71-5450

Westinghouse Electric Corporation **Commercial Nuclear Fuel Division**

Drawer R
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(803) 776 2610

RE-EKR-89-055

October 5, 1989

U. S. Nuclear Regulatory Commission
ATTN: Mr. C. E. MacDonald, Chief
Transportation Branch
Division of Fuel Cycle and Material Safety
Office of Nuclear Material Safety and Safeguards
Division of Safeguards
Washington, DC 20555

Gentlemen:

Subject: Application for Amendment for Certificate of Compliance No. 5450 (Docket 71-5450)

The Westinghouse Electric Corporation hereby submits this revised application for an amendment to Certificate of Compliance No. 5450 (Docket No. 71-5450) for the RCC fuel shipping container. The only changes requested as part of this application are to increase the authorized maximum U-235 enrichment for Westinghouse 17x17 12-foot OFA fuel designs from 4.3 wt % to 4.45 wt % for two separate conditions. Either each assembly contains a minimum of 32 Integrated Fuel Burnable Absorber (IFBA) rods per specification and loading pattern described in Westinghouse drawing SKA-89044, or there is only one assembly shipped per container. These fuel shipments will be limited to the RCC type containers with Gadolinium Oxide poison plates.

Attachment 1A has been provided to demonstrate the integrity of the fuel rod and ZrB_2 (ceramic) pellet coating as a result of the MCA tests. In the B&W drop test (Attachment 1) a conclusion was drawn that indicated the assembly maintained its relative design configuration such that undamaged fuel assemblies were modeled in the Nuclear Safety Analysis. In the ZrB_2 pellet coating process, pellets are coated and tested at temperatures above the MCA thermal test temperature of 1475°F. Therefore, the ZrB_2 integrity is assured for the MCA test conditions.

Attachment 19 has been revised to justify this U-235 enrichment increase from 4.30 wt % to 4.45 wt % with one assembly per container or with a minimum of 32 IFBA rods per assembly located in accordance with Westinghouse drawing SKA-89044. The calculated K-effective with the inclusion of a 95/95 confidence level (bias and uncertainties in the calculation and benchmark) are below 0.950.

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Log Oct-2-90
Remitter
Check No. 461950
Amount $150
Fee Category 10 A
Type of Fee Amd
Date Check Rec'd. 10/4/89
Date Completed 10/4/89
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Pages 18-4, 18-5 and 18-6, provided as an attachment, have been revised to reflect these enrichment increases.

Your timely review of this application would be appreciated as Westinghouse has need to make a shipment of this fuel design on December 15, 1989.

A check in the amount of $150 in payment of the application fee specified in 10CFR170.31 for this application is submitted.

If you have any questions concerning this application, please contact me by telephone at (803) 776-2610, Extension 3247 or R. D. Montgomery at Extension 3550.

Sincerely,

WESTINGHOUSE ELECTRIC CORPORATION

E. K. Reitler, Manager
Regulatory Engineering

lm
WP3063E:3p.2

ATTACHMENT 1A

INTEGRITY JUSTIFICATION FOR ZrB_2 INTEGRATED FUEL BURNABLE ABSORBER (IFBA) CERAMIC PELLET COATINGS UNDER MCA TEST CONDITIONS

INTEGRITY JUSTIFICATION FOR ZrB_2
INTEGRATED FUEL BURNABLE ABSORBER (IFBA)
CERAMIC PELLET COATINGS UNDER MCA TEST CONDITIONS

INTRODUCTION

In the B&W drop test of a Model B fuel shipping container (Attachment 1), a conclusion was drawn that indicated the assemblies maintained their relative design configuration. Therefore, two (2) undamaged fuel assemblies were modeled in the Nuclear Safety Analysis with UO_2 pellets and zircaloy clad intact at their relative design configuration. Since the fuel assemblies tested in Attachment 1 had no internal neutron poisons (heterogeneous or homogeneous) additional testing is necessary to justify its use as a neutron poison for shipment of fuel assemblies in RCC type shipping containers.

IFBA DESIGN

A zirconium diboride (ZrB_2) coating is deposited onto the cylindrical portion of a uranium dioxide (UO_2) pellet by a sputtering system. This coating process is conducted in a cryogenicly pumped vacuum chamber housing a rotating drum. The coating process is conducted at a temperature range of 1300-1470°F for twelve (12) hours. Planar Magnetron cathodes mounted both within and outside of the rotating drum permit coating of the cylindrical surface of the UO_2 pellets nearly all round, simultaneously.

Each batch of pellets produced is identified with a specific coater lot. Extensive testing of each coater lot is necessary from a quality standpoint to ensure that the ZrB_2 will adhere to the pellet.

IFBA INTEGRITY TESTING

The basic IFBA load pattern is provided in attached Westinghouse Drawing SKA-89044. This load pattern shows that all of the IFBA rods are located internal to the assembly. Thus, the outer rods will provide impact and thermal shielding for all IFBA rods in the MCA test.

The IFBA integrity can be assured for the MCA thermal test of 1475°F, since the coating is applied at temperatures to 1470°F for twelve (12) hours. The integrity of the zircaloy clad has previously been assured through fuel rod burst tests conducted by Westinghouse. The design maximum internal pressure for IFBA fuel rods is 200 psig nominal. From the burst strength test data the measured burst temperature was 1833 ±295°F at a 95/95 confidence level. This produces a minimum burst temperature of 1538°F which is 63°F above the 1475°F MCA thermal test. This temperature difference is sufficient to ensure the fuel rod clad integrity.

Several ZrB_2 adherence tests are conducted on each coater lot. Specifically, a destructive test to fragment uncoated and ZrB_2 coated pellets called hydrogen off-gasing. During pellet hydrogen analysis the temperature of the pellet exceeds 1675°C (3047°F). This high temperature gradient results in fragmentation of the pellet. Metallographic examination of the pellet fragments has shown that despite the extremely high temperature and severe fragmentation, the ZrB_2 coating continues to adhere to the pellet surface.

