluated array for 5.0 wt% fuel produces a value of N = 112/2 = 56. This in turn produces a CSI of 50/56 = 0.9 for HAC. For the 1 wt% fuel, the evaluated array produces a value of N = 264/2 = 132 which gives a CSI of 0.4.

Table 7. HAC Array - Water Variations Results

Run ID	Array	Pellet OD (cm)	Pitch (cm)	U (kg)	Interspersed Water (vol fraction)	Vermiculite Water (%wt)	Water between packages (vol frac)	V_m/V_f	k_s ($k_{eff}+2\sigma$)
hau70-pd28-pt129-a882-im1void-vr6-tolp	8x8x2	0.700	1.294	70	0.01	6.0[1]	0.0	3.349	0.9306
hau70-pd28-pt129-a882-im2void-vr6-tolp	8x8x2	0.700	1.294	70	0.02	6.0	0.0	3.349	0.9321
hau70-pd28-pt129-a882-im3void-vr6-tolp	8x8x2	0.700	1.294	70	0.03	6.0	0.0	3.349	0.9324
hau70-pd28-pt129-a882-im1void-vr6-tolp-sp	8x8x2	0.700	1.294	70	0.01	6.0	0.00	3.349	0.9349
hau80-pd28-pt121-a882-im2void-vr6-tolp-sp	8x8x2	0.700	1.210	80	0.02	6.0	0.00	2.805	0.9395
hau80-pd28-pt121-a882-im2pk1-vr6-tolp-sp	8x8x2	0.700	1.210	80	0.02	6.0	0.01	2.805	0.9397
hau80-pd28-pt121-a882-im3pk2-vr6-tolp-sp	8x8x2	0.700	1.210	80	0.03	6.0	0.02	2.805	0.9412
hau80-pd28-pt121-a882-im3pk1-vr6-tolp-sp	8x8x2	0.700	1.210	80	0.03	6.0	0.01	2.805	0.9417
hau80-pd28-pt121-a882-im4pk1-vr6-tolp-sp	8x8x2	0.700	1.210	80	0.04	6.0	0.01	2.805	0.9403
hau80-pd28-pt121-a882-im6pk1-vr6-tolp-sp	8x8x2	0.700	1.210	80	0.06	6.0	0.01	2.805	0.9419
hau80-pd28-pt121-a882-im6pk1-vr3-tolp-sp	**8x8x2**	**0.700**	**1.210**	**80**	**0.06**	**3.0[2]**	**0.01**	**2.805**	**0.9436**
hau80-pd28-pt121-a882-im6pk1-vr10-tolp-sp	8x8x2	0.700	1.210	80	0.06	10.0[3]	0.01	2.805	0.9391
hau80-pd28-pt121-a882-im10pk1-vr0-tolp-sp	8x8x2	0.700	1.210	80	0.10	0.0	0.01	2.805	0.9431
hau80-pd28-pt121-a882-im15pk1-vr0-tolp-sp	8x8x2	0.700	1.210	80	0.15	0.0	0.01	2.805	0.9390
hau80-pd28-pt121-a882-im10void-vr0-tolp-sp	8x8x2	0.700	1.210	80	0.10	0.0	0.0	2.805	0.9426

1. Nominal %wt water. Actual is 6*100/130 = 4.6 %wt
2. Nominal %wt water. Actual is 3*100/127 = 2.4 %wt
3. Nominal %wt water. Actual is 10*100/134 = 7.5 %wt

Table 8. HAC Array Results

Run ID	Array	Pellet OD (cm)	Pitch (cm)	U (kg)	Interspersed Water (vol fraction)	Vermiculite Water (%wt)	Water between packages (vol frac)	V_m/V_f	k_s (k_{eff} +2σ)
hau70-pd28-pt129-a782-im6pk1-vr3-tolp-sp	7x8x2	0.700	1.294	70	0.06	3.0[1]	0.01	3.349	0.9252
hau80-pd28-pt121-a782-im6pk1-vr3-tolp-sp	7x8x2	0.700	1.210	80	0.06	3.0	0.01	2.805	0.9319
htru80-pd28-pt130-a782-im6pk1-vr3-tolp-sp	7x8x2	0.700	1.300	80	0.06	3.0	0.01	2.805	0.9305[2]
hau90-pd28-pt114-a782-im6pk1-vr3-tolp-sp	7x8x2	0.700	1.141	90	0.06	3.0	0.01	2.382	0.9305
htru90-pd28-pt123-a782-im6pk1-vr3-tolp-sp	7x8x2	0.700	1.226	90	0.06	3.0	0.01	2.382	0.9309[2]
hau100-pd28-pt108-a782-im6pk1-vr3-tolp-sp	7x8x2	0.700	1.082	100	0.06	3.0	0.01	2.044	0.9240
hau120-pd28-pt099-a782-im6pk1-vr3-tolp-sp	7x8x2	0.700	0.988	120	0.06	3.0	0.01	1.537	0.9046
hau80-pd35-pt154-a782-im6pk1-vr3-tolp-sp	7x8x2	0.889	1.537	80	0.06	3.0	0.01	2.805	0.9286
hau90-pd35-pt145-a782-im6pk1-vr3-tolp-sp	7x8x2	0.889	1.449	90	0.06	3.0	0.01	2.382	0.9276
hau80-pd4-pt176-a782-im6pk1-vr3-tolp-sp	7x8x2	1.016	1.756	80	0.06	3.0	0.01	2.805	0.9253
hau90-pd4-pt165-a782-im6pk1-vr3-tolp-sp	7x8x2	1.016	1.656	90	0.06	3.0	0.01	2.382	0.9281
hau80-pd28-pt121-a782-im10pk1-vr0-tolp-sp	7x8x2	0.700	1.210	80	0.10	0.0	0.01	2.805	0.9312
hau80-pd28-pt121-a782-im10void-vr0-tolp-sp	**7x8x2**	**0.700**	**1.210**	**80**	**0.10**	**0.0**	**0.0**	**2.805**	**0.9338**
hau90-pd28-pt114-a782-im10void-vr0-tolp-sp	7x8x2	0.700	1.141	90	0.10	0.0	0.0	2.382	0.9321
hau80-pd28-pt116-a782-im10void-vr0-tolp-sp	7x8x2	0.700	1.161	80	0.10	0.0	0.0	2.501	0.9008[3]
hau80-pd28-pt108-a782-im10void-vr0-tolp-sp	7x8x2	0.700	1.082	80	0.10	0.0	0.0	2.044	0.8359[4]
hau120-pd28e1-pt099-a11122-im10void-vr0-tolp-sp	**11x12x2**	**0.700**	**0.988**	**120**	**0.10**	**0.0**	**0.0**	**1.537**	**0.6062[5]**
hau100-pd28e1-pt108-a11122-im10void-vr0-tolp-sp	11x12x2	0.700	1.082	100	0.10	0.0	0.0	2.044	0.5970[5]
hau90-pd28e1-pt114-a11122-im10void-vr3-tolp-sp	11x12x2	0.700	1.141	90	0.10	0.0	0.0	2.382	0.5873[5]

