71-9297

Westinghouse

Westinghouse Electric Company
Nuclear Fuel
Columbia Fuel Site
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USA

U. S. Nuclear Regulatory Commission
Attn: Mr. Stewart Brown
Package Certification Section
Office of Nuclear Material Safety and Safeguards
Washington, DC 20555

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Our ref: NMS-NRC-05-003
Your Ref:

Mr. Brown:

March 4, 2005

Subject: CERTIFICATE OF COMPLIANCE NO. 9297 FOR THE MODEL NO. TRAVELLER PACKAGE: COMMENTS ON PROPOSED COC WORDING AND SUBMISSION of REVISION 3 TO THE SAFETY ANALYSIS REPORT (SAR)

Reference: (1) NMS-NRC-05-002 dated February 16, 2005

Attached please find Westinghouse Electric Company's comments on the proposed wording for the Traveller Certificate of Compliance, and the submission of Revision 3 to the Safety Analysis Report (SAR). It was decided while performing a review of the draft CoC that Revision 3 was needed to correct one error, revise certain tables to make the SAR parameter tables consistent with those that will be published in the CoC, clarify the results of the rod container analysis, and clarify the maintenance requirements for the shock mounts.

An error was discovered during a final thorough review of the fuel assembly parameters for all fuel types in the SAR. Westinghouse Sweden noticed that the 16x16ATOM specified an incorrect number of fuel rods and non-fuel rods. The table specified 235 fuel rods and 21 non-fuel rods rather than the actual 236 fuel rods and 20 non-fuel rods. A review found that the 16x16ATOM model contained the same error. The model was corrected and calculations were re-run. Results show that the original premise is still valid, namely that the 16x16ATOM is bounded by the 17x17OFA in the range of interest.

In addition, the fuel assembly parameter tables in the SAR (tables 6-20, 6-21, 6-22, and 6-23) have been revised to be consistent with the respective tables in the draft CoC. The revised tables list dimensions as nominal, and are given in centimeters and inches to the third decimal place. The order of information presented is revised to reflect the order in the draft CoC tables. Finally, the guide tube outer dimension and thickness data for some fuel types are revised for completeness. No guide tube data was given in the fuel assembly parameter tables in Revision 0 of the SAR because guide tube dimensions have minimal effect on k_{eff}. Section 6.7.10 of the SAR discusses the effect of zirconium thickness reduction in the model. The guide tube data was added in Revision 2 as requested. See reference 1. However, a final review of the fuel parameter

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tables found that the guide tube data provided in Revision 2 for the 16x16ATOM, 17x17STD, and 18x18 ATOM was incomplete.

It was noticed that the model for the 17x17STD had 4 non-fuel rods position out of place. This model was corrected and calculations were re-run. Again, the results show that repositioning the non-fuel rods had essentially no effect on k_{eff}. The 17x17STD is bounded by the 17x17OFA in the range of interest.

The rod container section (Section 6.10.7) was revised to clarify the following:

- The array cases that were run for the pellet pitch/diameter sensitivity calculations were for infinite planar arrays along the x/y axes not three dimensional arrays.
- These infinite planar array cases assumed a void in the interstitial regions (outside fuel envelope). It was found that the individual package k_{eff} values were greater than the array cases with void in the interstitial regions.
- An interspersed moderation density study was performed to investigate the effect on k_{eff} of varying the water density of the interstitial regions. It was found that the highest k_{eff} value occurred when the interstitial regions were flooded with full density water, which effectively isolated the package. There is no optimum condition between zero density and full density water for the rod container. Essentially, the package array with full density moderation is an array of isolated packages and results for full density water were the same as individual package cases.
- The summary table for rod containers (Table 6-3) was therefore revised to indicate that the highest k_{eff} for a package array is equivalent to the k_{eff} of the individual package.
- A three dimensional infinite array case was run to confirm that there is no difference between it and the infinite planar array case. Hence, a CSI=0.0 is reasonable for the rod container.

Enclosed please find review comments on the draft CoC, including the modified fuel assembly parameter tables. Also please find the change pages that make up revision 3 to the SAR, including the revised list of effective pages. Please direct any questions to the me at (803) 647-3552.

Sincerely,
WESTINGHOUSE ELECTRIC COMPANY, LLC

Norman A. Kent

Norman A. Kent
Manager Transport Licensing and Regulatory Compliance
Nuclear Material Supply

Enclosure:
(1) Comments on draft Certificate of Compliance
(2) Rev 3 Change pages

Enclosure 1: Comments on draft Certificate of Compliance

General

- Recommend capitalizing the word Uranium wherever it appears.

Page 1 of 6

Section 5(a)(2) Description

- Change "piano type" to "piano-type".

Page 2 of 6

Section 5(a)(2) Description (Continued)

- Add the word "*thick*" to the last sentence of the first paragraph as noted here, "The pipes are secured with a 11.18 millimeter (mm /0.44 in.) *thick* ..."

- Dimensions for the Traveller STD and Traveller XL are difficult to read because of the "draft" watermark. However, the values are offered below.

Traveller STD		
Gross weight	2041 kg	4500 lb
Outer Dimensions		
Length	500 cm	197 in.
Width	68.6 cm	27.1 in.
Height	100 cm	39.3 in,
Traveller XL		
Gross weight	2313 kg	5100 lb
Outer Dimensions		
Length	574 cm	226 in.
Width	68.6 cm	27.1 in.
Height	100 cm	39.3 in,

Section 5(b)(1) Fuel Assembly (Continued)

Parameters for 14x14 Fuel Assemblies

- Converted mm to cm.
- Adjusted to 3 decimal places.
- Corrected values (metric) for GT thickness for 14x14 W-STD and 14x14 W-OFA. (These were incorrect to 4th decimal but were corrected to 3rd decimal.)
- Corrected values (metric and in.) for GT OD for 14x14 W-STD.
- Changed *Nominal Assembly Envelop* to *Nominal Assembly Envelope*

Parameters for 14x14 Fuel Assemblies

Fuel Assembly Description	14 X 14	14 X 14	14 X 14
Fuel Assembly Type	W-STD	W-OFA	CE-1/CE-2
No. Fuel Rods per Assembly	179	179	176
No. Non-Fuel Rods	17	17	20
Nominal Guide Tube Wall Thickness	0.043 cm (0.017 in.)	0.043 cm (0.017 in.)	0.097 cm (0.038 in.)
Nominal Guide Tube Outer Diameter	1.369 cm (0.539 in.)	1.336 cm (0.526 in.)	2.822 cm (1.111 in.)
Nominal Pellet Diameter	0.929 cm (0.366 in.)	0.875 cm (0.344 in.)	0.956/0.966 cm (0.376/0.381 in.)
Nominal Clad Outer Diameter	1.072 cm (0.422 in.)	1.016 cm (0.400 in.)	1.016 cm (0.440 in.)
Nominal Clad Thickness	0.062 cm (0.024 in.)	0.062 cm (0.024 in.)	0.071/0.066 cm (0.028/0.026 in.)
Clad Material	Zirconium alloy	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	19.70 cm (7.76 in.)	19.70 cm (7.76 in.)	20.60 cm (8.11 in.)
Nominal Lattice Pitch	1.412 cm (0.556 in.)	1.412 cm (0.556 in.)	1.473 cm (0.580 in.)

Parameters for 15x15 Fuel Assemblies

- Converted mm to cm.
- Adjusted to 3 decimal places.
- Changed *Nominal Assembly Envelop* to *Nominal Assembly Envelope*

Parameters for 15x15 Fuel Assemblies

Fuel Assembly Description	15 X 15	15 X 15
Fuel Assembly Type	STD/OFA	B&W
No. Fuel Rods per Assembly	205	208
No. Non-Fuel Rods	20	17
Nominal Guide Tube Wall Thickness	0.043/0.043 cm (0.017/0.017 in.)	0.043 cm (0.017 in.)
Nominal Guide Tube Outer Diameter	1.387/1.354 cm (0.546/0.533 in.)	1.354 cm (0.533 in.)
Nominal Pellet Diameter	0.929 cm (0.366 in.)	0.929 cm (0.366 in.)
Nominal Clad Outer Diameter	1.072 cm (0.422 in.)	1.072 cm (0.422 in.)
Nominal Clad Thickness	0.062 cm (0.024 in.)	0.062 cm (0.024 in.)
Clad Material	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	21.39 cm (8.42 in.)	21.66 cm (8.53 in.)
Nominal Lattice Pitch	1.430 cm (0.563 in.)	1.443 cm (0.568 in.)

Section 5(b)(1) Fuel Assembly (Continued)

Parameters for 16x16 Fuel Assemblies

- Moved *Nominal Guide Tube Wall Thickness* and *Nominal Guide Tube Outer Diameter* lines ahead of *Nominal Pellet Diameter* line to be consistent with other tables.
- Converted mm to cm.
- Adjusted to 3 decimal places.
- Changed *Nominal Assembly Envelop* to *Nominal Assembly Envelope.*
- Revised *No Fuel Rods per Assembly (235 becomes 236)* and *No. Non-Fuel Rods (21 becomes 20)* for 16x16ATOM.
- Corrected values (metric and in.) for GT OD for 16x16ATOM.