CONCLUSIONS

The ZrB_2 pellet coating for the IFBA fuel rod is applied and tested at temperatures beyond the MCA thermal test of 1475°F for 30 minutes. Previous MCA drop and burst strength tests have demonstrated the integrity of the UO_2 pellets and zircaloy clad. As a result, it is expected that the ZrB_2 coating will perform its intended function as a neutron poison in reactor as well as shipping container conditions.

Therefore, the ZrB_2 is an effective and reliable neutron poison that can be modeled in the Westinghouse Shipping Container Criticality Analysis provided in Attachment 19.

(iii) Uranium dioxide as clad unirradiated fuel elements. Two (2) neutron absorber plates consisting of carbon steel, 0.035 inches in thickness, with 0.02 gm-GD203/sq. cm affixed to each side of the plate are required between fuel elements of the following specifications:

Type	14x14 Zr Clad	15x15 Zr Clad	14x14 SST Clad	15x15 SST Clad	17x17 Zr Clad	17x17 Zr Clad	16x16 Zr Clad	16x16 Zr Clad
Pellet diameter (nom), in	0.344 0.367	0.367	0.384	0.384	0.322	0.308	0.322	0.325
Rod diameter (nom), in	0.400-0.422	0.422	0.422	0.422	0.374	0.360	0.374	0.382
Maximum fuel length, in	144	144	120	120	168	168	144	150
Maximum rods/ element	180	204	180	204	264	264	235	236
Maximum cross section, (nom, in sq	7.8	8.4	7.8	8.4	8.4	8.4	7.8	7.98
Maximum U-235/ element, kg	26.3	21.5	27.5	22.0	21.75 (144"L) 25.5 (168"L)	19.9 (144"L) 23.3 (168"L)	24.7	25.1
Maximum U-235/ enrichment, w/o	5.0	4.3	5.0	4.3	4.7	4.3	5.0	5.0

(iv) Uranium dioxide as clad unirradiated fuel elements. Two (2) neutron absorber plates consisting of carbon steel, 0.035 inches in thickness, with 0.02 gm-GD203/sq. cm affixed to each side of the plate are required between fuel elements of the following specifications:

Type	17x17 Zr Clad
Pellet diameter (nom), in	0.308
Rod diameter (nom), in	0.360
Maximum fuel length, in	168
Maximum rods/ element	264
Maximum cross section, (nom, in sq	8.4
Maximum U-235/ element, kg	20.6 (144"L)
Maximum U-235/ enrichment, w/o	4.45

(v) Uranium dioxide as clad unirradiated fuel elements. Two (2) neutron absorber plates consisting of carbon steel, 0.035 inches in thickness, with 0.02 gm-GD203/sq. cm affixed to each side of the plate are required between fuel elements of the following specifications:

Type	17x17 Zr Clad	17x17 Zr Clad
Pellet diameter (nom), in	0.308	0.308
Rod diameter (nom), in	0.360	0.360
Maximum fuel length, in	168	168
Maximum rods/ element	264	264
Maximum cross section, (nom, in sq	8.4	8.4
Maximum U-235/ element, kg	20.6 (144"L)	23.2 (144"L)
Minimum ZrB_2 IFBA rods/element	32(1)	48(1)
Maximum U-235/ enrichment, w/o	4.45	5.0

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(1) Load pattern per Westinghouse Drawing SKA-89044.

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(vi) Uranium dioxide as [illegible]aloy or stainless steel clad unirradiated fuel rods of the following specification:

Type	SST Clad	ZR Clad	ZR Clad	ZR Clad	ZR Clad	ZR Clad
Pellet diameter (nom), inches	0.384	0.344- 0.367	0.308 0.322	0.322	0.3805	0.325
Rod diameter (nom), inches	0.422	0.400- 0.422	0.360- 0.374	0.374	0.44	0.382
Fuel length (max), inches	120	144	168	144	144	150
U-235 enrichment (max), w/o						
Note 1	4.0	4.0	3.65	4.0	3.85	---
Note 2	4.2	4.2	4.3	4.3	---	4.2
Note 3	---	---	3.55	---	---	---

NOTES:

(1) Two neutron absorber plates consisting of 0.19 inch thick full length stainless steel containing 1.3% (minimum) Boron or 0.19 inch thick OFHC copper are required between the rod boxes.

(2) Two neutron absorber plates consisting of carbon steel, 0.035 inches in thickness, with minimum 0.02 gm-Gd203/sq. cm affixed to each side of the plate are required between the rod boxes.

(3) Two neutron absorber plates consisting of 0.19 inch thickness carbon steel are required between the rod boxes.

(2) Maximum quantity of material per package:

(i) For the contents described in (1)(i), (1)(ii), (1)(iii), and (1)(v):

Two fuel elements.

(ii) For the contents described in (1)(iv):

One fuel element.

(iii) For the contents described in (1) (vi):

Two inner containers containing not more than 80 kilgrams U-235.

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WESTINGHOUSE SHIPPING CONTAINER CRITICALITY ANALYSIS

INTRODUCTION

Criticality calculations are performed using the AMPX modules NITAWL and XSDRNPM for cross-section generation and KENO-IV for eigenvalue calculations. These methods have been benchmarked to various critical experiments and are now used exclusively for fuel assembly criticality calculations.

In addition to the standard RCC container (copper absorber plates), an upgraded RCC container with Gd_2O_3 coated carbon steel absorber plates is analyzed.

Westinghouse has used two separate design criterion for the criticality of the shipping containers. The first criterion is that K_{eff} is less than or equal to 0.95 on a best estimate basis with minimal additional uncertainties for the maximum credible accident (MCA). The second criterion is that k_{eff} is less than or equal to 0.98 for "optimum moderation" conditions on a best estimate basis with minimal additional uncertainties for the MCA.

The MCA model for the RCC container analysis was either two flooded containers crushed together such that the assemblies are separated by four inches of moderator or an infinite number of containers crushed together such that the assemblies are separated by four inches of moderator on one side, sixteen inches on two sides, and 30 inches of moderator on the fourth side. The container shell is assumed to be in place, with adjacent container shells in contact with each other.