1. Nominal %wt water. Actual is 3*100/127 = 2.4 %wt
2. Triangular lattice cell
3. Partial height fuel mixture - 23.00 inches
4. Partial height fuel mixture – 20.00 inches
5. 1% U-235 enriched fuel

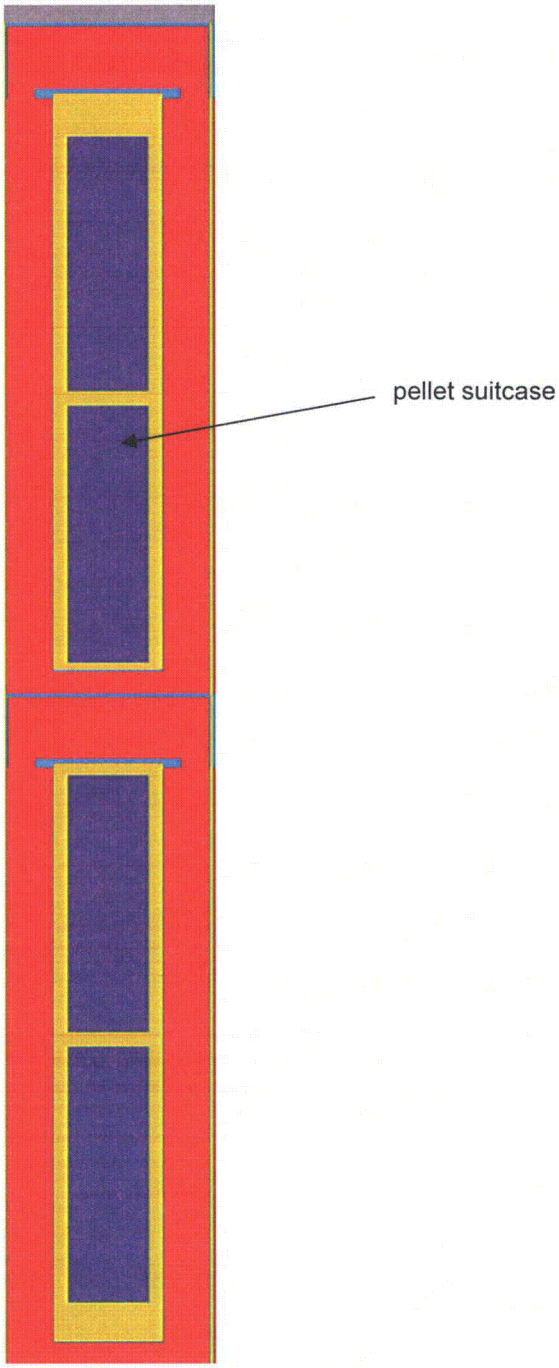


Figure 8. ANF-250 HAC Model, Non-Centered Pellet Suitcases

8.0 CONCLUSION

For 5.0 wt% enriched fuel pellets, the HAC is the limiting condition for criticality. The maximum calculated reactivity (k_s = 0.9338) is for the HAC 8x7x2 array of ANF-250 packages and is less than the USL value of 0.9406. The CSI for the transport is 0.9, minimum. Each package is limited to 120 kg of Uranium and 6.0 kg of U-235. The maximum number of ANF-250 packages that may be loaded in a single exclusive use transport is determined to be 100/0.9 = 111.

For 1.0 wt% enriched pellets, the HAC is the limiting condition for criticality. The maximum calculated reactivity (k_s = 0.6062) is for the HAC 11x12x2 array and is less than the USL value of 0.937. The CSI for transport is 0.4 minimum. Each package is limited to 120 kg of Uranium and 1.2 kg of U-235. The maximum number of ANF-250 packages that may be loaded in a single exclusive use transport is determined to be 100/0.4 = 250.

9.0 BENCHMARK EVALUATIONS

A separate calculation was performed for the SCALE6 computer program benchmark analysis [5].

The ORNL USLSTATS code [6] is used to establish a USL for the analysis. USLSTATS provides a simple means of evaluating and combining the statistical error of the calculation, code biases, and benchmark uncertainties. The USLSTATS calculation uses the combined uncertainties and data to provide a linear trend and an overall uncertainty. Computed multiplication factors, k_{eff}, for the package are deemed to be adequately subcritical if the computed value of k_s is less than or equal to the USL as follows:

$$k_s = k_{eff} + 2\sigma \leq USL$$

The USL includes the combined effects of code bias, uncertainty in the computational evaluation of the benchmark experiments, and an administrative margin. This methodology has accepted precedence in establishing criticality safety limits for transportation packages complying with 10 CFR 71.

9.1 Bias Determination

The USL is calculated by application of the USLSTATS computer program [6]. USLSTATS receives as input the k_{eff} as calculated by SCALE6 and a trending parameter. Three trending parameters have been selected: Energy of the Average neutron Lethargy causing Fission (EALF), ratio of the number of the hydrogen to U-235 number densities (H/X), and U-235 enrichment.