Parameters for 16x16 Fuel Assemblies

Fuel Assembly Description	16 X 16	16 X 16	16 X 16	16 X 16
Fuel Assembly Type	W-STD	CE	NGF	ATOM
No. Fuel Rods per Assembly	235	236	235	236
No. Non-Fuel Rods	21	20	21	20
Nominal Guide Tube Wall Thickness	0.046 cm (0.018 in.)	0.102 cm (0.040 in.)	0.041 cm (0.016 in.)	0.057 cm (0.023 in.)
Nominal Guide Tube Outer Diameter	1.196 cm (0.471 in.)	2.489 cm (0.980 in.)	1.204 cm (0.474 in.)	1.354 cm (0.533 in.)
Nominal Pellet Diameter	0.819 cm (0.323 in.)	0.826 cm (0.325 in.)	0.784 cm (0.309 in.)	0.914 cm (0.360 in.)
Nominal Clad Outer Diameter	0.950 cm (0.374 in.)	0.970 cm (0.382 in.)	0.914 cm (0.360 in.)	1.075 cm (0.423 in.)
Nominal Clad Thickness	0.057 cm (0.023 in.)	0.064 cm (0.025 in.)	0.057 cm (0.023 in.)	0.072 cm (0.029 in.)
Clad Material	Zirconium alloy	Zirconium alloy	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	19.72 cm (7.76 in.)	20.63 cm (8.12 in.)	19.72 cm (7.76 in.)	22.95 cm (9.03 in.)
Nominal Lattice Pitch	1.232 cm (0.485 in.)	1.285 cm (0.506 in.)	1.232 cm (0.485 in.)	1.430 cm (0.563 in.)

Parameters for 17x17 and 18x18 Fuel Assemblies

- Converted mm to cm.
- Adjusted to 3 decimal places.
- Changed *Nominal Assembly Envelop* to *Nominal Assembly Envelope.*
- Added values for *Nominal Guide Tube Wall Thickness* and *Nominal Guide Tube Outer Diameter* for 17x17-STD or XL.
- Corrected values for *Nominal Guide Tube Wall Thickness* and *Nominal Guide Tube Outer Diameter* for 18x18ATOM.

Parameters for 17x17 and 18x18 Fuel Assemblies

Fuel Assembly Description	17 X 17	17 X 17	18 X 18
Fuel Assembly Type	W-STD or XL	W-OFA	ATOM
No. Fuel Rods per Assembly	264	264	300
No. Non-Fuel Rods	25	25	24
Nominal Guide Tube Wall Thickness	0.041/0.051 cm (0.016/0.020 in.)	0.041 cm (0.016 in.)	0.065 cm (0.026 in.)
Nominal Guide Tube Outer Diameter	1.204/1.224/1.24 cm (0.474/0.482/0.488 in.)	1.204 cm (0.474 in.)	1.240 cm (0.488 in.)
Nominal Pellet Diameter	0.819 cm (0.323 in.)	0.784 cm (0.309 in.)	0.805 cm (0.317 in.)
Nominal Clad Outer Diameter	0.950 cm (0.374 in.)	0.914 cm (0.360 in.)	0.950 cm (0.374 in.)
Nominal Clad Thickness	0.057 cm (0.023 in.)	0.057 cm (0.023 in.)	0.064 cm (0.025 in.)
Clad Material	Zirconium alloy	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	21.39 cm (8.42 in.)	21.39 cm (8.42 in.)	22.94 cm (9.03 in.)
Nominal Lattice Pitch	1.260 cm (0.496 in.)	1.260 cm (0.496 in.)	1.270 cm (0.500 in.)

Page 5 of 6

Section 5(b)(1) Fuel Assembly (Continued)

Keep following sentences

- *There is no restriction on the length of top and bottom annular blankets..*

Add following sentences

- *For fuel assembly types other than 17x17OFA, +/- 0.0254 cm (+/- 0.01 in.) variations are permitted in Nominal Guide Tube Wall Thickness and Guide Tube Outer Diameter if analysis demonstrates that the fuel assembly type is bounded by 17x17OFA.*
- *Non-fissile base-plate mounted core components and spider-body core components are permitted.*
- *Neutron sources or other radioactive material are not permitted.*
- *Materials with moderating capability greater than full density water are not permitted.*

Section 5(b)(2) Loose Fuel Rods

Parameter	Limit
Maximum Enrichment	5.0 weight percent Uranium-235
Pellet Diameter	0.508 – 1.524 cm (0.20 – 0.60 in.)
Maximum Stack Length	Up to rod container length
Cladding	Zirconium alloy
Integral absorber	Permitted (types include: Gadolinia, Erbia, Boron)
Wrapping or sleeving	Plastic or other material with moderating capability not greater than full density water.
Maximum number of rods	Up to rod container capacity

Page 6 of 6

Supplements Added

- Add *March 3, 2005* as supplement

Enclosure 2: SAR Revision 3 Change Pages

Section 6

Page 6-9:	Revised rod container array k_{eff} values in Table 6-3
Page 6-13:	Revised Figure 6-5
Page 6-14:	Revised Table 6-5 to make it consistent with CoC Table.
Page 6-54:	Revised Figure 6-21 to include 16ATOM fuel assembly pattern.
Page 6-55:	Revised Figures 6-20 and 6-21 to make them consistent with CoC Tables.
Page 6-56:	Revised Figures 6-22 and 6-23 to make them consistent with CoC Tables.
Page 6-57:	Revised Figure 6-23
Page 6-58:	Revised Table 6-24 to correct 17x17 STD and 18x18 ATOM results.
Page 6-104A:	Revised Section 6.10.7.5 to clarify explanation of rod container results.
Page 6-107:	Revised Figure 6-39
Page 6-107A:	Revised Table 6-36 to correct the Run # IDs for 1.5 cm Pitch Results.
Page 6-107M:	Revised Table 6-36D to include updated interspersed moderation results.
Page 6-107BB-107-HH	Revised interspersed moderation input deck.
Page 8-8A:	Added new section (Section 8.2.2.3) to provide guidance on shock mount maintenance.

Westinghouse Electric Company, LLC
Columbia Fuel Fabrication Plant
Columbia, SC

Application for Certificate of Compliance for the Traveller PWR Fuel Shipping Package

NRC Certificate of Compliance

USA/9297/AF-96

Docket 71-9297

Initial Submittal: March 2004
Revision 1: November 2004
Revision 2: February 2005
Revision 3: March 2005

Westinghouse

6.1.1.6.5 Region 5 – Polyurethane Foam Region

The polyurethane foam region is the floodable space that is formed when the polyurethane foam burns away. As mentioned above, since it is difficult to predict how much foam will actually burn away, the entire foam region is modeled as *water* for the *individual package cases* and *as a void for the array cases. These are* the most conservative configurations.

6.1.1.6.6 Region 6 – Outside Outerpack Region

This is the volume outside the Outerpack. It has been modeled both flooded and dry to determine which configuration is most conservative for single package and array.

6.1.1.7 Array Spacing Significant Components

The single component that affects the physical separation of the fissile material contents in package arrays is the Outerpack. The Outerpack outer radius is 12.50 inches ± 1.0 inch (317.50 mm ±25.40 mm). It is a cylindrical annular shell split along the longitudinal axis to form two separate halves. The inner and outer shells are fabricated from 12-gauge [0.104 in. 0.264 cm)] stainless steel sheet, and the space between the shells is filled with polyurethane foam. The foam has a nominal 3.0 in. (7.62 cm) radial thickness and axial thickness of approximately 8.0 in. (20.32 cm). The foam material limits impact forces on the fuel assembly and insulates the fuel assembly from heat generated by a fire. Circumferential stiffeners mounted outside provide significant impact protection to the Outerpack diameter. The Outerpack diameter is not reduced at all following hypothetical accident tests. *A sensitivity study was performed to evaluate k_{eff} as a function of Outerpack diameter. This evaluation is described in Section 6.7.11.*

6.1.2 Summary Tables of Criticality Evaluation

Sensitivity studies were performed using the Traveller XL to determine the most conservative *configurations for the normal and hypothetical accident conditions for an individual package and package arrays. These* results, rounded to three decimal places, *are shown in Table 6-1. Calculations were also made to show that* the Traveller *STD is bounded by the* Traveller XL. *Results for the Traveller STD are given in Table 6-2. Finally,* Table 6-3 *shows* results for the two types of rod containers, the Rod Box and Rod Pipe, *in the Traveller XL.*

Table 6-1 Summary Table for Traveller XL with PWR Fuel Assembly	
Traveller XL	K_{eff}
Single Package	
Normal	0.201
HAC	0.885
Package Array	
Normal	0.272
HAC	0.939

Table 6-2 Summary Table for Traveller STD with PWR Fuel Assembly	
Traveller STD	K_{eff}
Single Package	
Normal	n/a
HAC	0.865
Package Array	
Normal	0.256
HAC	0.897

Table 6-3 Summary Table for Traveller XL with the Rod Box and Rod Pipe	
	K_{eff}
Single Package	
Rod Box	0.710
Rod Pipe	0.750
Package Array	
Rod Box	*0.710*
Rod Pipe	*0.750*

This analysis indicates that the 17x17OFA is the most reactive fuel assembly over the range of interest. However, the difference between the 17x17STD and the 17x17OFA is less significant at the top end of the range (9.6 inches/24.384 cm). The 17x17OFA is the most reactive contents and fuel assembly to use in all calculations.

