Westinghouse Electric Corporation Commercial Nuclear Fuel Division RE-EKR-89-055 Drawer R Columbia SC 29250 (803) 776 2610

71-5450

NTOI

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 raintained 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 terted 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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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

Eleval f

E. K. Reitler, Manager Regulatory Engineering

1m WP3063E:3p.2

INTEGRITY JUSTIFICATION FOR ZrB2

INTEGRATED FUEL BURNABLE ABSORBER (IFBA)

CERAMIC PELLET COATINGS UNDER MCA TEST CONDITIONS

1. 4

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INTEGRITY JUSTIFICATION FOR ZrB₂ 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 UO₂ pellets and zircaloy clad intact at their relative design configuration. Since the fuel assemblies tested in Attachment 1 had no internal neutron poisons (hetrrogeneous 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 $(2rB_2)$ 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 UC, pellets nearly all round, simultaneously.

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

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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 $1475^{\circ}F$, since the coating is applied at temperatures to $1470^{\circ}F$ 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 $1833 \pm 295^{\circ}F$ at a 95/95confidence level. This produces a minimum burst temperature of $1538^{\circ}F$ which is $63^{\circ}F$ above the $1475^{\circ}F$ MCA thermal test. This temperature difference is sufficient to ensure the fuel rod clad integrity.

Several $2rB_2$ adherence tests are conducted on each coater lot. Specifically, a destructive test to fragment uncoated and $2rB_2$ 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 $2rB_2$ coating continues to adhere to the pellet surface.

CONCLUSIONS

The $2rB_2$ pellet coasing 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 UO₂ pellets and zircaloy clad. As a result, it is expected that the $2rB_2$ coating will perform its intended function as a neutron poison in reactor as well as shirping container conditions.

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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.

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*

No									
. 7		14x14 Zr	15x15 Zr	14x14 SST	15x15 SST	17x17 Zr	17x17 Zr	16x16 Zr	16x16 Zr
1-545	Туре	Clad	Clad	Clad	Clad	<u>6lad</u>	Clad	Clad	Clad
50	Pellet diameter	0.344							
	(nom), in	0.367	0.367	0.384	0.384	0.322	0.308	0.322	0.325
	Rod diameter	0.400-							
In Re	(nom), in	0.422	0.422	0.422	0.422	0.374	0.360	0.374	0.382
it	Maximut fuel								
18	length, in	144	144	120	120	168	168	144	150
on	Maximum rods/								
Su	element	180	204	180	204	264	264	235	236
bmit ubmi	Maximum cross section,								
tta	(nom, in sç	7.8	8.4	7.8	8.4	8.4	8.4	7.8	7.98
1	Maximum U-235/								
Date	element, kg	26.3	21.5	27.5	22.0	21.75 (144"L)	19.9 (144"L)	24.7	25.1
e						25.5	23.3		
· .						(168"L)	(168"L)		
LH	Maxisum U-235/								
0/0	enrichment, w/o	5.0	4.3	5.0	4.3	4.7	4.3	5.0	5.0

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

•		17x17
71		Zr
-54	Туре	Clad
50	Peliet diameter	
	(aor), in	0.308
	Rod diameter	
In	(nom), 'n	0.360
vi	Maximum fuel	
5 10	length, in	168
on	Maximum rods/	
200	eicment	264
ub	Salimum cross	
mit	retion,	
tte	inom, in sq	8.4
81	Maxim.m 0-235/	20.6
Da	alement, kg	(144"L)
ate	Maximum U-235/	
e	enrichment, w/o	4.45
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(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:

*

	17x17	17x17
	Zr	Zr
Туре	Clad	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/	20.6	23.2
element, kg	(144"L)	(144"L)
Minimum ZrB ₂ IFBA	32(1)	48(1)
rods/element		
Maximum U-235/		
enrichment, w/o	4.45	5.0

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(1) I bad pattern per Westinghouse Drawing SKA-89644.

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Uranium dioxide as aloy or stainless steel clad unirradiated fuel rods of the following , specification:

Туре	SST Clad	ZR Clad	ZR Clad	ZR Clad	ZR Clad	ZR Clad
Pellet diameter (nom), inches	0.384	0.344-0.357	0.308	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:

- Two neutron absorber plates consisting of 0.19 inch thick. full length stainless steel (1)containing 1.3% (minimum) Boron or 0.19 inch thick OFHC reper 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.
- Two neutron absorber plates consisting of 0.19 inch thickness carbon steel are required (3) between the rod boxes.