The EALF of the ANF-250 HAC criticality models falls within the range of the benchmark experiments, with a typical range between 0.1 and 0.3 eV. However, the EALF of the ANF-250 NCT criticality models is outside the range of the benchmark experiments, with typical

values in excess of 1 eV. Such behavior is expected, because the benchmark experiments are thermal, while the under-moderated NCT cases have an intermediate to fast spectrum. Because the reactivity of the NCT cases is relatively low (<0.82) fast uranium benchmarks are not developed.

The H/U-235 of most reactive cases for the ANF-250 HAC criticality models falls within the range of the benchmark experiments, with a value of approximately 150. The H/U-235 of the ANF-250 NCT criticality models lie in the range from approximately 40 to 100. The maximum reactivity NCT cases all fall outside the acceptable range. For the ANF-250 NCT criticality models, the EALF and H/U-235 parameters are not applicable because the fuel is not well moderated.

The minimum USLs generated for each of the trending parameters [5] are provided in Table 9, in addition to the range of applicability of the benchmarks. The lowest USL value is obtained for the EALF trending parameter for HAC with a USL = 0.9406. Therefore, this minimum USL is utilized in the analysis for the 5.0 wt% enriched fuel. For the 1.0 wt% enriched fuel, the enrichment USL is limiting at an extrapolated value of approximately 0.937.

Table 9. USL Results

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	

10.0 APPENDIX

10.1 References

1 EHS&L Document No. E1702-002, Version 1.1, "Transportation – Container Safety Analysis, Safety Analysis Report Model ANF-250."

2 SCALE 6: 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

3 Siemens Power Corp., Drawing No. EMF-304,306, Rev 8, "Pellet Shipping Suitcase, R-8."

4 Siemens Power Corp., Drawing No. EMF306,175, Rev 6, "Shipping Container Model ANF-250, R-16."

5 TN Calculation ANF250-0600, Rev 0, "USL Evaluation for Low Enriched UO_2 Powder and Pellet".

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

7 AREVA NP., Drawing No. 9099864 Rev 0, "K Box Pellet Shipping Tray".

8 AREVA NP., Drawing No. EMF306,176, Rev 6, "Shipping Container Inserts".

10.2 Sample Input File

Filename: u126-pd4-pt120-s-im100-rf100-vr100-tolp-traym.inp

```
=csas5  parm=nitawl
'  parm=chk
ANF-250 NCT. single 0.40" pellets vw/vf=1.072 explicit model max H
238GROUPNDF5
read comp
uo2  1  1.0 293  92235 5.0   92238 95.0  end
'MIX=2
'  CARBON STEEL
carbonsteel     2  1.0  end
'MIX= 3
'  SS304
ss304   3 1.0   end
' MIX= 4
'   100% WATER in package
h2o  4  1.00    end
'  END MIXT
' This case also contains  100% water in the void fractions of the vermic.
```

```
' vermiculite composition from English question response Table 4 max
' arbm-sio2  0.080469 2 0 1 0 14000 1 8016 2 5 0.46 end
' arbm-al2o3 0.080469 2 0 1 0 13027 2 8016 3 5 0.16 end
' arbm-mgo   0.080469 2 0 1 0 12000 1 8016 1 5 0.35 end
' arbm-cao   0.080469 2 0 1 0 20000 1 8016 1 5 0.05 end
' arbm-k2o   0.080469 2 0 1 0 19000 2 8016 1 5 0.06 end
' arbm-fe2o3 0.080469 2 0 1 0 26000 2 8016 3 5 0.13 end
' arbm-tio2  0.080469 2 0 1 0 22000 1 8016 2 5 0.03 end
' h2o  5 DEN=0.080469 0.50    end
  h2o  5  1.00  end
' moderator for unit cell use polystyrene
arbm-polystyr  1.06 2 0 1 0 1001 8 6012 8  6 1.3672  end
' reflector water
h2o     7 1.0  end
end comp
'  574.5 g H = 7.42 kg PS @ 20 C = 7.00L total in suitcases
'  pellet OD=.40" = 1.016cm effective pitch=1.2026cm
read celldata
latticecell squa  pitch=1.2026  6  fueld=1.016  1    end
end celldata
READ PARAM RUN=yes PLT=no  GEN=805 NPG=1000 NSK=5 END PARAM
READ GEOMETRY
UNIT  1
' fuel pellet/rod 0.40" OD and polystyrene cell
' pitch 0.469" (in pellet tray) x 0.478" (between tray)
cylinder  1  1  0.5080  59.690  0.000
cuboid  6  1  2p0.5956  2p0.6071  59.690  0.000
UNIT  2
UNIT  11
' + tol 7.88" WIDE X 4.88" TALL X 25.00" LONG FUEL REGION IN SUITCASE
'CUBOID  500 1  2P10.0076 2P6.1976 53.2562 0.000
'  Array of 9 pellet trays loaded with pellets (assumed to be 15 rods)
Array  4  -8.934  -5.4639  0.000
CUBOID   0  1  2P10.0076 2P6.1976 63.5000 0.000
'  ADD 0.0598" SS WALL EXCEPT AT -Y
REPL  3 1 3R0.1519 0.0 2R0.1519 1
'  ADD MODERATION TO BASE DIMS (9.375" x 26.5")
CUBOID  4 1 2P11.9062 6.3495 -6.1976 65.4050  -1.9050
'  ADD STEEL FLANGE (12 GAGE) &
CUBOID  3 1 2P11.9062 6.3495 -6.4633 65.4050  -1.9050
UNIT 12
COM=" TWO EDGE-EDGE SUITCASES IN INNER CONTAINER  "
ARRAY 1 -11.9062 -6.4633 -67.310
' INSIDE LENGTH OF INNER CONTAINER = 56.5" (min tol)"
' 0.4375" (min tol) IS IN THE UNIT WITH THE FLANGE
' LENGTH OF TWO SUITCASES = 53"
' CENTER THE SUITCASES IN THE 56.5" REGION (ID=11.25" min tol)
CYLI  4 1 14.2875 70.0088 -72.39
' ADD 0.049" (min tol) CAR STL DRUM WALL & BOTTOM (1/8")
CYLI  2 1 14.412 70.0088 -72.7075
'INTERSPERSED MOD TO 22.5" ID, & 4.125"
' FOR normal  CONDITIONS, USE 22.25" min tol ID also add 4.125 at -Z
CYLI  5 1 28.2575 70.0088 -83.1850
' Add 0.049" (min tol) carbon stl drum wall & bottom (0.05")
CYLI  2 1 28.3820 70.0088 -83.3120
' ENCLOSE IN CUBOID
CUBO  7 1 4P28.3820 70.0088 -83.3120
UNIT 13
```

```
COM=" FLANGE & LID OF INNER CONTAINER   "
' INTERSPERSED MODERATION IN INNER CONTAINER (min tol for flange-lid)
CYLI  4 1 14.2875 0.0 -1.1113
'  FLANGE OD=15.5", LID OD=14.75", USE 14.625" FOR BOTH (min tol)
CYLI  2 1 18.5738 2P1.1113
' INTERSPERSED MOD TO 22.25" min tol ID, ALSO ADD 6.125" AT +Z
' FOR undamaged CONDITIONS, USE 22.5" ID & 6.125"
CYLI  5 1 28.2575 14.4462 -1.1113
' ADD 0.049" (min tol) CAR STL WALL & LID (0.3125" min tol)
CYLI  2 1 28.3820 15.2399 -1.1113
'  ENCLOSE IN CUBOID
CUBO  7 1 4P28.3820 15.2399 -1.1113
GLOBAL
UNIT 14
COM="  COMPLETE ANF-250 PACKAGE   "
ARRAY 2 3R0.0
GLOBAL
' UNIT 15
' ARRAY 3 3R0.0
END GEOMETRY
READ ARRAY
' stack two pellet suitcases in z direction
ARA=1 NUX=1 NUY=1 NUZ=2
FILL F11 END FILL
' form ANF-250 container
ARA=2
NUX=1 NUY=1 NUZ=2
FILL 12 13 END FILL
' form array of containers
' ARA=3 NUX=10 NUY=11 NUZ=3
' FILL F14 END FILL
' array of pellet(rod) trays
ARA=4  nux=15 nuy=9  nuz=1
fill f1  end fill
END ARRAY
READ BOUNDS
ALL=WATER
END BOUNDS
READ PLOT
TTL= 'package cross section'
XUL=0.  YUL=60.  ZUL=60.  XLR=60.  YLR=0. ZLR=60.
UAX=1  VDN=-1
NAX=1000 LPI=10.0 END
SCR=YES
TTL= 'array Longitudinal View'
XUL=0.  YUL=30.  ZUL=180.  XLR=60.  YLR=30. ZLR=0.
UAX=1  WDN=-1
NAX=1000 LPI=10.0 END
SCR=YES
END PLOT
END DATA
END
```