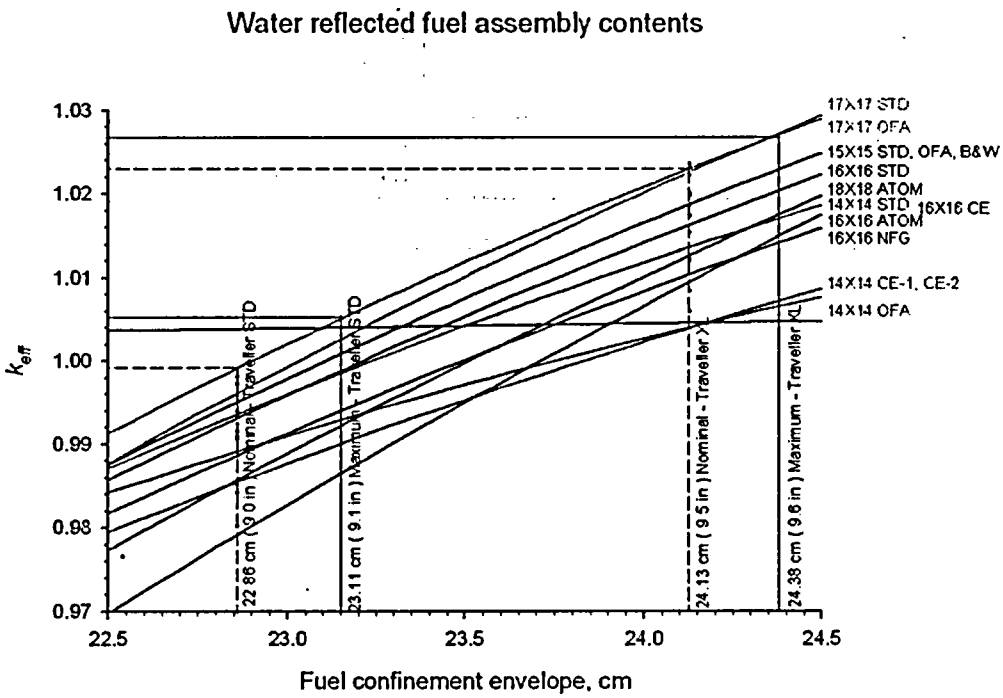


Figure 6-5 Regression Curves of k_{eff} Versus Fuel Assembly Envelope over Range of Interest

6.2.2 PWR and BWR Rods

The Traveller will carry loose rods in rod containers. Table 6-5 below gives the nominal parameter ranges for the fuel rods. Analysis for the rod container was based solely on pellet diameter and pellet pitch. Therefore, there is no restrictions on the non-fuel components of the rods. Fuel rods that satisfy the criteria of Table 6-5 may be transported. This applies to PWR and BWR fuel rods.

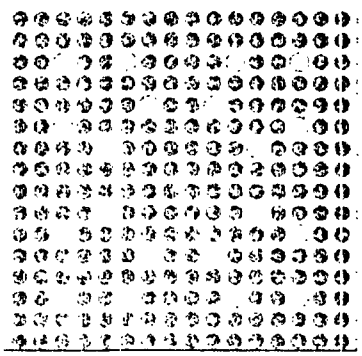
Table 6-5 Fuel Rod Parameters	
Parameter	**Limit**
Maximum Enrichment	5.0 weight percent Uranium-235
Pellet diameter	0.508 – 1.524 cm (0.20 – 0.60 in.)
Maximum stack length	Up to rod container length
Cladding	Zirconium alloy
Integral absorber	Permitted (types include: Gadolinia, Erbia, Boron)
Wrapping or sleeving	Plastic or other material with moderating capability not greater than full density water.
Maximum number per container	Up to rod container capacity

6.10.1 PWR FUEL ASSEMBLY PARAMETERS

The following tables and figures provide the fuel assembly parameters important to criticality safety for the 14x14, 15x15, 16x16, 17x17, and 18x18 fuel types to be transported in the Traveller. Fuel assemblies with other product names, but which satisfy the parameters found in this section may be transported in the Traveller.

18ATOM 17OFA/STD/XL

Figure 6-20 Cross Section for 18x18 and 17x17 Assemblies



16STD/NGF *16CE* *16 ATOM(WSE)*

Figure 6-21 Cross Sections for 16x16 Assemblies

Table 6-20 Parameters for 14x14 Fuel Assemblies

Fuel Assembly Description	14 X 14	14 X 14	14 X 14
Fuel Assembly Type	W-STD	W-OFA	CE-1/CE-2
No. Fuel Rods per assembly	179	179	176
No. Non-Fuel Rods	17	17	20
Nominal Guide Tube Wall Thickness	*0.043 cm (0.017 in.)*	*0.043 cm (0.017 in.)*	*0.097 cm (0.038 in.)*
Nominal Guide Tube Outer Diameter	*1.369 cm (0.539 in.)*	*1.336 cm (0.526 in.)*	*2.822 cm (1.111 in.)*
Nominal Pellet Diameter	*0.929 cm (0.366 in.)*	*0.875 cm (0.344 in.)*	*0.956/0.966 cm (0.376/0.381 in.)*
Nominal Clad Outer Diameter	*1.072 cm (0.422 in.)*	*1.016 cm (0.400 in.)*	*1.016 cm (0.440 in.)*
Nominal Clad Thickness	*0.062 cm (0.024 in.)*	*0.062 cm (0.024 in.)*	*0.071/0.066 cm (0.028/0.026 in.)*
Clad Material	Zirconium alloy	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	*19.70 cm (7.76 in.)*	*19.70 cm (7.76 in.)*	*20.60 cm (8.11 in.)*
Nominal Lattice Pitch	*1.412 cm (0.556 in.)*	*1.412 cm (0.556 in.)*	*1.473 cm (0.580 in.)*

Table 6-21 Parameters for 15x15 Fuel Assemblies

Fuel Assembly Description	15 X 15	15 X 15
Fuel Assembly Type	STD/OFA	B&W
No. Fuel Rods per Assembly	205	208
No. Non-Fuel Rods	20	17
Nominal Guide Tube Wall Thickness	*0.043/0.043 cm (0.017/0.017 in.)*	*0.043 cm (0.017 in.)*
Nominal Guide Tube Outer Diameter	*1.387/1.354 cm (0.546/0.533 in.)*	*1.354 cm (0.533 in.)*
Nominal Pellet Diameter	*0.929 cm (0.366 in.)*	*0.929 cm (0.366 in.)*
Nominal Clad Outer Diameter	*1.072 cm (0.422 in.)*	*1.072 cm (0.422 in.)*
Nominal Clad Thickness	*0.062 cm (0.024 in.)*	*0.062 cm (0.024 in.)*
Clad Material	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	*21.39 cm (8.42 in.)*	*21.66 cm (8.53 in.)*
Nominal Lattice Pitch	*1.430 cm (0.563 in.)*	*1.443 cm (0.568 in.)*

Table 6-22 Parameters for 16x16 Fuel Assemblies				
Fuel Assembly Description	**16 X 16**	**16 X 16**	**16 X 16**	**16 X 16**
Fuel Assembly Type	W-STD	CE	NGF	ATOM
No. Fuel Rods per Assembly	235	236	235	236
No. Non-Fuel Rods	21	20	21	20
Nominal Guide Tube Wall Thickness	*0.046 cm (0.018 in.)*	*0.102 cm (0.040 in.)*	*0.041 cm (0.016 in.)*	*0.057 cm (0.023 in.)*
Nominal Guide Tube Outer Diameter	*1.196 cm (0.471 in.)*	*2.489 cm (0.980 in.)*	*1.204 cm (0.474 in.)*	*1.354 cm (0.533 in.)*
Nominal Pellet Diameter	*0.819 cm (0.323 in.)*	*0.826 cm (0.325 in.)*	*0.784 cm (0.309 in.)*	*0.914 cm (0.360 in.)*
Nominal Clad Outer Diameter	*0.950 cm (0.374 in.)*	*0.970 cm (0.382 in.)*	*0.914 cm (0.360 in.)*	*1.075 cm (0.423 in.)*
Nominal Clad Thickness	*0.057 cm (0.023 in.)*	*0.064 cm (0.025 in.)*	*0.057 cm (0.023 in.)*	*0.072 cm (0.029 in.)*
Clad Material	Zirconium alloy	Zirconium alloy	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	*19.72 cm (7.76 in.)*	*20.63 cm (8.12 in.)*	*19.72 cm (7.76 in.)*	*22.95 cm (9.03 in.)*
Nominal Lattice Pitch	*1.232 cm (0.485 in.)*	*1.285 cm (0.506 in.)*	*1.232 cm (0.485 in.)*	*1.430 cm (0.563 in.)*