DESIGN METHODS

As mentioned previously, the current Westinghouse criticality design methods employ the two AMPX(1) modules NITAWL and XSDRNPM along with the Monte Carol code KENO-IV.(2) The NITAWL code is used to add resolved resonance parameters to the master library.(3,7) The XSDRNPM code then takes the revised group library and performs a cell calculation. An additional cell calculation is performed if ZrB_2 Integral Fuel Burnable Absorbers (IFBA) are modeled. Cross sections for the IFBA cell are obtained by placing the B10 material from the absorber in the cladding region of the cell. The solution for this cell calculation is then used to collapse the cross-sections into a working library. This library is then used as input to KENO-IV.

Cross-sections for a shipping container are obtained from a cell calculation. The cross-sections for the structural material and the absorber are obtained by introducing trace amounts into the moderator in the cell. This procedure does not produce any bias in the results due to the fineness of the group structure.

The geometric capabilities of KENO-IV are used to provide an essentially exact two-dimensional representation of the problem. The problem is considered to extend infinitely along the length of the fuel assemblies, conservatively ignoring the benefits of axial leakage. Each cell (or box type) is modeled explicitly as a fuel pellet, cladding, and associated moderator. Fuel rods containing ZrB_2 IFBA are modeled by placing the B10 absorber material in the fuel rod cladding. Thimble cells are also modeled explicitly. No credit is taken for the presence of U-234 or U-236; neither is credit taken for any structural material (grids, clamping frames, etc.) that does not extend the full length of the assembly.

A representation of the MCA problem with two crushed containers is given in Figure 1. The boundary conditions on the top and left are zero current, while those on the bottom and right are zero flux. A representation of the MCA problem with an infinite number of crushed containers is given in Figure 1A. The boundary conditions are zero current on all sides.

The Westinghouse criticality method has been benchmarked to a set of critical experiments from several sources. Two sets of the experiments were performed at Battelle's Pacific Northwest Laboratories (4,5); the third was performed at ORNL.(6) The PNL experiments were performed with LWR-type fuel in LWR-type geometries; the ORNL experiments were performed with dry highly enriched uranium metal cylinders. Table 1 provides general information about the critical experiments. Table 2 provides statistical information about the PNL analyses, the ORNL analyses, and the combined set. As is evident, there is very little difference between the PNL analyses and the combined set, indicating the wide range of applicability of the method. The results of the benchmark calculations show that there is essentially no bias to the experiments, with a 95/95 uncertainty of 0.013. No critical experiment was eliminated on the basis of an anomalous result.

CONTAINER ANALYSES

The RCC container (copper absorber plates) was analyzed for three different Westinghouse Optimized Fuel Assemblies (OFA) - the 14x14 OFA, the 15x15 OFA, and the 17x17 OFA. These assemblies were designed to maximize reactivity by optimizing the H/U ratio. Each of these assemblies uses Zircaloy-4 cladding. Figure 2 shows LEOPARD calculations of K_{eff} versus H/U for the 14x14 and 17x17 lattices (the 15x15 assemblies are already optimized, and no changes have been made to the H/U ratio between standard 15x15 and 15x15 OFA). In both cases, the OFA is more reactive than the standard assembly, indicating that the OFA is limiting from a criticality standpoint. An analysis has also been performed for a 17x17 standard fuel assembly in a container in which the copper absorber plate has been replaced by a carbon steel plate of the same dimensions.

The Westinghouse 16x16 assembly was designed to fit the same envelope as the 14x14 assembly. In the shipping container analyses, therefore, the more reactive of the two assemblies is limiting. Unit assembly calculations have been performed for both 14x14 standard and 16x16 assemblies under cold conditions. The 16x16 assembly is 0.007 delta-k less reactive than the standard 14x14 assembly which is 0.007 delta-k less reactive than the 14x14 OFA. The 14x14 OFA is limiting, therefore, both for 14x14 and 16x16 fuel types. Table 3 indicates the fuel types that are covered by each of the OFA types that will be analyzed.

Each of the three limiting fuel types (14x14 OFA, 15x15 OFA, 17x17 OFA) was analyzed in the RCC container with copper absorber plates in KENO. The MCA problem used in this analysis consists of two crushed containers as given in Figure 1. A summary of the results is given in Table 4, the KENO input listings are in Tables 5, 6 and 7 and the nuclide/nuclide number correspondence is given in Table 13. In each case, the best estimate K_{eff} is less than or equal to 0.95 while the final K_{eff} with uncertainties is less than 0.96. The 14x14 and 16x16 assemblies, therefore, exhibit no criticality safety problems at enrichments less than or equal to 4 w/o while the 15x15 and 17x17 assemblies behave similarly at enrichments less than or equal to 3.65 w/o.

The 17x17 standard fuel assembly with the carbon steel absorber plates is limited to an enrichment of 3.55 w/o. A summary of the KENO calculation results for this case is given in Table 4. The KENO input listing is given in Table 14, and the nuclide/nuclide number correspondence is given in Table 13. The best estimate K_{eff} is less than 0.95 while the final K_{eff} with uncertainties is less than 0.965.

The analysis for the CE-type fuel is given in Appendix 15B. The same benchmarks and methods apply. The MCA problem used in this analysis consists of the two crushed containers as given in Figure 1.

The limiting fuel types were also analyzed in the RCC container under optimum moderation conditions using the representation of the MCA problem with an infinite number of crushed containers (FIgure 1A). In the worst case, the best estimate K_{eff} was found to be less than 0.865. As a result, the fuel shipping containers with carbon steel or copper absorber plates under optimum moderation conditions, are bounded by the full moderator density cases and exhibit no criticality safety problems.