Filename: hau80-pd28-pt121-a782-im10void-vr0-tolp-sp.inp

```
=csas5  parm=nitawl
'  parm=chk
ANF-250 accident cond. 7x8x2 array 0.28" pellets vw/vf=2.805 split suitcases
238GROUPNDF5
read comp
uo2  1  1.0 293  92235 5.0   92238 95.0  end
'MIX=2
'  CARBON STEEL
carbonsteel     2  1.0  end
'MIX= 3
'  SS304
ss304   3 1.0   end
' MIX= 4
'   0% WATER AROUND PACKAGE
h2o    4 0.000001    end
'  END MIXT
' This case also contains  0% water in the void fractions of the vermic.
' vermiculite composition from English question response Table 4 max
arbm-sio2  0.080469 2 0 1 0 14000 1 8016 2 5 0.46 end
arbm-al2o3 0.080469 2 0 1 0 13027 2 8016 3 5 0.16 end
arbm-mgo   0.080469 2 0 1 0 12000 1 8016 1 5 0.35 end
arbm-cao   0.080469 2 0 1 0 20000 1 8016 1 5 0.05 end
arbm-k2o   0.080469 2 0 1 0 19000 2 8016 1 5 0.06 end
arbm-fe2o3 0.080469 2 0 1 0 26000 2 8016 3 5 0.13 end
arbm-tio2  0.080469 2 0 1 0 22000 1 8016 2 5 0.03 end
' h2o  5 DEN=0.080469 0.03    end
' moderator for unit cell use water
h2o    6 1.0  end
' water inside package
h2o    7 0.10   end
end comp
'   2595 g H = 23.19 kg h2o @ 20 C = 23.23L total in suitcases
'  pellet 0D=0.28" = 0.70cm pitch=1.2101cm  80kg UO2
read celldata
latticecell squa  pitch=1.2101  6  fueld=0.700  1  cellmix=500  end
end celldata
READ PARAM RUN=yes PLT=no  GEN=805 NPG=1000 NSK=5 END PARAM
READ GEOMETRY
UNIT  1
' + tol 7.88" WIDE X 4.88" TALL X 25.00" LONG FUEL REGION IN SUITCASE
CUBOID  500 1  2P10.0076 2P6.1976 2P31.75
'  ADD 0.0598" SS WALL EXCEPT AT -Y
REPL  3 1 3R0.1519 0.0 2R0.1519 1
'  ADD MODERATION TO BASE DIMS (9.375" x 26.5")
CUBOID  7 1 2P11.9062 6.3495 -6.1976 2P33.655
'  ADD STEEL FLANGE (12 GAGE) &
CUBOID  3 1 2P11.9062 6.3495 -6.4633 2P33.655
UNIT 2
COM=" TWO EDGE-EDGE SUITCASES IN INNER CONTAINER on the bottom  "
ARRAY 1 -11.9062 -6.4633 -72.39
' INSIDE LENGTH OF INNER CONTAINER = 56.5" (min tol)"
' 0.4375" (min tol) IS IN THE UNIT WITH THE FLANGE
' LENGTH OF TWO SUITCASES = 53"
```

```
'  SUITCASES IN THE Bottom of 56.5" REGION (ID=11.25" min tol)
CYLI  7 1 14.2875 70.0088 -72.39
' ADD 0.049" (min tol) CAR STL DRUM WALL & BOTTOM (1/8")
CYLI  2 1 14.412 70.0088 -72.7075
'INTERSPERSED MOD TO 22.5" ID, & 4.125"
' FOR normal  CONDITIONS, USE 22.25" min tol ID also add 4.125" at -Z
' For accident conditions, use 20.25" min tol ID also add 2.125" at -Z
CYLI  5 1 25.7175 70.0088 -78.105
' Add 0.049" (min tol) carbon stl drum wall & bottom (0.05")
CYLI  2 1 25.8420 70.0088 -78.232
' ENCLOSE IN CUBOID
CUBO  4 1 4P25.8420 70.0088 -78.232
UNIT 12
COM=" TWO EDGE-EDGE SUITCASES IN INNER CONTAINER on the top  "
ARRAY 1 -11.9062 -6.4633 -64.6112
' INSIDE LENGTH OF INNER CONTAINER = 56.5" (min tol)"
' 0.4375" (min tol) IS IN THE UNIT WITH THE FLANGE
' LENGTH OF TWO SUITCASES = 53"
'  SUITCASES IN THE Bottom of 56.5" REGION (ID=11.25" min tol)
CYLI  7 1 14.2875 70.0088 -72.39
' ADD 0.049" (min tol) CAR STL DRUM WALL & BOTTOM (1/8")
CYLI  2 1 14.412 70.0088 -72.7075
'INTERSPERSED MOD TO 22.5" ID, & 4.125"
' FOR normal  CONDITIONS, USE 22.25" min tol ID also add 4.125" at -Z
' For accident conditions, use 20.25" min tol ID also add 2.125" at -Z
CYLI  5 1 25.7175 70.0088 -78.105
' Add 0.049" (min tol) carbon stl drum wall & bottom (0.05")
CYLI  2 1 25.8420 70.0088 -78.232
' ENCLOSE IN CUBOID
CUBO  4 1 4P25.8420 70.0088 -78.232
UNIT 3
COM=" FLANGE & LID OF INNER CONTAINER   "
' INTERSPERSED MODERATION IN INNER CONTAINER (min tol for flange-lid)
CYLI  7 1 14.2875 0.0 -1.1113
'  FLANGE OD=15.5", LID OD=14.75", USE 14.625" FOR BOTH (min tol)
CYLI  2 1 18.5738 2P1.1113
' INTERSPERSED MOD TO 22.25" min tol ID, ALSO ADD 6.125" AT +Z
' FOR undamaged CONDITIONS, USE 22.25" ID & 6.125"
' For damaged conditions, Use 20.25"  ID  & 6.125" (2" remove from Unit 2)
CYLI  5 1 25.7175 14.4462 -1.1113
' ADD 0.049" (min tol) CAR STL WALL & LID (0.3125 min tol)
CYLI  2 1 25.8420 15.2399 -1.1113
'  ENCLOSE IN CUBOID
CUBO  4 1 4P25.8420 15.2399 -1.1113
' GLOBAL
UNIT 4
COM="  COMPLETE ANF-250 PACKAGEsuitcases at bottom   "
ARRAY 2 3R0.0
UNIT 5
COM="  COMPLETE ANF-250 PACKAGE suitcases at top   "
ARRAY 4 3R0.0
GLOBAL
UNIT 6
ARRAY 3 3R0.0
' repl  7  2  6r3.0  10
END GEOMETRY
READ ARRAY
' stack two pellet suitcases in z direction
```

```
ARA=1 NUX=1 NUY=1 NUZ=2
FILL F1 END FILL
' form ANF-250 container suitcases at bottom
ARA=2
NUX=1 NUY=1 NUZ=2
FILL 2 3 END FILL
' form array of containers
ARA=3 NUX=7 NUY=8 NUZ=2
FILL 56R5  56R4 END FILL
'  form ANF-250 container suitcases at top
ARA=4
NUX=1 NUY=1 NUZ=2
FILL 12 3 END FILL
END ARRAY
READ BOUNDS
ALL=WATER
END BOUNDS
READ PLOT
TTL= 'array cross section'
XUL=0.  YUL=200.  ZUL=60.  XLR=200.  YLR=0. ZLR=60.
UAX=1  VDN=-1
NAX=1000 LPI=10.0 END
SCR=YES
TTL= 'array Longitudinal View'
XUL=0.  YUL=30.  ZUL=350.  XLR=200.  YLR=30. ZLR=0.
UAX=1  WDN=-1
NAX=1000 LPI=10.0 END
SCR=YES
END PLOT
END DATA
END
```