Table 6-23 Parameters for 17x17 and 18x18 Fuel Assemblies			
Fuel Assembly Description	**17 X 17**	**17 X 17**	**18 X 18**
Fuel Assembly Type	W-STD *or* XL	W-OFA	ATOM
No. Fuel Rods per Assembly	264	264	300
No. Non-Fuel Rods	25	25	24
Nominal Guide Tube Wall Thickness	*0.041/0.051 cm (0.016/0.020 in.)*	*0.041 cm (0.016 in.)*	*0.065 cm (0.026 in.)*
Nominal Guide Tube Outer Diameter	*1.204/1.224/1.24 cm (0.474/0.482/0.488 in.)*	*1.204 cm (0.474 in.)*	*1.240 cm (0.488 in.)*
Nominal Pellet Diameter	*0.819 cm (0.323 in.)*	*0.784 cm (0.309 in.)*	*0.805 cm (0.317 in.)*
Nominal Clad Outer Diameter	*0.950 cm (0.374 in.)*	*0.914 cm (0.360 in.)*	*0.950 cm (0.374 in.)*
Nominal Clad Thickness	*0.057 cm (0.023 in.)*	*0.057 cm (0.023 in.)*	*0.064 cm (0.025 in.)*
Clad Material	Zirconium alloy	Zirconium alloy	Zirconium alloy
Nominal Assembly Envelope	*21.39 cm (8.42 in.)*	*21.39 cm (8.42 in.)*	*22.94 cm (9.03 in.)*
Nominal Lattice Pitch	*1.260 cm (0.496 in.)*	*1.260 cm (0.496 in.)*	*1.270 cm (0.500 in.)*

6.10.2 FUEL ASSEMBLY COMPARISON

The fuel assembly comparison study compares k_{eff} versus fuel assembly envelope when expanding a 100 cm length of each fuel assembly from nominal to 14 inches (35.56 cm). Figure 6-23 shows the k_{eff} versus fuel envelope over the entire range in order to ascertain the optimum envelope size for each. Tables 6-24 shows results for the 17x17 and 18x18 assemblies. Figure 6-24 shows a sample input deck.

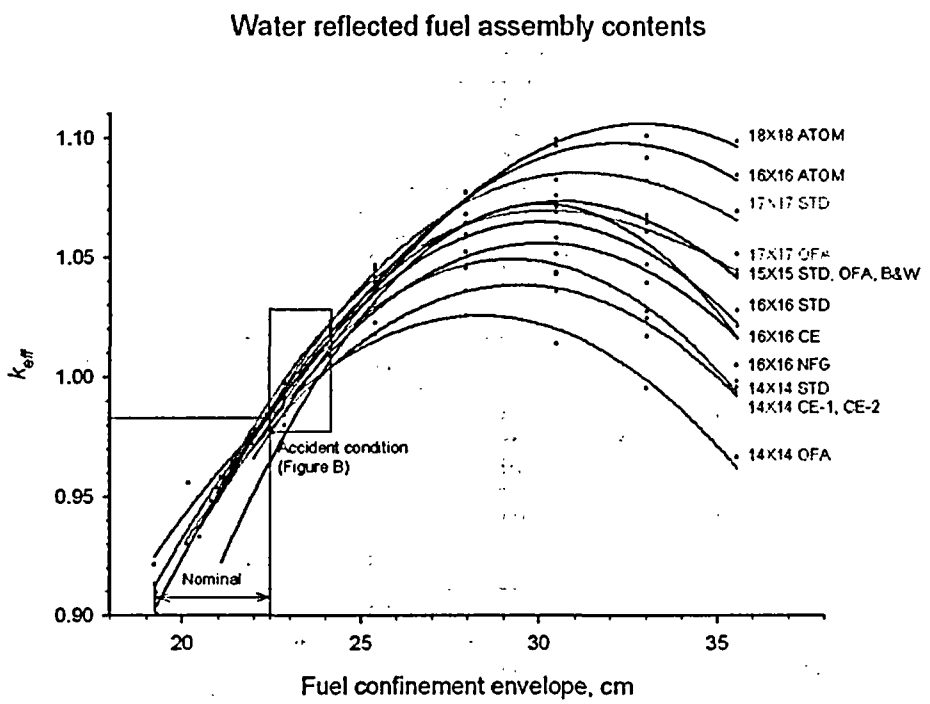


Figure 6-23 k_{eff} Curves vs Fuel Envelope Over Range of Interest

Table 6-24 17X17 and 18X18 Fuel Assemblies						
17X17 STD						
Case No.	Fuel envelope	Pitch (cm)	p/d ratio	k_s	σ_s	$k_s + 2\sigma_s$
89	Nominal	1.2598	1.5379	*0.9497*	*1.5000e-3*	*0.9527*
90	22.86 cm (9.0 inch)	1.3694	1.6717	*0.9885*	*1.5000e-3*	*0.9915*
91	24.13 cm (9.5 inch)	1.4488	1.7687	*1.0201*	*1.7000e-3*	*1.0235*
92	25.40 cm (10.0 inch)	1.5281	1.8655	*1.0419*	*1.5000e-3*	*1.0449*
93	27.94 cm (11.0 inch)	1.6869	2.0593	*1.0735*	*1.7000e-3*	*1.0769*
94	30.48 cm (12.0 inch)	1.8456	2.2531	*1.0793*	*1.6000e-3*	*1.0825*
95	33.02 cm (13.0 inch)	2.0044	2.4469	*1.0792*	*1.4000e-3*	*1.0820*
96	35.56 cm (14.0 inch)	2.1613	2.6385	*1.0666*	*1.4000e-3*	*1.0694*
17X17 OFA						
97	Nominal	1.2598	1.6062	0.9550	1.5000e-3	0.9580
98	22.86 cm (9.0 inch)	1.3716	1.7487	0.9910	1.5000e-3	0.9940
99	24.13 cm (9.5 inch)	1.4510	1.8499	1.0191	1.5000e-3	1.0221
100	25.40 cm (10.0 inch)	1.5303	1.9510	1.0427	1.6000e-3	1.0459
101	27.94 cm (11.0 inch)	1.6891	2.1535	1.0616	1.4000e-3	1.0644
102	30.48 cm (12.0 inch)	1.8479	2.3560	1.0656	1.6000e-3	1.0688
103	33.02 cm (13.0 inch)	2.0066	2.5583	1.0579	1.6000e-3	1.0611
104	35.56 cm (14.0 inch)	2.1654	2.7608	1.0419	1.4000e-3	1.0447
18X18 ATOM						
105	Nominal	1.2700	1.5778	*0.9731*	*1.7000e-3*	*0.9765*
106	22.86 cm (9.0 inch)	1.2888	1.6011	*0.9774*	*1.4000e-3*	*0.9802*
107	24.13 cm (9.5 inch)	1.3635	1.6939	*1.0088*	*1.6000e-3*	*1.0120*
108	25.40 cm (10.0 inch)	1.4382	1.7867	*1.0353*	*1.6000e-3*	*1.0385*
109	27.94 cm (11.0 inch)	1.5876	1.9723	*1.0739*	*1.8000e-3*	*1.0775*
110	30.48 cm (12.0 inch)	1.7371	2.1581	*1.0963*	*1.6000e-3*	*1.0995*
111	33.02 cm (13.0 inch)	1.8865	2.3437	*1.0980*	*1.5000e-3*	*1.1010*
112	35.56 cm (14.0 inch)	2.0359	2.5293	*1.0958*	*1.4000e-3*	*1.0986*

6.10.7.5 Results

The results indicate that both rod container types are geometry limiting with respect to criticality. Calculated k_{eff} results were found to be less than 0.75 for all cases. The rod pipe appears to be the bounding container, and the individual case results were higher than the *infinite planar* array cases *that were* modeled. *Note that the infinite planar array cases assumed full water density inside the rod container and void in all interstitial spaces. That is, referring to Figure 6-4 (Floodable Void Spaces), regions 3 through 6 were modeled as a void. While this flooding configuration is most conservative for a fuel assembly, an interspersed moderation density sensitivity study demonstrated that full density water in all interstitial spaces results in the highest k_{eff}. The infinite planar array case with full density interstitial moderation is essentially equivalent to an individual package in isolation. Therefore, the highest k_{eff} for an package array for rod containers will be equal to the highest k_{eff} for an individual package in isolation.*

Plots are provided *to* show k_{eff} versus pellet diameter for the pitch values for each of the four groups These are presented as Figures 6-35 *(Rod Pipe Individual Package)*, 6-36 *(Rod Pipe Package Array)*, 6-37 *(Rod Box Individual Package)*, and 6-38 *(Rod Box Package Array)*.