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Dock	(2)	Maximu	m quantity of material per package:
tet N		(i)	For the contents described in $(1)(i)$, $(1)(ii)$, $(1)(iii)$, and $(1)(v)$:
o. 71			Two fuel elements.
-5450		(11)	For the contents described in (1)(iv):
			One fuel element.
Initi Revis		(111)	For the contents described in (1) (vi):
al Submi ion Subm			Two inner containers containing not more than 80 kilgrams U-235.
ttal Date: ittal Date:	WP3063E	::3p.19	
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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_2^{0} 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.

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DESIGN METHODS

As mentioned previously, the current Westinghouse criticality design methods employ the two $AMPX^{(1)}$ modules NITAWL and XSDENPM 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 XSDENPM 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 Bl0 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.

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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 FNL 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

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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 NCA 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 inpulistings 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 17%17 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 lysis for the CE-type fuel is given in Appendix 16B. 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

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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 Keff 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 - $Gd_2 v_3/cm^2$ 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, Integral Fuel Burnable Absorper (IFBA) rods contained in the fuel assembly. The applicable fuel types for the OFA fuel assemblies ar shown in Table 3.

Table 3 summarizes the KENO calculated nominal Keff for each of the five problems analyzed. The KENO input listings are in Tables 9 through 12D

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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 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, IFBA or enrichments from 4.45 up to 5.0 w/o with a minimum of 48 ZrB₂ IFBA can be shipped under MCA conditions and not exceed the criticality criterion of Keff less than or equal to 0.95. Furthermore, Westinghouse 14x14 CFA, 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 0, 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 Gd₂O₃ coated absorber plates exhibit no criticality safety problems under optimum moderation conditions.

The Westinghouse 17x17 OFA, 17x17 OFA with 32 ZrB, IFBA, 17x17 OFA with 48 ZrB, 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.

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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 Gd203 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, 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.

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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 01 10 8	5.0	0.94978**	0.00261

* This and performed with one assembly per shipping container ** Reported KENO keff results include biases and 95/95 uncertainties

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TABLE 12B (1/2)