10.3 File Listing

Code: SCALE
Version: 6.0
Computer ID: TN-CBA-CALC-05

SCALE6 has been verified under the Transnuclear Implementing Procedures.

Spreadsheets:

```
12/10/2009          208,384 ANF250_pellet-scale6.xls
```

Input and Output Files:

NCT Discrete Model Single Package

```
12/04/2009      4,322 u62-pd28-pt104-s-im100-rf100-vr6-tolp-traym.inp
12/04/2009    467,140 u62-pd28-pt104-s-im100-rf100-vr6-tolp-traym.out
12/04/2009      4,319 u97-pd35-pt114-s-im100-rf100-vr6-tolp-tray.inp
12/04/2009    467,738 u97-pd35-pt114-s-im100-rf100-vr6-tolp-tray.out
12/04/2009      4,187 u126-pd4-pt120-s-im100-rf100-vr6-tolp-traym.inp
12/04/2009    466,351 u126-pd4-pt120-s-im100-rf100-vr6-tolp-traym.out
12/10/2009      4,187 u126-pd4-pt120-s-im100-rf100-vrmx-tolp-tray.inp
12/10/2009    467,318 u126-pd4-pt120-s-im100-rf100-vrmx-tolp-tray.out
12/04/2009      4,320 u97-pd35-pt114-s-im100-rf100-vr6-tolp-traym.inp
12/04/2009    466,928 u97-pd35-pt114-s-im100-rf100-vr6-tolp-traym.out
12/04/2009      4,187 u126-pd4-pt120-s-im100-rf100-vr18-tolp-traym.inp
12/04/2009    466,984 u126-pd4-pt120-s-im100-rf100-vr18-tolp-traym.out
12/04/2009      4,321 u62-pd28-pt104-s-im100-rf100-vr6-tolp-tray.inp
12/04/2009    468,015 u62-pd28-pt104-s-im100-rf100-vr6-tolp-tray.out
12/04/2009      4,185 u126-pd4-pt120-s-im90-rf100-vr6-tolp-traym.inp
12/04/2009    467,649 u126-pd4-pt120-s-im90-rf100-vr6-tolp-traym.out
12/04/2009      4,187 u126-pd4-pt120-s-im100-rf100-vr50-tolp-traym.i
12/04/2009    467,758 u126-pd4-pt120-s-im100-rf100-vr50-tolp-traym.o
12/04/2009      4,186 u126-pd4-pt120-s-im100-rf100-vr6-tolp-tray.inp
12/04/2009    469,378 u126-pd4-pt120-s-im100-rf100-vr6-tolp-tray.out
12/04/2009      4,185 u126-pd4-pt120-s-im70-rf100-vr6-tolp-traym.inp
12/04/2009    466,882 u126-pd4-pt120-s-im70-rf100-vr6-tolp-traym.out
12/10/2009      4,162 u126-pd4-pt120-s-im100-rf100-vrmn-tolp-tray.inp
12/10/2009    468,037 u126-pd4-pt120-s-im100-rf100-vrmn-tolp-tray.out
12/04/2009      4,185 u126-pd4-pt120-s-im50-rf100-vr6-tolp-traym.inp
12/04/2009    466,686 u126-pd4-pt120-s-im50-rf100-vr6-tolp-traym.out
12/04/2009      4,225 u126-pd4-pt120-s-im100-rf100-vr100-tolp-traym.inp
12/04/2009    452,806 u126-pd4-pt120-s-im100-rf100-vr100-tolp-traym.out
```