Results are *given in* Tables 6-36 *(Rod Pipe Indiviudal Package)*, 6-36A *(Rod Pipe Package Array)*, 6-36B *(Rod Box Individual)*, and 6-36C *(Rod Box Package Array)*. The *highest k_{eff} values from the four tables are shown below.*

Table	Run #	ks	sigma	Ks+2s	Pell. Diam. (inch)	Pell. Diam. (cm)	Rod Pitch (inch)	Rod Pitch (cm)	p/d
6-36	P-IP-15-6	0.7425	0.0015	0.7455	0.25	0.762	0.591	1.50	1.97
6-36A	P-ARR-15-6	0.6622	0.0016	0.6654	0.30	0.762	0.591	1.50	1.97
6-36B	B-IP-15-6	0.7008	0.0015	0.7038	0.30	0.762	0.591	1.50	1.97
6-36C	B-ARR-15-6	0.5512	0.0014	0.5540	0.30	0.762	0.591	1.50	1.97

The interspersed moderation density study was performed using the P-ARR-15-6 and B-ARR-15-6 array cases. Results are shown in Table 6-36D. It can be seen that there is good agreement between the *zero density interspersed case (B-INTER-000, P-INTER-000) and the package array case (B-ARR-15-6, P-ARR-15-6), and between the full density interspersed case (B-INTER-100, P-INTER-100) and the individual package case (B-IP-15-6, P-IP-15-6).* The data are plotted in Figure 6-39. *This analysis demonstrates that the full density water insterspersed case is the optimum infinite planar array case. A final calculation was made to show that the infinite 3-D array case compares weill with the infinite planar array case. The 3D array case was modeled by replacing the water boundary condition on the +/- z axes with a mirror boundary condition. These results are also shown in Table 6-36D.*

Sample input decks *for Rod Box Individual Package, Rod Pipe Package Array, and Rod Pipe Interspersed Modertion* are provided in Tables 6-36E, 6-36F, and 6-36G, *respectively.*

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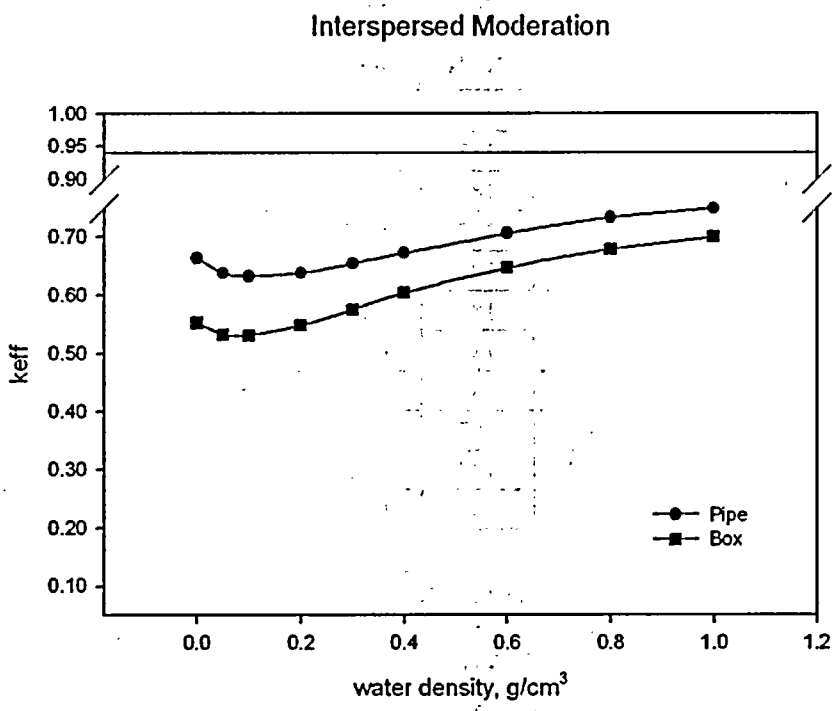

Figure 6-39 *Interspersed Moderation Curves for Rod Box and Rod Pipe*

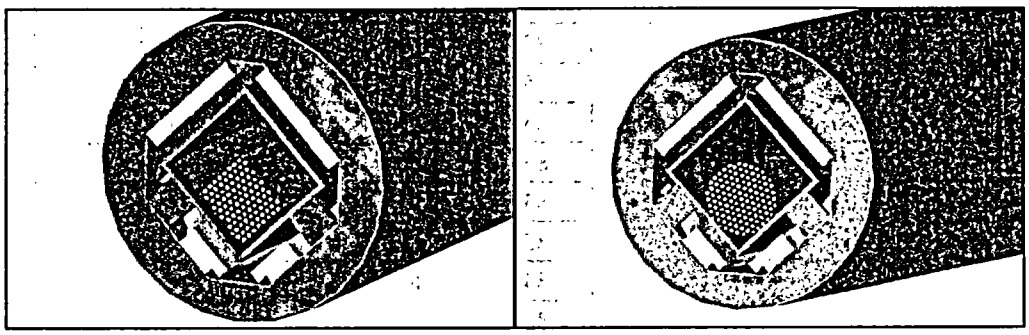

Figure 6-40 Rod *Box and Rod* Pipe in Traveller XL

Table 6-36 Results for Rod Pipe Individual Package HAC

Run #	ks	sigma	Ks+2s	No. Fuel Rods	Pell. Diam. (inch)	Pell. Diam. (cm)	Rod Pitch (inch)	Rod Pitch (cm)	p/d
1.2 cm Pitch									
P-IP-12-1	0.2118	0.0008	0.2134	187	0.05	0.127	0.472	1.20	9.45
P-IP-12-2	0.4917	0.0012	0.4941	187	0.10	0.254	0.472	1.20	4.72
P-IP-12-3	0.6545	0.0013	0.6571	187	0.15	0.381	0.472	1.20	3.15
P-IP-12-4	0.7281	0.0014	0.7309	187	0.20	0.508	0.472	1.20	2.36
P-IP-12-5	0.7416	0.0013	0.7442	187	0.25	0.635	0.472	1.20	1.89
P-IP-12-6	0.7233	0.0014	0.7261	187	0.30	0.762	0.472	1.20	1.57
P-IP-12-7	0.6731	0.0014	0.6759	187	0.35	0.889	0.472	1.20	1.35
P-IP-12-8	0.6049	0.0011	0.6071	187	0.40	1.016	0.472	1.20	1.18
P-IP-12-9	0.5329	0.0011	0.6071	187	0.45	1.143	0.472	1.20	1.05
P-IP-12-10				187	0.50	1.270	0.472	1.20	0.94
1.5 cm Pitch									
P-IP-15-2	0.3893	0.0011	0.3915	121	0.05	0.127	0.591	1.50	11.81
P-IP-15-3	0.5654	0.0013	0.5680	121	0.10	0.254	0.591	1.50	5.91
P-IP-15-4	0.6706	0.0015	0.6736	121	0.15	0.381	0.591	1.50	3.94
P-IP-15-5	0.7285	0.0015	0.7315	121	0.20	0.508	0.591	1.50	2.95
P-IP-15-6	0.7425	0.0015	0.7455	121	0.25	0.635	0.591	1.50	2.36
P-IP-15-7	0.7339	0.0014	0.7367	121	0.30	0.762	0.591	1.50	1.97
P-IP-15-8	0.7073	0.0015	0.7103	121	0.35	0.889	0.591	1.50	1.69
P-IP-15-9	0.6639	0.0013	0.6665	121	0.40	1.016	0.591	1.50	1.48
P-IP-15-10	0.6081	0.0014	0.6109	121	0.45	1.143	0.591	1.50	1.31
1.8 cm Pitch									
P-IP-18-1	0.1097	0.0005	0.1107	85	0.05	0.127	0.709	1.80	14.17
P-IP-18-2	0.3104	0.0009	0.3122	85	0.10	0.254	0.709	1.80	7.09
P-IP-18-3				85	0.15	0.381	0.709	1.80	4.72
P-IP-18-4	0.6039	0.0015	0.6069	85	0.20	0.508	0.709	1.80	3.54
P-IP-18-5	0.6776	0.0016	0.6808	85	0.25	0.635	0.709	1.80	2.83
P-IP-18-6	0.7225	0.0013	0.7251	85	0.30	0.762	0.709	1.80	2.36
P-IP-18-7	0.7384	0.0015	0.7414	85	0.35	0.889	0.709	1.80	2.02
P-IP-18-8	0.7425	0.0015	0.7455	85	0.40	1.016	0.709	1.80	1.77
P-IP-18-9	0.7246	0.0015	0.7276	85	0.45	1.143	0.709	1.80	1.57
P-IP-18-10	0.6977	0.0013	0.7003	85	0.50	1.270	0.709	1.80	1.42

Table 6-36C Results for Rod Box Package Array HAC (cont.)