The Westinghouse 14x14, 16x16, 15x15 and 17x17 fuel types with U-235 enrichments of up to 4.0, 4.0, 3.65 and 3.65 w/o respectively can be shipped with copper absorber plates under finite and infinite array MCA conditions and not exceed the criticality criterion of K_{eff} less than or equal to 0.95 for full density water and K_{eff} less than or equal to 0.98 for optimum moderation conditions. The Westinghouse 17x17 standard fuel assembly with the carbon steel absorber plates and U-235 enrichment up to 3.55 w/o can also be shipped under the same conditions.

Figure 3 shows the relationship (calculated by LEOPARD) between K_{eff} and rod pitch for all three rod types. In each case it is obvious that the drier the lattice, the less reactive it is. A square tight-packed lattice of individual fuel rods is, therefore, less reactive than those same fuel rods in a fuel assembly. The fuel assembly is, therefore, the limiting case for fuel rod shipments.

The upgraded RCC shipping container has two absorber plates made of carbon steel, 0.035 inches in thickness, with 0.02 g - Gd_2O_3/cm^2 affixed to each side of the plate. The MCA problem used in this analysis consists of an infinite number of crushed containers as given in Figure 1A. Five Westinghouse fuel assembly types were analyzed in this RCC shipping container. These were the 14x14 OFA, 15x15 OFA, 16x16 C-80 and 17x17 OFA/STD. An additional analysis was performed for 17x17 OFA, loading only one assembly per shipping container. The 17x17 OFA fuel assembly has also been analyzed with both 32 and 48 ZrB_2 Integral Fuel Burnable Absorber (IFBA) rods contained in the fuel assembly. The applicable fuel types for the OFA fuel assemblies are shown in Table 3.

Table 3 summarizes the KENO calculated nominal K_{eff} for each of the five problems analyzed. The KENO input listings are in Tables 9 through 12D and the nuclide/nuclide number correspondence is given in Table 13. The Westinghouse 17x17 OFA, STD and Westinghouse 15x15 OFA fuel assemblies with U-235 enrichments of up to 4.2, 4.7 and 4.2 w/o can be shipped under MCA conditions and not exceed the criticality criterion of K_{eff} less than or equal to 0.95. The 17x17 OFA fuel assembly with U-235 enrichments up to 4.45% can be shipped under MCA conditions by loading only one assembly per shipping container. The 17x17 OFA fuel with enrichments from 4.30 up to 4.45 w/o U-235 and containing a minimum of 32 ZrB_2 IFBA or enrichments from 4.45 up to 5.0 w/o with a minimum of 48 ZrB_2 IFBA can be shipped under MCA conditions and not exceed the criticality criterion of K_{eff} less than or equal to 0.95. Furthermore, Westinghouse 14x14 OFA, 16x16 and 16x16 C-80 fuel assemblies with U-235 enrichments of up to 5 w/o can also be shipped under MCA conditions. Enrichments greater than 5 w/o were not considered in this study for those three fuel assembly types.

The upgraded RCC shipping container with the two Gd_2O_3 coated absorber plates was also analyzed using the representation of the MCA problem with an infinite number of crushed containers (Figure 1a) under optimum moderation conditions. It was again found that the optimum moderation cases are bounded by the full moderator density cases, with the worst case best estimate K_{eff} under optimum moderation conditions less than 0.92. As a result the shipping containers with two Gd_2O_3 coated absorber plates exhibit no criticality safety problems under optimum moderation conditions.

The Westinghouse 17x17 OFA, 17x17 OFA with 32 ZrB_2 IFBA, 17x17 OFA with 48 ZrB_2 IFBA, 17x17 STD and 15x15 OFA fuel assemblies with U-235 enrichments of up to 4.30, 4.45, 5.0, 4.70 and 4.3 w/o can be shipped under the infinite array MCA conditions and not exceed the criticality criterion of K_{eff} less than or equal to 0.95 for full density water and K_{eff} less than or equal to 0.98 for optimum moderation conditions. The 17x17 OFA fuel assembly with U-235 enrichments up to 4.45 w/o can be safely shipped under MCA conditions by loading only one assembly per shipping container. Furthermore, Westinghouse 14x14 OFA, 16x16 and C-80 16x16 fuel assemblies with U-235 enrichments of up to 5.0 w/o can also be shipped under the same MCA conditions.

CONCLUSION

A Monte Carlo criticality analysis of the RCC shipping container under finite array and infinite array conditions, with copper absorber plates has demonstrated that, at enrichments of 4.0, 3.65, 4.0, and 3.65, the Westinghouse 14x14 OFA, 15x15 OFA, 16x16, and 17x17 OFA fuel assemblies, respectively, can be safety shipped without risk of criticality. The analysis has also shown that, since loose fuel rods in a tight lattice are less reactive than fuel assemblies, loose fuel rods of the above enrichments can also be safely shipped in the RCC container. With the carbon steel absorber plates, the Monte Carlo criticality analysis of the RCC shipping container has demonstrated that, at an enrichment of 3.55 w/o, the 17x17 fuel assemblies can be safely shipped without risk of criticality.

The Monte Carlo criticality analysis of the upgraded RCC shipping container under infinite array conditions, using Gd_2O_3 absorber plates has demonstrated that, at enrichments of 5.0, 4.3, 5.0, 4.3 and 4.7 w/o, the 14x14 OFA, 15x15 OFA, 16x16, C-80 16x16 and the 17x17 OFA and STD fuel assemblies, respectively, can be safely shipped without risk of criticality. 17x17 OFA fuel assemblies containing a minimum of 32 and 48 ZrB_2 IFBA per assembly with U-235 enrichments up to 4.45 w/o and 5.0 w/o, respectively, can also be shipped safely without risk of criticality. Furthermore, the 17x17 OFA fuel assembly with enrichments up to 4.45 w/o can be safely shipped by loading only one assembly per container.