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

000000000000000000000000000000000000	8.45 W/D 1 9.7 800 30	70FA IN 0 6 27	27 20 CAS	X WITH 4" 23 81 18	20 19 1 .	20 1 0 10	H20 1 A	SMBLY/CASK
1 -92238 0.000974 1 19228 0.022417 1 18018 0.022417 3 3001 0.023427 3 324020 0.043328 3 32601 0.023427 4 325000 0.00732 4 325000 0.00842 5 32618 0.000812 5 32618 0.00081210 5 32618 0.000132803 5 364182 0.000132803 5 364184 0.000132803 5 364185 0.000132803 5 364186 0.000132803 5 364186 0.000132803 5 364186 0.000132803 5 364186 0.000132803 6 316031 0.00008807 8 326050 0.06429952 8 326051 0.00008807 8 316032 0.382176 8 326055 0.002740.5 71/LANDER 0.48720 0.62982 70.140001	00 0 0	82388						
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OX. TYPE Z O. B6898 O. B6898 O. B2992 O. C O. C O. A5720 O. B5. 78 O. O. 27*O. B GUBOID 5 0.0 -C. 45720 365. 76 -O. O. 27*O. B O. C -O. 45720 365. 76 -O. O. 27*O. B GUBOID 5 0.0 -C. 45720 365. 76 -O. O. 27*O. B O. C -O. 45720 365. 76 -O. O. 27*O. B GUBOID 5 0.62992 -O. 45720 365. 76				-0.62882	0.62992	-0.85885	385.75	-0.0 27-0.5
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CUBDID 6 0.4872 0.0 0.0 -0.45720 365.78 -0.0 27*0.8 BOX TYPE 4 -0.0 0.0 -0.45720 365.76 -0.0 27*0.8 BOX TYPE 4 -0.0 0.0 -0.45720 365.76 -0.0 27*0.8 BOX TYPE 4 -0.0 -0.45720 365.76 -0.0 27*0.8 GUBCID 5 0.0 -0.45720 365.76 -0.0 27*0.8 GUBCID 5 0.0 -0.45720 365.78 -0.0 27*0.8 GUBCID 5 0.0 -0.45720 365.78 -0.0 27*0.8 GUBCID 5 0.62992 -0.62982 0.0 -0.45720 365.78 -0.0 27*0.5 GUBCID 5 0.62992 -0.62992 365.78 -0.0 27*0.5 GUBCID 6 0.82785 0.80896 0.82992 -0.62992 365.76 -0.0 27*0.5 GUBCID 5 0.97883 0.82992 -0.62992 365.76	BOY TYPE		. 02882	.0.02005	0.82982	-0.82882	300.70	-0.0 27-0.9
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BOX TYPE C.0.88788 C.0.88788 C.0.82882 -C.0.82882 365.78 -C.0.27*C.5 CUBCID S C.90805 C.78883 C.82892 -C.62892 365.78 -C.0.27*C.5 CUBCID S C.90805 C.78883 C.82892 -C.62892 365.78 -C.0.27*C.5 CUBCID S 2.99720 C.45720 C.82892 -C.62892 365.76 -C.0.27*C.5 CUBCID S 2.99720 C.0 D.82892 -C.62892 365.76 -C.0.27*C.5 CUBCID S 2.99720 C.0 D.82892 -C.62892 365.76 -C.0.27*C.5 CUBCID S 2.99720 C.0 D.82892 -C.62892 365.76 -C.0.27*C.5 CUBDID S -0.79883 -0.90805 C.82892 -C.62992 365.76 -C.0.27*C.5 CUBDID S -0.79883 -0.90805 C.82892 -C.82992 365.76 -C.0.27*C.5 CUBDID S -0.45720 -2.89720 C.82892 -0.32992 365.76 -O.0 27*C.5 CUBDID	CUROTO .		82002	-0 89889	~ ~	-0 48790		
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CUBDID 5 0.90805 0.78883 0.82882 -0.62892 365.76 -0.0 27*0.5 CUBDID 3 2.99720 0.45720 0.82892 -0.62892 365.76 -0.0 27*0.5 CUBDID 3 2.99720 0.45720 0.82892 -0.62892 365.76 -0.0 27*0.5 CUBDID 8 2.89720 0.0 0.82892 -0.82892 365.76 -0.0 27*0.5 BOX TYPE 7 0.80898 -0.89789 0.82892 -0.62992 365.76 -0.0 27*0.5 CUBDID 5 -0.79883 -0.90805 0.82892 -0.62992 365.78 -0.0 27*0.5 CUBDID 5 -0.79883 -0.90805 0.82892 -0.82992 365.78 -0.0 27*0.6 CUBDID 3 -0.45720 -2.89720 0.62892 -0.52992 365.76 -0.0 27*0.6 CUBDID 3 -0.45720 -2.89720 0.62892 -0.52992 365.76 </td <td>CUBOTO</td> <td></td> <td></td> <td>-</td> <td>-</td> <td>-0 00000</td> <td></td> <td>-0 0 07+0 8</td>	CUBOTO			-	-	-0 00000		-0 0 07+0 8
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CUBCID B 2.88720 0.0 0.82882 -0.82882 385.76 -0.0 27*0.5 BOX TYPE 7 -0.80888 -0.89788 0.82882 -0.82882 385.76 -0.0 27*0.5 CUBDID 5 -0.78883 -0.90805 0.82882 -0.62882 385.78 -0.0 27*0.5 CUBDID 5 -0.78883 -0.90805 0.82882 -0.62882 385.78 -0.0 27*0.5 CUBDID 3 -0.45720 -2.88720 0.62882 -0.32882 385.76 -0.0 27*0.5 CUBDID 3 -0.45720 -2.88720 0.62882 -0.32882 385.76 -0.0 27*0.5	CUBCID S		88720	0 45720	0 82882	-0 82882	398 78	-0.0 9720 5
BOX TYPE 7 CUBDID 6 -0.80888 -0.89788 0.82882 -0.82882 385.78 -0.0 27*0.8 CUBDID 5 -0.78883 -0.90805 0.82882 -0.62882 385.78 -0.0 27*0.8 CUBDID 5 -0.78883 -0.90805 0.82882 -0.62882 385.78 -0.0 27*0.8 CUBDID 3 -0.45720 -2.88720 0.82882 -0.32882 385.78 -0.0 27*0.8	CURCID .		89720	0.0	0 82882	-0 82892	338 78	-1. 0 27+0 8
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CUBOID 2 -0.45720 -2.89720 0.82892 -0.52992 385.78 -0.0 27+0.8	CUBOID	-0	79883	-0. 90805	0.62002	-0.89999	385 78	-0.0 27:0 5
	CUBOID	-0	45720	-2.88720	0.82002	-0. 39999	385 76	-0.0 2740 8
	CUBOID	i o	.0	-2.88720	0.82999	-0.82892	365 75	-0.0 2710 5
BOX TYPE &	BOX TYPE							
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CUBOID	8		0.	0		-2	. 8	8720	ō	. 6	2992	-0	. 6	8822	385	78	-0			27	0	
CUBOID	6		21	41							1998											
BOX TYPE	18		• • •	- • •		-			0	. 0		-0	. 48	5720	385	. 78	-0	.0	1	27:	0.	8
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Docket No. 71-5450 Initial Submittal Date: 10/05/89 Page No. 19.30.2 Revision Submittal Date: _____ Rev. No. __O___