Run #	ks	sigma	Ks+2s	No. Fuel Rods	Pell. Diam. (inch)	Pell. Diam. (cm)	Rod Pitch (inch)	Rod Pitch (cm)	p/d
3.0 cm Pitch									
B-ARR-30-1	*0.3011*	*0.0010*	*0.3031*	*23*	*0.25*	*0.635*	*1.181*	*3.00*	*4.72*
B-ARR-30-2	*0.3604*	*0.0011*	*0.3626*	*23*	*0.30*	*0.762*	*1.181*	*3.00*	*3.94*
B-ARR-30-3	*0.4042*	*0.0012*	*0.4066*	*23*	*0.35*	*0.889*	*1.181*	*3.00*	*3.37*
B-ARR-30-4	*0.4404*	*0.0012*	*0.4428*	*23*	*0.40*	*1.016*	*1.181*	*3.00*	*2.95*
B-ARR-30-5	*0.4714*	*0.0013*	*0.4740*	*23*	*0.45*	*1.143*	*1.181*	*3.00*	*2.62*
B-ARR-30-6	*0.4946*	*0.0013*	*0.4972*	*23*	*0.50*	*1.270*	*1.181*	*3.00*	*2.36*
B-ARR-30-7	*0.5184*	*0.0013*	*0.5210*	*23*	*0.60*	*1.524*	*1.181*	*3.00*	*1.97*
B-ARR-30-8	*0.5063*	*0.0012*	*0.5087*	*23*	*0.80*	*2.032*	*1.181*	*3.00*	*1.48*
B-ARR-30-9	*0.4758*	*0.0012*	*0.4782*	*23*	*0.90*	*2.286*	*1.181*	*3.00*	*1.31*
B-ARR-30-10	*0.4345*	*0.0011*	*0.4367*	*23*	*1.00*	*2.540*	*1.181*	*3.00*	*1.18*
4.0 cm Pitch									
B-ARR-40-1	*0.1926*	*0.0008*	*0.1942*	*14*	*0.25*	*0.635*	*1.575*	*4.00*	*6.30*
B-ARR-40-2	*0.2364*	*0.0009*	*0.2382*	*14*	*0.30*	*0.762*	*1.575*	*4.00*	*5.25*
B-ARR-40-3	*0.2784*	*0.0010*	*0.2804*	*14*	*0.35*	*0.889*	*1.575*	*4.00*	*4.50*
B-ARR-40-4	*0.3159*	*0.0013*	*0.3185*	*14*	*0.40*	*1.016*	*1.575*	*4.00*	*3.94*
B-ARR-40-5	*0.3522*	*0.0011*	*0.3544*	*14*	*0.45*	*1.143*	*1.575*	*4.00*	*3.50*
B-ARR-40-6	*0.3814*	*0.0011*	*0.3836*	*14*	*0.50*	*1.270*	*1.575*	*4.00*	*3.15*
B-ARR-40-7	*0.4332*	*0.0014*	*0.4360*	*14*	*0.60*	*1.524*	*1.575*	*4.00*	*2.62*
B-ARR-40-8	*0.4976*	*0.0013*	*0.5002*	*14*	*0.80*	*2.032*	*1.575*	*4.00*	*1.97*
B-ARR-40-9	*0.5137*	*0.0014*	*0.5165*	*14*	*0.90*	*2.286*	*1.575*	*4.00*	*1.75*
B-ARR-40-10	*0.5140*	*0.0014*	*0.5168*	*14*	*1.00*	*2.540*	*1.575*	*4.00*	*1.57*

Table 6-36D Rod Box and Rod Pipe Interspersed Moderation Results			
Run #	ks	sigma	Ks+2s
Rod Box Interspersed Moderation Cases			
B-INTER-000	*0.5501*	*0.0013*	*0.5527*
B-INTER-005	*0.5296*	*0.0014*	*0.5324*
B-INTER-010	*0.5284*	*0.0014*	*0.5312*
B-INTER-020	*0.5457*	*0.0014*	*0.5485*
B-INTER-030	*0.5731*	*0.0013*	*0.5757*
B-INTER-040	*0.6013*	*0.0015*	*0.6043*
B-INTER-060	*0.6443*	*0.0014*	*0.6471*
B-INTER-080	*0.6755*	*0.0015*	*0.6785*
B-INTER-100	*0.6962*	*0.0016*	*0.6994*
Corresponding Rod Box Individual Package and *Infinite Planar* Array Cases			
B-ARR-*15*-6	*0.5512*	*0.0014*	*0.5540*
B-IP-*15*-6	*0.7008*	*0.0015*	*0.7038*
Rod Box Infinite Three Dimensional Array Cases			
B-ARR-15-6-3D	*0.6962*	*0.0016*	*0.6994*
Rod Pipe Interspersed Moderation Cases			
P-INTER-000	*0.6611*	*0.0015*	*0.6641*
P-INTER-005	*0.6347*	*0.0016*	*0.6379*
P-INTER-010	*0.6299*	*0.0014*	*0.6327*
P-INTER-020	*0.6350*	*0.0015*	*0.6380*
P-INTER-030	*0.6514*	*0.0015*	*0.6544*
P-INTER-040	*0.6696*	*0.0014*	*0.6724*
P-INTER-060	*0.7028*	*0.0015*	*0.7058*
P-INTER-080	*0.7296*	*0.0016*	*0.7328*
P-INTER-100	*0.7455*	*0.0013*	*0.7481*
Corresponding Rod Pipe Individual Package and *Infinite Planar* Array Cases			
P-ARR-*15*-6	*0.6622*	*0.0016*	*0.6654*
P-IP-*15*-6	*0.7425*	*0.0015*	*0.7455*
Rod Pipe Infinite Three Dimensional Array Cases			
P-ARR-15-6-3D	*0.7455*	*0.0013*	*0.7481*

Table 6-36G Input Deck for Rod Pipe Interspersed Moderation – 60% H2O Density

```
PA_HAC_BORAL_6_3_INTER060_in
=csas26   parm=size=300000
TRAVELLER XL,ROD TUBE,PA,NPD=0.762     ,PITCH=1.5
44groupndf5  latticecell
 uo2 1 1 293 92235 5 92238 95 end
 h2o 2 1 293 end
 zirc4 3 1 293 end
 h2o 4 1 293 end
 h2o 5 1 293 end
 arbmfoam 0.1602e-20  4  0  0  0 6012 70 1001 10 8016 16 7014 4  6 1 293
 end
 al 7 1 293 end
 ss304 8 1 293 end
 polyethylene 9 DEN=0.828 1.0 293 end
 arbmfoam 0.1602e-20  4  0  0  0 6012 70 1001 10 8016 16 7014 4 11 1 293
 end
 b-10 12 0 0.0047781   end
 b-11 12 0 0.019398    end
 c  12 0 0.0060439   end
 al  12 0 0.043223    end
 arbmrubber 1.59  7  0  0  0 8016 46.94 13000 19.92 14000 17.54 6012
 10.79 1001 4.73 11000 0.06 26000 0.02  14 1 293 end
 h2o 15 DEN=0.60 1.0 293 end
 uo2 16 1 293 92235 5 92238 95 end
 h2o 17 1 293 end
 zirc4 18 1 293 end
 h2o 19 1 293 end
end comp
triangpitch 1.5        0.762      16 19 end
more data
res=1  cylinder 0.39218      dan(1)=0.22632      end

read parameter
gen=303
wrs=1
end parameter

read geometry
unit 10
com='individual package'
cuboid 1   16.904      -15.634      16.904      -15.634      533.1330 0
rotate  a1=45 a2=0 a3=0 origin x=0  y=-1.460 z=0
cuboid 2    21.5900  -21.5900    1.5720   -1.0310  533.1330    0
cuboid 3    20.0790  -20.0790   20.0790  -20.0790  533.1330    0
rotate  a1=45 a2=0 a3=0 origin x=0  y=-1.460 z=0
cuboid 4    20.3450  -20.3450   20.3450  -20.3450  533.3990   -0.2660
rotate  a1=45 a2=0 a3=0 origin x=0  y=-1.460 z=0
cuboid 5    21.5900  -21.590    23.1498  -23.1498  533.1330    0
cuboid 6    21.8560  -21.8560   23.4158  -23.4158  533.3990   -0.2660
cuboid 7    20.3840  -20.3840   20.3840  -20.3840  553.8922  -19.8448
rotate  a1=45 a2=0 a3=0 origin x=0  y=-1.460 z=0
```