TABLE 8

KENO CALCULATED RESULTS FOR THE MAXIMUM CREDIBLE ACCIDENT

(RCC Container with Gd203 Absorber Plates)

FUEL TYPE	U-235 WT % ENRICHMENT	KENO NOMINAL K-eff	1 SIGMA
W 15X15 OFA	4.3	0.93906	0.00335
W 17x17 STD	4.7	0.95479	0.00309
W 17x17 OFA	4.3	0.93974	0.00317
W 14x14 OFA	5.0	0.92391	0.00311
W 16x16	5.0	0.92391	0.00311
-80 16x16	5.0	0.92935	0.00307
W 17x17 OFA*	4.45	0.92643**	0.00333
W 17x17 32 IFBA	4.45	0.94043**	0.00228
W 17x17 O[illegible]A	5.0	0.94978**	0.00261

* This ana[illegible] performed with one assembly per shipping container

** Reported KENO k_{eff} results include biases and 95/95 uncertainties

TABLE 12B (1/2)

LISTING OF KENO INPUT DATA
FOR THE W 17X17 OFA FUEL PROBLEM
LOADING ONE ASSEMBLY PER SHIPPING CONTAINER

```
4.45 W/O 17OFA IN GD CASK WITH 4" CRSH GAP 1.0 G/CC H2O 1 ASMBLY/CASK
9.7 800 300 5 27 27 20 8 23 51 16 20 16 1 -20 1 0 1011 0 1 1 1 0 0 0
   00 0 0 82389
-1. -1. -1. -1. -1. -1.
1  -192235    0.0010574
1   192238    0.022417
1   18016     0.046949
2   240302    0.043326
3   31001     0.066854
3   38016     0.033427
4   324000    0.017386
4   325055    0.001732
4   326000    0.058019
4   328000    0.008142
5   38016     0.00981210
5   364152    0.000013083
5   364154    0.000142603
5   364155    0.000968128
5   364156    0.001339027
5   364157    0.001023731
5   364158    0.001624886
5   364160    0.001429952
6   326000    0.0842012
6   36012     0.00047290
6   325055    0.00038871
6   315031    0.00005807
6   316032    0.00006842
BOX TYPE   1
CYLINDER   1    0.392178                                   365.76 -0.0 27*0.5
CYLINDER   0    0.40005                                    365.76 -0.0 27*0.5
CYLINDER   2    0.45720                                    365.76 -0.0 27*0.5
CUBOID     3    0.62992   -0.62992   0.62992   -0.62992 365.76 -0.0 27*0.5
BOX TYPE   2
CYLINDER   3    0.56896                                    365.76 -0.0 27*0.5
CYLINDER   2    0.60198                                    365.76 -0.0 27*0.5
CUBOID     3    0.62992   -0.62992   0.62992   -0.62992 365.76 -0.0 27*0.5
BOX TYPE   3
CUBOID     6    0.4572     0.0       0.0       -0.45720 365.76 -0.0 27*0.5
CUBOID     3    2.9972     0.0       0.0       -0.45720 365.76 -0.0 27*0.5
BOX TYPE   4
CUBOID     6    0.0       -0.4572    0.0       -0.45720 365.76 -0.0 27*0.5
CUBOID     3    0.0       -2.9972    0.0       -0.45720 365.76 -0.0 27*0.5
BOX TYPE   5
CUBOID     6    0.62992   -0.62992   0.0       -0.45720 365.76 -0.0 27*0.5
BOX TYPE   6
CUBOID     6    0.89789    0.80898   0.62992   -0.62992 365.76 -0.0 27*0.5
CUBOID     5    0.90805    0.79883   0.62992   -0.62992 365.76 -0.0 27*0.5
CUBOID     3    2.99720    0.45720   0.62992   -0.62992 365.76 -0.0 27*0.5
CUBOID     6    2.99720    0.0       0.62992   -0.62992 365.76 -0.0 27*0.5
BOX TYPE   7
CUBOID     6   -0.80898   -0.89789   0.62992   -0.62992 365.76 -0.0 27*0.5
CUBOID     5   -0.79883   -0.90805   0.62992   -0.62992 365.76 -0.0 27*0.5
CUBOID     3   -0.45720   -2.99720   0.62992   -0.32992 365.76 -0.0 27*0.5
CUBOID     6    0.0       -2.99720   0.62992   -0.62992 365.76 -0.0 27*0.5
BOX TYPE   8
CUBOID     6    0.45720    0.0       0.62992   -0.62992 365.76 -0.0 27*0.5
CUBOID     3    2.99720    0.0       0.62992   -0.62992 365.76 -0.0 27*0.5
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TABLE .2B (2/2)

(CONTINUED)