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 1	170FA 3	2 IFBA	108 IN	B10*.9	5 STD S	HIPPIN	IG CASK	H20=:	1.0 G/CM3
19.7 900 3	300 5 2	7 27 2	7 9 30 34	11 18	19 1 -2	710	1011 0	1 1 1	1000
00 0 0	92189								
-111	11.	-11							
1 -192235	5	.00105	74						
1 192238	3	.02241	7						
1 18016		.04694	9						
2 -492235	5	.00105	74						
2 492238	3	.02241	7						
2 48016		.04694	9						
3 240302	2	.04332	5						
4 540302	2	.04332	6						
4 55010		.00016	4445						
5 31001		.06685	4						
5 38016		.03342	7						
6 61001		.06685	4						
6 68016		.03342	7						
7 326000)	.05801	9						
7 324000)	.01738	6						
7 328000)	.00814	2						
7 325055	5	.00173	2						
8 38016		.00981	210						
8 364152	2	.00001	3083						
8 364154	1	.00014	2603						
8 364155	5	.00096	8129						
8 364156	5	.00133	9027						
8 364157	7	.00102	3731						
8 364158	3	.00162	4886						
\$ 364160)	.00142	9952						
9 326000)	.08420	12						
9 36012		.00047	290						
9 325055	5	.00038	871						
9 315033	1	.00005	B(17						
9 316032	2	.00006	642						
BOX TYPE	1								
CYLINDER	1	.39217	6				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	.39217	6				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

Docket No. 71-5450 Initial Submittal Date: 10/05/89 Page No. 19.30.3 Revision Submittal Date: _____ Rev. No. ____

TABLE 12C (2/2)