Table 6-36G Input Deck for Rod Pipe Interspersed Moderation – 60% H2O Density (cont.)

```
PA_HAC_BORAL_6_3_INTER060_in
cuboid 8   21.8950  -21.895   23.4548  -23.4548  553.8922  -19.8448
cylinder 9   25.1050   533.4380   -0.2660
cylinder 10   25.1050   553.9312  -19.8448
cylinder 11   31.4840   533.4380   -0.2660
cylinder 12   31.4840   553.9312  -19.8448
cylinder 13   31.4840   533.4380  -19.8448
cylinder 14   31.7500   554.1972  -20.1100
plane 15  zpl=1  con= -10.0000
cylinder 16 7.62   0 -4.5
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=494.4364
cylinder 17 3.962  0 -7.60
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=494.4364
cylinder 18 7.62   0 -4.5
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=494.4364
cylinder 19 3.962  0 -7.60
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=494.4364
cylinder 20 7.62   0 -4.5
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=448.7164
cylinder 21 3.962  0 -7.60
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=448.7164
cylinder 22 7.62   0 -4.5
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=448.7164
cylinder 23 3.962  0 -7.60
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=448.7164
cylinder 24 7.62   0 -4.5
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=402.9964
cylinder 25 3.962  0 -7.60
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=402.9964
cylinder 26 7.62   0 -4.5
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=402.9964
cylinder 27 3.962  0 -7.60
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=402.9964
cylinder 28 7.62   0 -4.5
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=357.2764
cylinder 29 3.962  0 -7.60
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=357.2764
cylinder 30 7.62   0 -4.5
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=357.2764
cylinder 31 3.962  0 -7.60
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=357.2764
cylinder 54 7.62   0 -4.5
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=265.8364
cylinder 55 3.962  0 -7.60
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=265.8364
cylinder 56 7.62   0 -4.5
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=265.8364
cylinder 57 3.962  0 -7.60
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=265.8364
```

Table 6-36G Input Deck for Rod Pipe Interspersed Moderation – 60% H2O Density (cont.)

```
PA_HAC_BORAL_6_3_INTER060_in
cylinder 32 7.62  0 -4.5
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=174.3964
cylinder 33 3.962  0 -7.60
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=174.3964
cylinder 34 7.62  0 -4.5
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=174.3964
cylinder 35 3.962  0 -7.60
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=174.3964
cylinder 36 7.62  0 -4.5
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=128.6764
cylinder 37 3.962  0 -7.60
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=128.6764
cylinder 38 7.62  0 -4.5
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=128.6764
cylinder 39 3.962  0 -7.60
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=128.6764
cylinder 40 7.62  0 -4.5
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=82.9564
cylinder 41 3.962  0 -7.60
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=82.9564
cylinder 42 7.62  0 -4.5
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=82.9564
cylinder 43 3.962  0 -7.60
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=82.9564
cylinder 44 7.62  0 -4.5
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=37.2364
cylinder 45 3.962  0 -7.60
 rotate  a1=45 a2=90 a3=0 origin x=18.7310 y=-11.1270 z=37.2364
cylinder 46 7.62  0 -4.5
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=37.2364
cylinder 47 3.962  0 -7.60
 rotate  a1=-45 a2=90 a3=0 origin x=-18.7310 y=-11.1270 z=37.2364
hole 11 rotate  a1=45 a2=0 a3=0  origin  x=0 y=-17.700 z=5.240
cuboid 48   18.174   20.079   10.4238  -9.5152   533.3990   -0.2660
rotate  a1=-45 a2=0 a3=0 origin x=0  y=-1.460 z=0
cuboid 49   13.6554  -10.4238  16.904   20.079   533.3990   -0.2660
rotate  a1=45 a2=0 a3=0 origin x=0  y=-1.460 z=0
cuboid 50   16.904   20.079   13.6554  -10.4238  533.3990   -0.2660
rotate  a1=45 a2=0 a3=0 origin x=0  y=-1.460 z=0
cuboid 51   9.5152  -10.4238 -18.174  -20.079   533.3990   -0.2660
rotate  a1=-45 a2=0 a3=0 origin x=0  y=-1.460 z=0
cuboid 52   15.634   18.174   12.0238 -11.9197   533.3990   -0.2660
rotate  a1=-45 a2=0 a3=0 origin x=0  y=-1.460 z=0
cuboid 53   11.9197  -12.0238 -15.634  -18.174   533.3990   -0.2660
rotate  a1=-45 a2=0 a3=0 origin x=0  y=-1.460 z=0
media 15 1  1  3  5 -17 -19 -21 -23 -29 -31 -55 -57 -33 -35
-41 -43 -45 -47
media 15 1  -1  3  5 -48 -49 -50 -51 -52 -53
```

Table 6-36G Input Deck for Rod Pipe Interspersed Moderation – 60% H2O Density (cont.)

```
PA_HAC_BORAL_6_3_INTER060_in
media 9 1  3 -16 -17 -20 -21 -28 -29 -54 -55 -32 -33
-40 -41 -44 -45 48
media 9 1  3 -18 -19 -22 -23 -30 -31 -56 -57 -34 -35
-42 -43 -46 -47 51
media 9 1  3 -18 -22 -30 -56 -34 -42 -46 53
media 9 1  3 -16 -20 -28 -54 -32 -40 -44 52
media 9 1  3 49
media 9 1  3 50
media 8 1 -3  4  6
media 8 1  3 -5  6
media 15 1 -4  9
media 15 1  4 -6  9
media 15 1 -9  11
media 15 1 -7  10 -13
media 15 1  7 -8  10 -13  12
media 15 1 -10 -13  12
media 15 1 -11  13
media 15 1  7  8 -13  12
media 8 1 -12  14
media 15 1 16 -17 3 48
media 15 1 18 -19 3 51
media 15 1 20 -21 3 48
media 15 1 22 -23 3 51
media 15 1 28 -29 3 48
media 15 1 30 -31 3 51
media 15 1 54 -55 3 48
media 15 1 56 -57 3 51
media 15 1 32 -33 3 48
media 15 1 34 -35 3 51
media 15 1 40 -41 3 48
media 15 1 42 -43 3 51
media 15 1 44 -45 3 48
media 15 1 46 -47 3 51
media 15 1 16 -17 3 52
media 15 1 18 -19 3 53
media 15 1 20 -21 3 52
media 15 1 22 -23 3 53
media 15 1 28 -29 3 52
media 15 1 30 -31 3 53
media 15 1 54 -55 3 52
media 15 1 56 -57 3 53
media 15 1 32 -33 3 52
media 15 1 34 -35 3 53
media 15 1 40 -41 3 52
media 15 1 42 -43 3 53
media 15 1 44 -45 3 52
media 15 1 46 -47 3 53
media 14 1 17  3
```

Table 6-36G Input Deck for Rod Pipe Interspersed Moderation – 60% H2O Density (cont.)

```
PA_HAC_BORAL_6_3_INTER060_in
media 14 1 19 3
media 14 1 21 3
media 14 1 23 3
media 14 1 29 3
media 14 1 31 3
media 14 1 55 3
media 14 1 57 3
media 14 1 33 3
media 14 1 35 3
media 14 1 41 3
media 14 1 43 3
media 14 1 45 3
media 14 1 47 3
boundary 14

unit 11
com='fuel assembly confinement system'
cuboid 1  24.384    0 24.384    0 520.7000 2.5400
cuboid 2  25.337    -0.9525 25.337    -0.9525
 523.2400 0.0000
cuboid 3  19.812    4.572    24.429    -0.04545
 513.0800 3.81
cuboid 4  19.812    4.572    24.656    -0.27205
 513.0800 3.81
cuboid 5  19.812    4.572    24.702    -0.3175
 513.0800 3.81
cuboid 6  24.429    -0.04545    19.812    4.572
 513.0800 3.81
cuboid 7  24.656    -0.27205    19.812    4.572
 513.0800 3.81
cuboid 8  24.702    -0.3175    19.812    4.572
 513.0800 3.81
hole 13 origin x=8.4138    y=8.4138    z=16.5600 rotate a1=0 a2=0 a3=0
media 15 1  1
media 7 1 -1  2 -5 -8
media 7 1 -1  3
media 12 1 -3  4
media 7 1 -4  5
media 7 1 -1  6
media 12 1 -6  7
media 7 1 -7  8
boundary 2
unit 13
com='rod box with tri pitch rod array'
cylinder 1 8.4138    450.0 -0.0
cuboid 2 4p8.4138    450.0 -0.0
array 10    1 place 15 15 1 0 0 0
media 15 1 -1 2
boundary 2
```

Table 6-36G Input Deck for Rod Pipe Interspersed Moderation – 60% H2O Density (cont.)

```
PA_HAC_BORAL_6_3_INTER060_in
unit 67
com='solid fuel rod'
cylinder 1 0.381      448.3862    0
hexprism 2 0.75          450.0     -0.0
media 16  1 1
media 19  2 2 -1
boundary 2
global
unit 55
com='single package unit'
cylinder 1   31.75   554.1972 -20.1498
hole 10  origin  x=0 y=0  z=0  rotate  a1=0 a2=0 a3=0
cuboid   2 4p31.75 554.1972 -20.1498
media  15 1   1
media  15 1  -1 2
boundary 2

unit 66
com='individual package 0-deg rotation'
hexprism 1  31.75   554.1972  -20.1498
hole 10  origin  x=0 y=0  z=0  rotate  a1=0 a2=0 a3=0
media   0 1   1
boundary 1

unit 68
com='individual rod dummy cell'
hexprism 1  0.75        450.0  -0.0
media   19 1   1
boundary 1

unit 77
com='individual package 180-deg rotation'
hexprism 1  31.75   554.1972  -20.1498
hole 10  origin  x=0 y=0  z=0  rotate  a1=0 a2=0 a3=180
media   0 1   1
boundary 1

unit 88
com='dummy cell'
hexprism 1  31.75   554.1972  -20.1498
media  0 1   1
boundary 1

unit 99
com='package array'
cylinder 1  372.0761   554.1972  -20.1498
cylinder 2  392.0761   574.1972  -40.1498
cuboid 3  392.0761  -392.0761  392.0761  -392.0761   574.1972  -40.1498
```