NCT Discrete Model Package Array

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12/04/2009      4,324 u126-pd4-pt120-a10113-im100-rf0-vr25-tolp-traym.inp
12/04/2009    469,418 u126-pd4-pt120-a10113-im100-rf0-vr25-tolp-traym.out
12/04/2009      4,324 u126-pd4-pt120-a10113-im50-rf0-vr0-tolp-traym.inp
12/04/2009    467,379 u126-pd4-pt120-a10113-im50-rf0-vr0-tolp-traym.out
12/04/2009      4,325 u126-pd4-pt120-a10113-im1-rf0-vr0-tolp-traym.inp
12/04/2009    467,905 u126-pd4-pt120-a10113-im1-rf0-vr0-tolp-traym.out
12/04/2009      4,324 u126-pd4-pt120-a10113-im100-rf0-vr50-tolp-traym.inp
```

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12/04/2009    469,078 u126-pd4-pt120-a10113-im100-rf0-vr50-tolp-traym.out
12/04/2009      4,323 u126-pd4-pt120-a10113-im100-rf0-vr6-tolp-traym.inp
12/04/2009    469,269 u126-pd4-pt120-a10113-im100-rf0-vr6-tolp-traym.out
12/04/2009      4,324 u126-pd4-pt120-a10113-im25-rf0-vr0-tolp-traym.inp
12/04/2009    467,488 u126-pd4-pt120-a10113-im25-rf0-vr0-tolp-traym.out
12/04/2009      4,324 u126-pd4-pt120-a10113-im10-rf0-vr0-tolp-traym.inp
12/04/2009    467,597 u126-pd4-pt120-a10113-im10-rf0-vr0-tolp-traym.out
12/04/2009      4,325 u126-pd4-pt120-a10113-im100-rf0-vr0-tolp-traym.inp
12/04/2009    467,520 u126-pd4-pt120-a10113-im100-rf0-vr0-tolp-traym.out
12/04/2009      4,325 u126-pd4-pt120-a10113-im5-rf0-vr0-tolp-traym.inp
12/04/2009    468,094 u126-pd4-pt120-a10113-im5-rf0-vr0-tolp-traym.out
12/04/2009      4,364 u126-pd4-pt120-a10113-im100-rf0-vr100-tolp-traym.inp
12/04/2009    456,267 u126-pd4-pt120-a10113-im100-rf0-vr100-tolp-traym.out
12/08/2009      4,349 u126-pd4e1-pt120-a13134-im10-rf0-vr0-tolp-traym.inp
12/08/2009    470,082 u126-pd4e1-pt120-a13134-im10-rf0-vr0-tolp-traym.out
```

NCT Homogenized Fuel Model Package Array

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12/04/2009      4,367 u120-pd45-pt148-a10113-im10pk0-vr0-tolp-p2-ps.inp
12/04/2009    772,317 u120-pd45-pt148-a10113-im10pk0-vr0-tolp-p2-ps.out
12/04/2009      4,366 u120-pd4-pt131-a10113-im10pk0-vr0-tolp-p2-ps.inp
12/04/2009    771,459 u120-pd4-pt131-a10113-im10pk0-vr0-tolp-p2-ps.out
12/04/2009      4,367 u120-pd35-pt115-a10113-im10pk0-vr0-tolp-p2-ps.inp
12/04/2009    770,336 u120-pd35-pt115-a10113-im10pk0-vr0-tolp-p2-ps.out
12/04/2009      4,350 u90-pd5-pt178-a10113-im10pk0-vr0-tolp-p2-ps.inp
12/04/2009    774,589 u90-pd5-pt178-a10113-im10pk0-vr0-tolp-p2-ps.out
12/04/2009      4,350 u80-pd5-pt185-a10113-im10pk0-vr0-tolp-p2-ps.inp
12/04/2009    773,684 u80-pd5-pt185-a10113-im10pk0-vr0-tolp-p2-ps.out
12/04/2009      3,840 u120-pd5-pt164-a10113-im0-vr3-tol-ps.inp
12/04/2009    512,272 u120-pd5-pt164-a10113-im0-vr3-tol-ps.out
12/04/2009      3,810 u120-pd5-pt164-a10113-im0-vr3-tolp-ps.inp
12/04/2009    771,114 u120-pd5-pt164-a10113-im0-vr3-tolp-ps.out
12/04/2009      3,810 u120-pd5-pt164-a10113-im0-vr3-ps.inp
12/04/2009    771,550 u120-pd5-pt164-a10113-im0-vr3-ps.out
12/04/2009      4,356 u120-pd5-pt164-a10113-im10pk0-vr0-tolp-p2-ps.inp
12/04/2009    774,099 u120-pd5-pt164-a10113-im10pk0-vr0-tolp-p2-ps.out
12/04/2009      4,351 u100-pd5-pt173-a10113-im10pk0-vr0-tolp-p2-ps.inp
12/04/2009    774,363 u100-pd5-pt173-a10113-im10pk0-vr0-tolp-p2-ps.out
12/04/2009      4,355 u120-pd28-pt092-a10113-im10pk0-vr0-tolp-p2-ps.inp
12/04/2009    769,029 u120-pd28-pt092-a10113-im10pk0-vr0-tolp-p2-ps.out
12/05/2009      4,343 tru80-pd5-pt198-a10113-im10pk0-vr0-tolp-p2-ps.inp
12/05/2009    773,645 tru80-pd5-pt198-a10113-im10pk0-vr0-tolp-p2-ps.out
12/05/2009      4,357 tru90-pd5-pt191a10113-im10pk0-vr0-tolp-p2-ps.inp
12/05/2009    773,386 tru90-pd5-pt191a10113-im10pk0-vr0-tolp-p2-ps.out
12/05/2009      4,358 tru100-pd5-pt185a10113-im10pk0-vr0-tolp-p2-ps.inp
12/05/2009    774,131 tru100-pd5-pt185a10113-im10pk0-vr0-tolp-p2-ps.out
12/05/2009      4,343 tru120-pd5-pt176-a10113-im10pk0-vr0-tolp-p2-ps.inp
12/05/2009    773,078 tru120-pd5-pt176-a10113-im10pk0-vr0-tolp-p2-ps.out
```

HAC Homogenized Fuel Model Single Package