2

BUX TIPE	4																									
CUBOID	9		.457	2	0.0)	0.	0			45	72			:	36	5.	76		-0	.0	2	7:	0.	5	
CUBOID	5	2	2.997	2	0.0)	0.	0			45	72			1	36	5.	76	; -	-0	.0	2	71	0.	5	
BOX TYPE	5																									
CUBOID	9		. 629	92	6	299	2 0	.0		-	45	72			:	36	5.	76	; -	-0	.0	2	71	0.	5	
BOX TYPE	6		12750	17.			999																			
CUBOID	9		.897	89	. 8	089	9.	62	99:		62	99	2			36	5.	76		-0	. 0	2	71	0.	5	
CUBOTD	8		.908	05		988	3	62	99:	-	62	99	2			36	5.	76		-0	. 0	2	71	0	5	
CUBOTD	5	,	997	2		572	•••	62	99:	-	62	99	2			36	5	76		-0	. 0	2	7 1	0	5	
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BOX TYPE	2	•		•	0.		•	02	222		. 02	23	-			50	۶.	10		-0	•••	•	1		2	
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CUBOID	5		.45/	2	0.	0	•	62	224		602	39	-			20	5.	70		0	.0	20			5	
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BOX TYPE	9																_						_			
CUBOID	9		.457	2	0.	0		2.	71.	272	0.	0				36	5.	76		-0	.0	2	71	•0.	5	
CUBOID	5	2	2.997	2	0.	0		5.	08	0	. 0					36	5.	76	, .	-0	.0	2	71	0.	5	
BOX TYPE	10			111																				÷		
CUBOID	9		.897	89	. 8	1089	9	•	629	92	0.	18	288	3		36	5.	76	· ·	-0	. 0	2	71	10.	5	
CUBOID	8		.908	105	. 7	988	3		629	92	0.	19	288	3		36	5.	76	5 -	-0	.0	2	71	•0.	5	
CUBOID	5	2	2.997	2	.4	572			629	92		62	992	2		36	5.	76	; •	-0	.0	2	71	•0.	5	
CUBOID	9	2	2.997	2	0.	0			629	92		62	992	2		36	5.	76	5 •	-0	.0	2	71	10.	5	
BOX TYPE	11																									
CUBOID	9		.897	89	. 8	8089	9		299	72		62	992	2		36	5.	76	; .	-0	.0	2	71	+0.	5	
CUBOID	8		.908	105		988	3		299	72		62	992	2		36	5.	76	; .	-0	.0	2	71	10.	5	
CUBOID	5	2	2.997	2	. 4	572			629	92		62	99:	2		36	5.	76	; .	-0	.0	2	71	.0	5	
CUBOID	9	2	2.997	2	0.	0			629	92		62	992	2		36	5.	76	5 .	-0	. 0	2	71	+0.	5	
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CUBOID	-		10 00	724	-	12.5	272	4	13	47	724		51	12	00	4	36	5.	76	5	-0	. 0		271	0.	5
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CUBOID 1 1 18 2 3 15 2 2 16 2 7 11 2 8 10 2 8 10 2 8 10 2 8 10 2 4 14 2 4 5 2 13 14 3 3 15 3 4 14 3 6 12 4 18 18 5 1 17 6 18 18 7 18 18 8 1 17	5 9 12 14 4 2 10 1 1 3 10 3 1 1 1 1	1 1 3 4 5 5 6 8 9 9 7 5 4 1 1 3 8 9	12.20 12.20 18 17 16 15 14 12 11 13 15 16 18 19	0724 14 12 10 10 8 4 22 3 10 12 1 1 1 1 1 1 1 1 1 1 1 1 1		2.7		10	13 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		330		51.	. 34	610	D	36	5.	76	5	-0	.0				
CUBOID 1 1 18 2 3 15 2 2 16 2 7 11 2 8 10 2 8 10 2 8 10 2 8 10 2 4 14 2 4 5 2 13 14 3 3 15 3 4 14 3 6 12 4 18 18 5 1 17 6 18 18 7 18 18 8 1 17 9 18 18	5 9 12 14 4 2 10 1 1 3 10 3 1 1 1 1 1	1 1 3 4 5 5 6 8 9 9 7 5 4 1 1 3 8 9 9 7 5 4 1 1 3 8 9 9 7 5 4 1 1 3 8 9 9 7 5 4 1 1 3 4 5 5 6 8 9 9 7 5 4 1 1 3 4 1 1 3 8 9 9 7 5 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	12.20 12.20 18 17 16 15 14 12 11 13 15 16 18 19 19	0724 14 12 10 10 8 4 22 3 10 12 1 1 1 1 1 1 1 1 1 1 1 1 1		2.7	533 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	10	13 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		330		51.	. 34	610	D	36	5.	76	5	-0	.0				
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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/ 14.7 50	/0 1 00 3	70FA 00 5	48	1	FBA 7 2	108	30 3	B10*	.95 18	5 ST 19 1	D SHI -27	PPII 1 0	NG C 101	ASK 1 0	H20= 1 1	1.0	0 G,	/CM3 0
		10036																
-11.	-1	1.		1.	-1													
1 -192	2235		•	00	119	99												
1 192	2238		1961	02	227	5												
1 180	016		•	04	695	5												
2 -492	2235			00	119	99												
2 492	2238		•	02	227	6												
2 480	016			04	695	5												
3 240	0302			04	332	6												
4 540	0302			04	332	6												
4 550	010			00	016	4445	5											
5 310	001			06	685	4												
5 380	016			03	342	7												
6 610	001			06	685	4												
6 680	016			03	342	7												
7 326	5000			05	801	9												
7 324	1000			01	738	6												
7 328	3000			00	814	2												
7 325	5055			00	173	2												
8 380	016		100	00	981	210												
8 364	1152			00	001	3083	3											
8 364	1154			00	014	2603	3											
8 364	1155			00	096	8129												
8 364	4156			00	133	9027	7											
8 364	1157			00	102	3731												
8 364	1158			00	162	4886	5											
8 364	1160	1.1.1.1.1		00	142	995	5											
9 326	5000			08	420	12												
9 360	012			00	047	290												
9 324	5055			00	038	871												
9 31	5031			00	005	807												
9 316	5032			00	006	642												
BOY TVI	DF	1		~~	000	042												
CVLIND	TD	1		20	217	6							265	76	-0 0		7+0	5
CVLINDI	PD	0		10	005	0							265	76	-0.0	5.	7+0	
CYLINDI	PD	2	•	40	720								305	. 70	-0.0	2	7+0	.5
CUPOTD	DR	5	•	40	000			620	00	- 62	000		305	. 10	-0.0	2	7+0	. 5
COBUID	-	5	•	02	992		2992	029	92	02	992		305	. /0	-0.0	2	/*0	. 5
BUX TIL	PL PD	2													~ ~		-+-	-
CYLIND	SK ED	2	•	39	211	0							365	. /0	-0.0	2	/=0	. 2
CYLINDI	CX CD	0	•	40	005								305	. 10	-0.0	2	/*0	.5
CYLIND	ER	4	•	40	120				~~				365	. 10	-0.0	2	/*0	.5
COBOID		0	•	02	992	,	52992		92	62	992		365	.76	-0.0	2	/*0	.5
BOX TY	PE	3																-
CYLIND	ER	5	•	56	896								365	.76	-0.0	2	7*0	.5
CYLINDI	ER	3	•	60	198								365	. 16	-0.0	2.	/*0	.5
CUBOID		5	•	62	992	(52992	.629	92	62	992		365	.76	-0.0	2	7*0	.5
BOX TY	PE	4																
CUBOID		9		45	72	0.0	0	0.0		45	72		365	.76	-0.0	2.	7*0	.5
CUBOID		5	2.	99	72	0.0	0	0.0		45	72		365	.76	-0.0	2.	7*0	.5