```
BOX TYPE  9
CUBOID    6    0.0       -0.45720  0.62992  -0.62992 365.76 -0.0 27*0.5
CUBOID    3    0.0       -2.99720  0.62992  -0.62992 365.76 -0.0 27*0.5
BOX TYPE  10
CUBOID    3    0.62992   -0.62992  5.08000   0.0     365.76 -0.0 27*0.5
BOX TYPE  11
CUBOID    6    0.45720    0.0      2.71272   0.0     365.76 -0.0 27*0.5
CUBOID    3    2.99720    0.0      5.08000   0.0     365.76 -0.0 27*0.5
BOX TYPE  12
CUBOID    6    0.0       -0.45720  2.71272   0.0     365.76 -0.0 27*0.5
CUBOID    3    0.0       -2.99720  5.08000   0.0     365.76 -0.0 27*0.5
BOX TYPE  13
CUBOID    6    0.89789    0.80899  0.62992   0.18288 365.76 -0.0 27*0.5
CUBOID    5    0.90805    0.79883  0.62992   0.18288 365.76 -0.0 27*0.5
CUBOID    3    2.99720    0.45720  0.62992  -0.62992 365.76 -0.0 27*0.5
CUBOID    6    2.99720    0.0      0.62992  -0.62992 365.76 -0.0 27*0.5
BOX TYPE  14
CUBOID    6   -0.80899   -0.89789  0.62992   0.18288 365.76 -0.0 27*0.5
CUBOID    5   -0.79883   -0.90805  0.62992   0.18288 365.76 -0.0 27*0.5
CUBOID    3   -0.45720   -2.99720  0.62992  -0.62992 365.76 -0.0 27*0.5
CUBOID    6    0.0       -2.99720  0.62992  -0.62992 365.76 -0.0 27*0.5
BOX TYPE  15
CUBOID    6    0.89789    0.80899 -0.29972  -0.62992 365.76 -0.0 27*0.5
CUBOID    5    0.90805    0.79883 -0.29972  -0.62992 365.76 -0.0 27*0.5
CUBOID    3    2.99720    0.45720  0.62992  -0.62992 365.76 -0.0 27*0.5
CUBOID    6    2.99720    0.0      0.62992  -0.62992 365.76 -0.0 27*0.5
BOX TYPE  16
CUBOID    6   -0.80899   -0.89789 -0.29972  -0.62992 365.76 -0.0 27*0.5
CUBOID    5   -0.79883   -0.90805 -0.29972  -0.62992 365.76 -0.0 27*0.5
CUBOID    3   -0.45720   -2.99720  0.62992  -0.62992 365.76 -0.0 27*0.5
CUBOID    6    0.0       -2.99720  0.62992  -0.62992 365.76 -0.0 27*0.5
BOX TYPE  17
CUBOID    6    21.41728   0.0      0.0      -0.45720 365.76 -0.0 27*0.5
BOX TYPE  18
CUBOID    3    21.41728   0.0      0.62992  -0.62992 365.76 -0.0 27*0.5
BOX TYPE  19
CUBOID    3    21.41728   0.0      5.08000   0.0     365.76 -0.0 27*0.5
CORE BDY  0    24.41448 -24.41448 13.47724 -13.47724 365.76 -0.0 27*0.5
CUBOID    3    44.73448 -44.73448 13.47724 -51.12004 365.76 -0.0 27*0.5
CUBOID    6    44.96054 -44.96054 13.70330 -51.34610 365.76 -0.0 27*0.5
   1  1 20  1  1  19  1  1  1  1  0
   2  3 15  3  7  13  3  1  1  1  0
   2  4 14 10  5  15 10  1  1  1  0
   2  6 12  3  4  16 12  1  1  1  0
   3 18 18  1  1   1  1  1  1  1  0
   4 19 19  1  1   1  1  1  1  1  0
   5  1 17  1  1   1  1  1  1  1  0
   6 18 18  1  3  16  1  1  1  1  0
   7 19 19  1  3  16  1  1  1  1  0
   8 18 18  1 18  18  1  1  1  1  0
   9 19 19  1 18  18  1  1  1  1  0
  10  1 17  1 19  19  1  1  1  1  0
  11 18 18  1 19  19  1  1  1  1  0
  12 19 19  1 19  19  1  1  1  1  0
  13 18 18  1  2   2  1  1  1  1  0
  14 19 19  1  2   2  1  1  1  1  0
  15 18 18  1 17  17  1  1  1  1  0
  16 19 19  1 17  17  1  1  1  1  0
  17 20 20  1  1   1  1  1  1  1  0
  18 20 20  1  2  18  1  1  1  1  0
  19 20 20  1 19  19  1  1  1  1  1
-1
END KENO
```

TABLE 12C(1/2)

LISTING OF KENO INPUT DATA
FOR THE W 17X17 OFA FUEL ASSEMBLY
CONTAINING 4.45 W/O FUEL AND 32 ZRB2 IFBA

```
4.45 W/O 17OFA 32 IFBA 108 IN  B10*.95  STD SHIPPING CASK H20=1.0 G/CM3
19.7 900 300 5 27 27 27 9 30 34 11 18 19 1 -27 1 0 1011 0 1 1 1 0 0 0
   00 0 0 92189
-1. -1. -1. -1. -1. -1.
1  -192235      .0010574
1   192238      .022417
1   18016       .046949
2  -492235      .0010574
2   492238      .022417
2   48016       .046949
3   240302      .043326
4   540302      .043326
4   55010       .000164445
5   31001       .066854
5   38016       .033427
6   61001       .066854
6   68016       .033427
7   326000      .058019
7   324000      .017386
7   328000      .008142
7   325055      .001732
8   38016       .00981210
8   364152      .000013083
8   364154      .000142603
8   364155      .000968129
8   364156      .001339027
8   364157      .001023731
8   364158      .001624886
8   364160      .001429952
9   326000      .0842012
9   36012       .00047290
9   325055      .00038871
9   315031      .00005807
9   316032      .00006642
BOX TYPE  1
CYLINDER  1     .392176                           365.76 -0.0 27*0.5
CYLINDER  0     .40005                            365.76 -0.0 27*0.5
CYLINDER  3     .45720                            365.76 -0.0 27*0.5
CUBOID    5     .62992 -.62992 .62992 -.62992     365.76 -0.0 27*0.5
BOX TYPE  2
CYLINDER  2     .392176                           365.76 -0.0 27*0.5
CYLINDER  0     .40005                            365.76 -0.0 27*0.5
CYLINDER  4     .45720                            365.76 -0.0 27*0.5
CUBOID    6     .62992 -.62992 .62992 -.62992     365.76 -0.0 27*0.5
BOX TYPE  3
CYLINDER  5     .56896                            365.76 -0.0 27*0.5
CYLINDER  3     .60198                            365.76 -0.0 27*0.5
CUBOID    5     .62992 -.62992 .62992 -.62992     365.76 -0.0 27*0.5
```

TABLE 12C (2/2)