```
12/04/2009        3,895 hau80-pd35-pt154-single-im100-vr100-tolp.inp
12/04/2009      754,531 hau80-pd35-pt154-single-im100-vr100-tolp.out
12/04/2009        3,895 hau80-pd45-pt197-single-im100-vr100-tolp.inp
12/04/2009      754,744 hau80-pd45-pt197-single-im100-vr100-tolp.out
12/04/2009        3,894 hau80-pd4-pt175-single-im100-vr100-tolp.inp
```

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12/04/2009     754,992 hau80-pd4-pt175-single-im100-vr100-tolp.out
12/04/2009       3,968 hau70-pd28-pt121-single-im100-vr100-tolp.inp
12/04/2009     754,560 hau70-pd28-pt121-single-im100-vr100-tolp.out
12/04/2009       3,893 hau60-pd28-pt140-single-im100-vr100-tolp.inp
12/05/2009     753,849 hau60-pd28-pt140-single-im100-vr100-tolp.out
12/04/2009       3,894 hau90-pd28-pt114-single-im100-vr100-tolp.inp
12/04/2009     753,570 hau90-pd28-pt114-single-im100-vr100-tolp.out
12/04/2009       3,894 hau80-pd28-pt121-single-im100-vr100-tolp.inp
12/04/2009     753,679 hau80-pd28-pt121-single-im100-vr100-tolp.out
2/04/2009        3,894 hau100-pd28-pt108-single-im100-vr100-tolp.inp
2/04/2009      753,072 hau100-pd28-pt108-single-im100-vr100-tolp.out
12/04/2009       3,895 hau70-pd28-pt129-single-im100-vr100-tolp.inp
12/04/2009     752,297 hau70-pd28-pt129-single-im100-vr100-tolp.out
2/04/2009        3,894 hau120-pd28-pt099-single-im100-vr100-tolp.inp
2/04/2009      751,936 hau120-pd28-pt099-single-im100-vr100-tolp.out
12/04/2009       3,968 hau70-pd28-pt125-single-im100-vr100-tolp.inp
12/04/2009     753,936 hau70-pd28-pt125-single-im100-vr100-tolp.out
12/04/2009       3,968 hau70-pd28-pt116-single-im100-vr100-tolp.inp
12/04/2009     754,422 hau70-pd28-pt116-single-im100-vr100-tolp.out
```