Table 6-36G Input Deck for Rod Pipe Interspersed Moderation – 60% H2O Density (cont.)

```
PA_HAC_BORAL_6_3_INTER060_in
array 1 1 place 8 8 1 0 0 0
media  0 1 -1  2
media  0 1 -2  3
boundary 3

end geometry

read array
ara=1 typ=triangular nux=15 nuy=15 nuz=1 gbl=1
fill

88 88 88 88 88 88 88 88 88 88 88 88 88 88 88
 88 88 88 88 88 88 88 88 88 66 66 66 88 88 88
  88 88 88 88 88 88 88 77 77 77 77 77 77 88 88
   88 88 88 88 88 88 66 66 66 66 66 66 66 88 88
    88 88 88 88 88 77 77 77 77 77 77 77 77 88 88
     88 88 88 88 66 66 66 66 66 66 66 66 66 88 88
      88 88 88 77 77 77 77 77 77 77 77 77 77 88 88
       88 88 66 66 66 66 66 66 66 66 66 66 66 88 88
        88 88 77 77 77 77 77 77 77 77 77 77 88 88 88
         88 88 66 66 66 66 66 66 66 66 66 88 88 88 88
          88 77 77 77 77 77 77 77 77 77 77 88 88 88 88
           88 66 66 66 66 66 66 66 66 66 88 88 88 88 88
            88 88 77 77 77 77 77 77 88 88 88 88 88 88 88
             88 88 88 88 88 88 88 88 88 88 88 88 88 88 88
              88 88 88 88 88 88 88 88 88 88 88 88 88 88 88

end fill


ara=10 typ=triangular nux=30 nuy=30 nuz=1
com='rodbox filled'
fill 900*67 end fill

end array

read bnds
+xb=mirror
-xb=mirror
+yb=mirror
-yb=mirror
+zb=h2o
-zb=h2o
end bnds

end data
end
```

6.10.8 CALCULATIONS FOR SENSITIVITY STUDIES

6.10.8.1 Partial Density Interspersed Moderation *Data*

The data below reports the results of one of the interspersed moderation studies. The Traveller STD package accident condition model was run with different moderation densities. Table 6-37 shows the *results* for the graph in section 6.7.1.5. Table 6-38 shows *a sample* input deck.

Table 6-37 Partial Density Interspersed Moderation Results for Traveller *XL*

Run No.	Intespersed Water Density (g/cc)	ks	σks	ks+2xσks
XL-HAC-ARRAY-100	*0.0000*	*0.9377*	*0.0008*	*0.9393*
INTER-005	*0.0500*	*0.9203*	*0.0008*	*0.9219*
INTER-010	*0.1000*	*0.9127*	*0.0009*	*0.9145*
INTER-030	*0.3000*	*0.8991*	*0.0009*	*0.9009*
INTER-060	*0.6000*	*0.8998*	*0.0010*	*0.9018*
INTER-080	*0.8000*	*0.9003*	*0.0009*	*0.9021*
INTER-100	*1.0000*	*0.9035*	*0.0010*	*0.9055*

6.10.8.2 Partial Flooding Data

Table 6-37A Results for Partial Flooding Scenario #1

Run #	*Level*	*ks*	*σks*	*ks+2xσks*
XL-HAC-ARRAY-100	*0.0000*	*0.9377*	*0.0008*	*0.9393*
PREF-LVL1	*2.1657*	*0.9268*	*0.0008*	*0.9284*
PREF-LVL2	*9.3761*	*0.9229*	*0.0008*	*0.9245*
PREF-LVL3	*15.6340*	*0.9220*	*0.0010*	*0.9240*
PREF-LVL4	*21.7746*	*0.9176*	*0.0008*	*0.9192*
PREF-LVL5	*28.4553*	*0.9162*	*0.0010*	*0.9182*
PREF-LVL6	*32.5380*	*0.9158*	*0.0008*	*0.9174*

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b) Heat Definition – A heat shall consist of the total molten metal output from a single heating in a batch melting process or the total metal output from essentially a single heating in a continuous melting operation and targeted at a fixed metal chemistry at the furnace spout.

c) *Deleted.*

d) Coupon (BORAL) – A selected sample of the thinnest section of a lot of the neutron absorber used for acceptance testing of the candidate material.

8.1.5.3 Polyethylene Sheeting

This section establishes the requirements and acceptance criteria for inspection and testing of Ultra High Molecular Weight (UHMW) Polyethylene sheeting utilized within the Traveller packaging.

8.1.5.3.1 Polyethylene Composition

The supplier shall certify that the polyethylene is Ultra High Molecular Weight (UHMW).

8.1.6 Shielding Tests

The Traveller package does not contain any biological shielding.

8.1.7 Thermal Tests

The material properties utilized in Chapter 3, Thermal Evaluation, are consistently conservative for the Normal Conditions of Transport (NCT) thermal analysis performed. The Hypothetical Accident Condition (HAC) fire certification testing of the Traveller package (see Section 2.12.4, 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

This section describes the maintenance program used to ensure continued performance of the Traveller package.

Visual inspection for damage of all exposed surfaces will be performed before each use. Individual components will also be inspected as described in the sections below. If any defects are found during inspection, the package will be segregated and dispositioned by standard site procedure before its next use.

8.2.1 Structural and Pressure Tests

The Traveller packaging does not contain any structural or lifting/tiedown devices that require testing. There is also no pressure testing requirement.

8.2.2 Leak Tests

The Traveller packaging does not have any requirements for leak testing.

8.2.3 Component and Material Tests

8.2.3.1 Fasteners

All threaded components shall be inspected prior to each use for deformed or stripped threads. Damaged components shall be repaired or replaced prior to further use.

8.2.3.2 Braided Fiberglass Sleaving

Prior to each use, visual inspection of the braided fiberglass sleaving shall be performed for tears, damage, or deterioration. Unacceptable sleaving shall be replaced.

8.2.3.3 Shock Mounts

Prior to first use and at an interval not to exceed five years, each Lord Sandwich Shock Mount (Part Number J-5425-275 or engineering approved equivalent) shall be visually inspected. The inspection shall verify the condition of the shock mount for tears, missing material or deterioration from aging. Damaged or suspect shock mounts shall be replaced with Lord Sandwich Shock Mount Part Number J-5425-275 or engineering approved equivalent.

8.2.4 Thermal

No thermal tests are necessary to ensure continued performance of the Traveller packaging.

8.2.5 Neutronic Confirmation

On a periodic basis (not to exceed five years), packages will be inspected to verify the poison plate configuration complies with the drawing requirements. Quality Control Instructions and Mechanical Operating Procedures will define the specific inspection requirements. In accordance with established

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6-33	1	6-64	1	6-107B	2	6-118	1
6-34	1	6-64A	1	6-107C	2	6-119	1
6-35	1	6-64B	1	6-107D	2	6-120	1
6-36	1	6-65	2	6-107E	2	6-121	1
6-37	1	6-66	1	6-107F	2	6-122	1
6-38	1	6-67	1	6-107G	2	6-123	1
6-39	1	6-68	0	6-107H	2	6-124	1
6-40	2	6-69	1	6-107I	2	6-125	1
6-41	1	6-70	1	6-107J	2	6-126	1
6-42	1	6-71	1	6-107K	2	6-127	1
6-42A	1	6-72 – 6-76	1	6-107L	2	6-128	1
6-42B	1	6-77	1	6-107M	3	6-129	1
6-43	1	6-78	1	6-107N	2	6-13	1
6-44	1	6-79	1	6-107O	2	6-131	1
6-45	1	6-80	1	6-107P	2	6-132	1
6-46	1	6-81	1	6-107Q	2	6-133	1
6-46A	1	6-82	1	6-107R	2	6-134	1
6-46B	1	6-82A	1	6-107S	2	6-135	1

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6-141	1						
6-142	1	i	3				
6-143	1						
6-144	1	8-1	1				
6-145	1	8-2	0				
6-146	1	8-3	0				
6-147	1	8-4	0				
6-148	1	8-5	2				
6-149	1	8-5A	2				
6-150	1	8-5B	2				
6-151	1	8-5C	2				
6-152	1	8-5D	1				
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6-155	1	8-8	3				
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6-157	1	8-8B	1				
6-158	1	8-9	0				
6-159	1						
6-160	1						
6-160A	2						
6-160B	2						
6-160C	2						
6-160D	2						
6-160E	2						
6-160F	2						
6-160G	2						
6-160H	2						
6-160I	2						
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6-161	1						
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6-163	1						
6-164	1						
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i	0						