```
BOX TYPE  4
CUBOID     9     .4572  0.0     0.0      -.4572        365.76 -0.0 27*0.5
CUBOID     5    2.9972  0.0     0.0      -.4572        365.76 -0.0 27*0.5
BOX TYPE  5
CUBOID     9     .62992 -.62992 0.0      -.4572        365.76 -0.0 27*0.5
BOX TYPE  6
CUBOID     9     .89789  .80899 .62992 -.62992         365.76 -0.0 27*0.5
CUBOID     8     .90805  .79883 .62992 -.62992         365.76 -0.0 27*0.5
CUBOID     5    2.9972   .4572  .62992 -.62992         365.76 -0.0 27*0.5
CUBOID     9    2.9972   0.0    .62992 -.62992         365.76 -0.0 27*0.5
BOX TYPE  7
CUBOID     9     .4572   0.0    .62992 -.62992         365.76 -0.0 27*0.5
CUBOID     5    2.9972   0.0    .62992 -.62992         365.76 -0.0 27*0.5
BOX TYPE  8
CUBOID     5     .62992  -.62992 5.08  0.0             365.76 -0.0 27*0.5
BOX TYPE  9
CUBOID     9     .4572   0.0     2.71272 0.0           365.76 -0.0 27*0.5
CUBOID     5    2.9972   0.0     5.08  0.0             365.76 -0.0 27*0.5
BOX TYPE  10
CUBOID     9     .89789  .80899   .62992 0.18288       365.76 -0.0 27*0.5
CUBOID     8     .90805  .79883   .62992 0.18288       365.76 -0.0 27*0.5
CUBOID     5    2.9972   .4572    .62992 -.62992       365.76 -0.0 27*0.5
CUBOID     9    2.9972   0.0      .62992 -.62992       365.76 -0.0 27*0.5
BOX TYPE  11
CUBOID     9     .89789  .80899  -.29972 -.62992       365.76 -0.0 27*0.5
CUBOID     8     .90805  .79883  -.29972 -.62992       365.76 -0.0 27*0.5
CUBOID     5    2.9972   .4572    .62992 -.62992       365.76 -0.0 27*0.5
CUBOID     9    2.9972   0.0      .62992 -.62992       365.76 -0.0 27*0.5
CORE BDY   0    12.20724 -12.20724 13.47724 -13.47724 365.76 -0.0 27*0.5
CUBOID     5    12.20724 -32.52724 13.47724 -51.12004 365.76 -0.0 27*0.5
CUBOID     9    12.20724 -32.75330 13.70330 -51.34610 365.76 -0.0 27*0.5
  1  1 18  1  1  18   1   1   1   1   0
  2  3 15 12  3  17  14   1   1   1   0
  2  2 16 14  4  16  12   1   1   1   0
  2  7 11  4  5  15  10   1   1   1   0
  2  8 10  2  5  15  10   1   1   1   0
  2  8 10  2  6  14   8   1   1   1   0
  2  4 14 10  8  12   4   1   1   1   0
  2  4  5  1  9  11   2   1   1   1   0
  2 13 14  1  9  11   2   1   1   1   0
  3  3 15  3  7  13   3   1   1   1   0
  3  4 14 10  5  15  10   1   1   1   0
  3  6 12  3  4  16  12   1   1   1   0
  4 18 18  1  1   1   1   1   1   1   0
  5  1 17  1  1   1   1   1   1   1   0
  6 18 18  1  3  16   1   1   1   1   0
  7 18 18  1 18  18   1   1   1   1   0
  8  1 17  1 19  19   1   1   1   1   0
  9 18 18  1 19  19   1   1   1   1   0
 10 18 18  1  2   2   1   1   1   1   0
 11 18 18  1 17  17   1   1   1   1   1
-1
END KENO
```

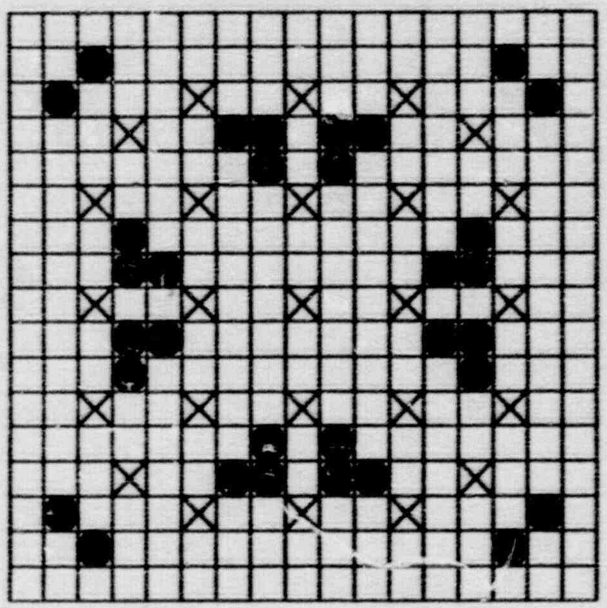
TABLE 12D (1/2)

LISTING OF KENO INPUT DATA
FOR THE W 17X17 OFA FUEL ASSEMBLY
CONTAINING 5.05 W/O FUEL AND 48 ZRB2 IFBA

```
5.05 W/O 17OFA 48 IFBA 108 IN  B10*.95  STD SHIPPING CASK H20=1.0 G/CM3
14.7 500 300 5 27 27 27 9 30 34 11 18 19 1 -27 1 0 1011 0 1 1 1 0 0 0
   00 0 0 100389
-1. -1. -1. -1. -1. -1.
1  -192235      .0011999
1   192238      .022276
1   18016       .046952
2  -492235      .0011999
2   492238      .022276
2   48016       .046952
3   240302      .043326
4   540302      .043326
4   55010       .000164445
5   31001       .066854
5   38016       .033427
6   61001       .066854
6   68016       .033427
7   326000      .058019
7   324000      .017386
7   328000      .008142
7   325055      .001732
8   38016       .00981210
8   364152      .000013083
8   364154      .000142603
8   364155      .000968129
8   364156      .001339027
8   364157      .001023731
8   364158      .001624886
8   364160      .001429952
9   326000      .0842012
9   36012       .00047290
9   325055      .00038871
9   315031      .00005807
9   316032      .00006642
BOX TYPE  1
CYLINDER  1     .392176                              365.76 -0.0 27*0.5
CYLINDER  0     .40005                               365.76 -0.0 27*0.5
CYLINDER  3     .45720                               365.76 -0.0 27*0.5
CUBOID    5     .62992 -.62992 .62992 -.62992        365.76 -0.0 27*0.5
BOX TYPE  2
CYLINDER  2     .392176                              365.76 -0.0 27*0.5
CYLINDER  0     .40005                               365.76 -0.0 27*0.5
CYLINDER  4     .45720                               365.76 -0.0 27*0.5
CUBOID    6     .62992 -.62992 .62992 -.62992        365.76 -0.0 27*0.5
BOX TYPE  3
CYLINDER  5     .56896                               365.76 -0.0 27*0.5
CYLINDER  3     .60198                               365.76 -0.0 27*0.5
CUBOID    5     .62992 -.62992 .62992 -.62992        365.76 -0.0 27*0.5
BOX TYPE  4
CUBOID    9     .4572  0.0     0.0     -.4572        365.76 -0.0 27*0.5
CUBOID    5    2.9972  0.0     0.0     -.4572        365.76 -0.0 27*0.5
```

TABLE 12D (2/2)