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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 8 CUBOID .90805 .79883 .62992 -.62992 365.76 -0.0 27*0.5 2.9972 .4572 .62992 -.62992 5 CUBOID 365.76 -0.0 27*0.5 .62992 -.62992 CUBOID 9 2.9972 0.0 365.76 -0.0 27*0.5 7 BOX TYPE 9 .4572 0.0 .62992 -.62992 5 2.9972 0.0 .62992 -.62992 CUBOID 365.76 -0.0 27*0.5 CUBOID .62992 -.62992 5 2.9972 0.0 365.76 -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 2.71272 0.0 5.08 0.0 CUBOID 9 .4572 0.0 365.76 -0.0 27*0.5 2.9972 0.0 CUBOID 5 365.76 -0.0 27*0.5 BOX TYPE 10 .89789 .80899 .62992 0.18288 CUBOID 9 365.76 -0.0 27*0.5 .90805 .79883 8 CUBOID .62992 0.18288 365.76 -0.0 27*0.5 CUBOID 5 2.9972 .4572 .62992 -.62992 365.76 -0.0 27*0.5 .62992 -.62992 CUBOID 9 2.9972 0.0 365.76 -0.0 27*0.5 BOX TYPE 11 .89789 .80899 -.29972 -.62992 CUBOID 9 365.76 -0.0 27*0.5 .90805 .79883 -.29972 -.62992 365.76 -0.0 27*0.5 8 CUBOID 365.76 -0.0 27*0.5 CUBOID 5 2.9972 .4572 .62992 -.62992 9 CUBOID 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 5 CUBOID 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 3 15 4 3 17 14 1 0 2 1 1 2 2 15 14 4 16 4 1 1 1 0 5 15 10 8 10 1 2 2 1 1 0 2 8 10 2 6 14 8 1 1 1 0 2 8 12 4 1 8 10 2 1 1 0 5 15 10 1 2 7 11 4 1 1 0 7 11 4 2 9 11 2 0 1 1 1 4 14 10 8 12 4 1 1 2 1 0 2 4 14 10 2 9 11 1 1 1 0 2 5 13 8 2 9 1 11 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 6 12 3 4 3 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 1 7 18 18 1 18 18 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

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Rev. No. 0

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. KEND MODEL PARAMETERS: 1. MODELED B " LOADING: 1.9 MG LIN. 2. MODELED POISONED FUEL LENGTH: 108 IN. Y EGEND : POISON FUEL RODS (32 ROD/ASSY) : FUEL RODS (232 ROD/ASSY) X . THIMBLE AND INSTRUMENT LOCATIONS (25 LOC/ASSY)

C	JPR.	10/05 89		Westinghou	ise Electri	c Corporat	ion
•	₩D			WATER REACTOR	DIVISIONS - CO	LIMBIA S.C. U	S.A.
•	PPO RD montgomen	10/05	AREA / PROCESS	WATER REACTOR	011101040 04	2010111, 0.0. 0	
	990			1001 (05			TIC
A	940		TLAN	4 45 WT%	17 OFA	FLIEL ASS	SY
·	PD		1			TOLL MO	
~	PPD		SIZE REON NO	DWG ND			REV
	PPD		A 558	55 S	KA-80	9044	01
A	PD		1/2		I	01 01	