HAC Homogenized Fuel Model Package Array

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12/04/2009       4,910 hau80-pd35-pt154-a782-im6pk1-vr3-tolp-sp.inp
12/05/2009     775,358 hau80-pd35-pt154-a782-im6pk1-vr3-tolp-sp.out
12/04/2009       4,910 hau90-pd35-pt145-a782-im6pk1-vr3-tolp-sp.inp
12/05/2009     775,432 hau90-pd35-pt145-a782-im6pk1-vr3-tolp-sp.out
12/04/2009       4,912 hau90-pd4-pt165-a782-im6pk1-vr3-tolp-sp.inp
12/05/2009     776,247 hau90-pd4-pt165-a782-im6pk1-vr3-tolp-sp.out
12/04/2009       4,912 hau80-pd4-pt176-a782-im6pk1-vr3-tolp-sp.inp
12/05/2009     775,937 hau80-pd4-pt176-a782-im6pk1-vr3-tolp-sp.out
12/05/2009       4,915 hau80-pd28-pt121-a782-im10void-vr0-tolp-sp.inp
12/05/2009     773,024 hau80-pd28-pt121-a782-im10void-vr0-tolp-sp.out
12/04/2009       4,909 hau70-pd28-pt129-a782-im6pk1-vr3-tolp-sp.inp
12/05/2009     774,607 hau70-pd28-pt129-a782-im6pk1-vr3-tolp-sp.out
12/04/2009       4,909 hau80-pd28-pt121-a882-im6pk1-vr6-tolp-sp.inp
12/04/2009     774,297 hau80-pd28-pt121-a882-im6pk1-vr6-tolp-sp.out
12/04/2009       4,913 hau80-pd28-pt121-a882-im2void-vr6-tolp-sp.inp
11/22/2009     775,564 hau80-pd28-pt121-a882-im2void-vr6-tolp-sp.out
12/04/2009       3,868 hau70-pd28-pt129-a882-im1void-vr6-tolp.inp
12/04/2009     769,253 hau70-pd28-pt129-a882-im1void-vr6-tolp.out
12/04/2009       4,910 hau120-pd28-pt099-a782-im6pk1-vr3-tolp-sp.inp
12/05/2009     773,640 hau120-pd28-pt099-a782-im6pk1-vr3-tolp-sp.out
12/05/2009       4,915 hau90-pd28-pt114-a782-im10void-vr0-tolp-sp.inp
12/05/2009     773,202 hau90-pd28-pt114-a782-im10void-vr0-tolp-sp.out
12/04/2009       4,913 hau70-pd28-pt129-a882-im1void-vr6-tolp-sp.inp
12/04/2009     775,028 hau70-pd28-pt129-a882-im1void-vr6-tolp-sp.out
12/05/2009       5,096 hau80-pd28-pt108-a782-im10void-vr0-tolp-sp.inp
12/05/2009     777,232 hau80-pd28-pt108-a782-im10void-vr0-tolp-sp.out
12/04/2009       4,909 hau80-pd28-pt121-a882-im6pk1-vr3-tolp-sp.inp
12/04/2009     774,816 hau80-pd28-pt121-a882-im6pk1-vr3-tolp-sp.out
12/05/2009       4,911 hau80-pd28-pt121-a882-im15pk1-vr0-tolp-sp.inp
12/05/2009     773,024 hau80-pd28-pt121-a882-im15pk1-vr0-tolp-sp.out
12/05/2009       5,085 hau80-pd28-pt116-a782-im10void-vr0-tolp-sp.inp
12/05/2009     777,125 hau80-pd28-pt116-a782-im10void-vr0-tolp-sp.out
12/04/2009       4,909 hau80-pd28-pt121-a882-im2pk1-vr6-tolp-sp.inp
12/04/2009     774,644 hau80-pd28-pt121-a882-im2pk1-vr6-tolp-sp.out
12/04/2009       3,868 hau70-pd28-pt129-a882-im2void-vr6-tolp.inp
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12/04/2009     768,969 hau70-pd28-pt129-a882-im2void-vr6-tolp.out
12/04/2009       4,910 hau80-pd28-pt121-a882-im6pk1-vr10-tolp-sp.inp
12/04/2009     774,541 hau80-pd28-pt121-a882-im6pk1-vr10-tolp-sp.out
12/05/2009       4,915 hau80-pd28-pt121-a882-im10void-vr0-tolp-sp.inp
12/05/2009     773,373 hau80-pd28-pt121-a882-im10void-vr0-tolp-sp.out
12/04/2009       4,909 hau80-pd28-pt121-a882-im3pk1-vr6-tolp-sp.inp
12/04/2009     774,873 hau80-pd28-pt121-a882-im3pk1-vr6-tolp-sp.out
12/04/2009       4,909 hau90-pd28-pt114-a782-im6pk1-vr3-tolp-sp.inp
12/05/2009     774,836 hau90-pd28-pt114-a782-im6pk1-vr3-tolp-sp.out
12/05/2009       4,911 hau80-pd28-pt121-a882-im10pk1-vr0-tolp-sp.inp
12/05/2009     773,821 hau80-pd28-pt121-a882-im10pk1-vr0-tolp-sp.out
12/04/2009       4,909 hau80-pd28-pt121-a882-im4pk1-vr6-tolp-sp.inp
12/04/2009     774,916 hau80-pd28-pt121-a882-im4pk1-vr6-tolp-sp.out
12/04/2009       4,909 hau80-pd28-pt121-a782-im6pk1-vr3-tolp-sp.inp
12/05/2009     774,789 hau80-pd28-pt121-a782-im6pk1-vr3-tolp-sp.out
12/05/2009       4,911 hau80-pd28-pt121-a782-im10pk1-vr0-tolp-sp.inp
12/05/2009     772,856 hau80-pd28-pt121-a782-im10pk1-vr0-tolp-sp.out
12/04/2009       4,910 hau100-pd28-pt108-a782-im6pk1-vr3-tolp-sp.inp
12/05/2009     774,216 hau100-pd28-pt108-a782-im6pk1-vr3-tolp-sp.out
12/04/2009       3,925 hau70-pd28-pt129-a882-im3void-vr6-tolp.inp
12/04/2009     771,783 hau70-pd28-pt129-a882-im3void-vr6-tolp.out
12/04/2009       4,909 hau80-pd28-pt121-a882-im3pk2-vr6-tolp-sp.inp
12/04/2009     774,683 hau80-pd28-pt121-a882-im3pk2-vr6-tolp-sp.out
12/05/2009       4,906 htru90-pd28-pt123-a782-im6pk1-vr3-tolp-sp.inp
12/05/2009     774,325 htru90-pd28-pt123-a782-im6pk1-vr3-tolp-sp.out
12/05/2009       4,906 htru80-pd28-pt130-a782-im6pk1-vr3-tolp-sp.inp
12/05/2009     774,844 htru80-pd28-pt130-a782-im6pk1-vr3-tolp-sp.out
12/08/2009       4,944 hau90-pd28e1-pt114-a11122-im10void-vr0-tolp-sp.inp
12/08/2009     775,241 hau90-pd28e1-pt114-a11122-im10void-vr0-tolp-sp.out
12/08/2009       4,946 hau100-pd28e1-pt108-a11122-im10void-vr0-tolp-sp.inp
12/08/2009     775,705 hau100-pd28e1-pt108-a11122-im10void-vr0-tolp-sp.out
12/08/2009       4,948 hau120-pd28e1-pt099-a11122-im10void-vr0-tolp-sp.inp
12/08/2009     774,312 hau120-pd28e1-pt099-a11122-im10void-vr0-tolp-sp.out
```

Listing of Disk Numbering and Contents for Computer Files Associated with Enclosure 5

Disk No ZIP File Name (size)	Discipline	Folder in the ZIP File	Content	Number of Files
Disk 1 ANF-250-Files.zip (367,337 bytes)	Criticality	001-usl	• The input and output files of the USLSTATS runs for powder and pellet	14
	Criticality	002-pellet	• The CSAS5 input and output of the design basis configuration for pellet.	4
	Criticality	003-scrap	• The CSAS5 input and output of the design basis configuration for pellet scrap.	4
	Criticality	004-powder	• The CSAS5 input and output of the design basis configuration for powder.	4