```
BOX TYPE  5
CUBOID    9      .62992 -.62992 0.0     -.4572        365.76 -0.0 27*0.5
BOX TYPE  6
CUBOID    9      .89789  .80899 .62992 -.62992        365.76 -0.0 27*0.5
CUBOID    8      .90805  .79883 .62992 -.62992        365.76 -0.0 27*0.5
CUBOID    5     2.9972   .4572  .62992 -.62992        365.76 -0.0 27*0.5
CUBOID    9     2.9972   0.0    .62992 -.62992        365.76 -0.0 27*0.5
BOX TYPE  7
CUBOID    9      .4572   0.0    .62992 -.62992        365.76 -0.0 27*0.5
CUBOID    5     2.9972   0.0    .62992 -.62992        365.76 -0.0 27*0.5
BOX TYPE  8
CUBOID    5      .62992  -.62992 5.08  0.0            365.76 -0.0 27*0.5
BOX TYPE  9
CUBOID    9      .4572   0.0     2.71272 0.0          365.76 -0.0 27*0.5
CUBOID    5     2.9972   0.0     5.08  0.0            365.76 -0.0 27*0.5
BOX TYPE  10
CUBOID    9      .89789  .80899    .62992 0.18288     365.76 -0.0 27*0.5
CUBOID    8      .90805  .79883    .62992 0.18288     365.76 -0.0 27*0.5
CUBOID    5     2.9972   .4572     .62992 -.62992     365.76 -0.0 27*0.5
CUBOID    9     2.9972   0.0       .62992 -.62992     365.76 -0.0 27*0.5
BOX TYPE  11
CUBOID    9      .89789  .80899   -.29972 -.62992     365.76 -0.0 27*0.5
CUBOID    8      .90805  .79883   -.29972 -.62992     365.76 -0.0 27*0.5
CUBOID    5     2.9972   .4572     .62992 -.62992     365.76 -0.0 27*0.5
CUBOID    9     2.9972   0.0       .62992 -.62992     365.76 -0.0 27*0.5
CORE BDY  0     12.20724 -12.20724 13.47724 -13.47724 365.76 -0.0 27*0.5
CUBOID    5     12.20724 -32.52724 13.47724 -51.12004 365.76 -0.0 27*0.5
CUBOID    9     12.20724 -32.75330 13.70330 -51.34610 365.76 -0.0 27*0.5
  1  1 18  1  1  18   1   1   1   1   0
  2  3 15  4  3  17  14   1   1   1   0
  2  2 16 14  4  16   4   1   1   1   0
  2  8 10  2  5  15  10   1   1   1   0
  2  8 10  2  6  14   8   1   1   1   0
  2  8 10  2  8  12   4   1   1   1   0
  2  7 11  4  5  15  10   1   1   1   0
  2  7 11  4  9  11   2   1   1   1   0
  2  4 14 10  8  12   4   1   1   1   0
  2  4 14 10  9  11   2   1   1   1   0
  2  5 13  8  9  11   2   1   1   1   0
  3  3 15  3  7  13   3   1   1   1   0
  3  4 14 10  5  15  10   1   1   1   0
  3  6 12  3  4  16  12   1   1   1   0
  4 18 18  1  1   1   1   1   1   1   0
  5  1 17  1  1   1   1   1   1   1   0
  6 18 18  1  3  16   1   1   1   1   0
  7 18 18  1 18  18   1   1   1   1   0
  8  1 17  1 19  19   1   1   1   1   0
  9 18 18  1 19  19   1   1   1   1   0
 10 18 18  1  2   2   1   1   1   1   0
 11 18 18  1 17  17   1   1   1   1   1
-1
END KENO
```



ENGINEERING SPECIFICATIONS:

1. NOMINAL B^{10} LOADING: 1.5 MG LIN
2. TOLERANCE-NOMINAL ON LOADING: ± 5.0 %
3. ACTIVE ZR B2 POISONED FUEL LENGTH: 120 IN.

KENO MODEL PARAMETERS:

1. MODELED B^{10} LOADING: 1.0 MG LIN.
2. MODELED POISONED FUEL LENGTH: 108 IN.

LEGEND

● : POISON FUEL RODS (32 ROD/ASSY)

☐ : FUEL RODS (232 ROD/ASSY)

☒ : THIMBLE AND INSTRUMENT LOCATIONS
(25 LOC/ASSY)

DFTM	JPR.	10/05 89
CHKD		
APPD	RD Montgomery	10/05 89
APPD		
APPD		
APPD		
APPD		
APPD		
APPD		

Westinghouse Electric Corporation
WATER REACTOR DIVISIONS - COLUMBIA, S.C. U.S.A.

AREA / PROCESS

TITLE IFBA (32) LOAD PATTERN & DETAILS
FOR 4.45 WT% 17 OFA FUEL ASSY

SIZE	REQN. NO	DWG NO	REV
A	5555	SKA-89044	01

SCALE 1/2
DWG. TYPE
SHEET 01 OF 01 SHEETS

CADAM DRAWING
DO NOT REVISE MANUALLY