

## 10.7 Criticality Evaluation for MARK 22 Fuel

A Mark 22 fuel assembly consists of two concentric fuel tubes with uranium-aluminum cores containing a total of 3.2 kilograms of uranium-235 as shown in Figure X-14. The cores are clad with Type 8001 aluminum and the assembly previously included inner and outer targets, which have been removed. The uranium was initially enriched to contain 66-80 w/o uranium-235. An enrichment of 80 w/o uranium-235 was used in the criticality analysis as a bounding case. The densities used in the analyses were obtained directly from the manufacturer and are listed in Table X-10.

Table X-10  
Mark 22 Fuel Densities

<u>Isotope</u>	<u>Inner Core (atoms/barn-cm)</u>	<u>Outer Core (atoms/barn-cm)</u>
U-235	1.9887-3	2.0288-3
U-236	2.3300-4	2.3275-4
U-238	2.1426-4	2.1391-4
Aluminum	5.6357-2	5.6363-2

Cross-section sets were prepared by NITAWL using infinite dilution. Dancoff factors are not applicable for this assembly because of the annular cylinder geometry and resonance calculations were conservatively ignored in these analyses. The cross-section set used for these analyses is the 27 group version of the ENDF-B/IV library. These cross-sections were not collapsed or weighted, and were passed directly from NITAWL to KENO-IV. The output for NITAWL is given in Appendix E. Oak Ridge National Laboratory has validated the codes and cross-section set used in the analyses and shows that SCALE is conservative for reflected, highly enriched uranium systems.

Two Mark 22 assemblies or one Mark 22 assembly with the two cores separated will be transported in the NLI-1/2 cask; therefore, two quadrants of the four-quadrant "Rockwell basket" will contain fuel. The criticality analyses were performed for the bounding case of two adjacent intact fuel

assemblies as shown in Figure X-15. The cask geometry that was modeled in KENO-IV is shown in Figure X-16. This analysis resulted in a  $k_{eff}$  of 0.533. Values for  $k_{eff}$  were calculated for the Mark 22 assembly at different pitches. The assembly was assumed to be moderated by heavy water as it is in the reactor. The most reactive pitch is approximately 26 centimeters, which cannot be achieved by two Mark 22 assemblies in the NLI-1/2 cask. The low  $k_{eff}$  of 0.533 is then understandable when it is realized that the fuel was analyzed in a light water, under moderated and poisoned configuration. The input and output for this case are given in Appendix D. Table X-12 demonstrates that the loaded cask meets the criteria established for Fissile Class I packages, as determined by 10 CFR 71.57.

An alternate configuration of the fuel was also modeled to simulate a hypothetical accident scenario. The fuel was evaluated as two cylinders centered in adjacent quadrants as shown in Figure X-17. The accident configuration yielded a  $k_{eff}$  lower than 0.533. This analysis shows that the initial annular configuration of the Mark 22 fuel assembly is the most reactive one as was the case for the Mark 42 assembly. The criticality results for the different cases are presented in Table X-11. Table X-12 demonstrates that the loaded cask meets the criteria established for Fissile Class I packages, as determined by 10 CFR 71.57. The results of the criticality evaluation for the NLI-1/2 cask containing two Mark 22 fuel assemblies show that  $k_{eff}$  does not exceed 0.533.

Table X-11  
Mark 22 Fuel Criticality Results Summary

<u>Case</u>	<u><math>k_{eff}</math></u>
Normal Operation	0.533
Hypothetical Accident	0.363

**Table X-12**  
**SUMMARY OF CRITICALITY EVALUATION FOR MARK 22 FUEL ASSEMBLIES**  
**FISSILE CLASS I**

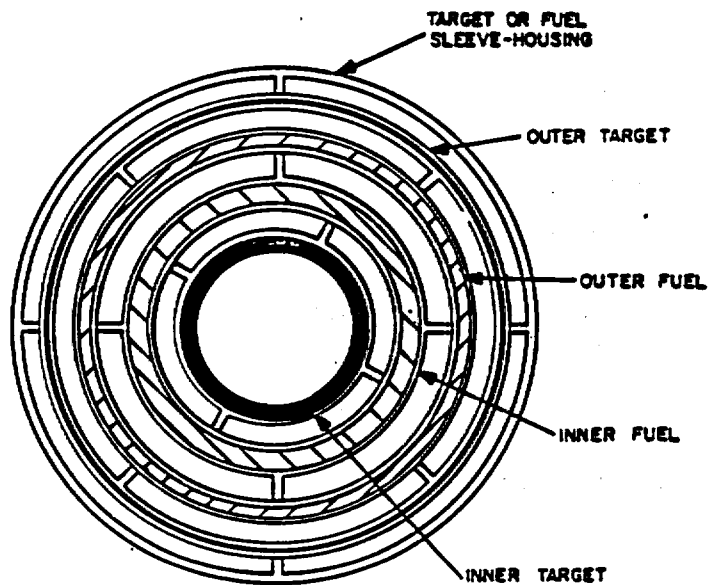
**NORMAL CONDITIONS**

Number of undamaged packages calculated to be subcritical (Fissile Class I must be infinite)	Infinite
Optimum interspersed hydrogenous moderation (required for Fissile Class I)	yes
Closely reflected by water (required for Fissile Class II and III)	yes
Package size, cm <sup>3</sup>	60,240

**ACCIDENT CONDITIONS**

Number of damaged packages calculated to be subcritical	Infinite
Optimum interspersed hydrogenous moderation, full water reflection	yes
Package size, cm <sup>3</sup>	60,240
Other Transport Index	Not applicable

Figure X-14  
MARK 22 ASSEMBLY CROSS SECTION



MARK 22  
Cross Section  
NOT TO SCALE

Dimensions (inches) and Characteristics:

	Universal Sleeve- housing	Outer Target			Fuel Tubes						Inner Target		
					Outer			Inner					
		Cladding	Core	Both	Cladding	Core	Both	Cladding	Core	Both	Cladding	Core	Both
Material	Al	Al	Li-Al	-	Al	235U-Al	-	Al	235U-Al	-	Al	Li-Al	-
Length	251.68 <sup>a</sup>	170.50	159	-	163.00	150	-	161.50	150	-	176.44	163	-
W	4.110	3.700	3.642	-	3.200	3.140	-	2.353	2.293	-	1.590	1.530	-
W	4.010	3.540	3.600	-	2.892	2.932	-	1.993	2.033	-	1.233	1.293	-
Mid circle dia	3.740	3.230 <sup>b</sup>	-	-	-	-	-	-	-	-	1.965	-	-
Thickness <sup>c</sup>	0.030	0.030 <sup>d</sup>	0.021	0.080	0.030	0.094	0.154	0.030	0.119	0.179	0.030	0.118	0.178
Weight, lb	13.6 <sup>d</sup>	-	-	16.1	-	-	26.8	-	-	23.1	-	-	14.2
235U, g	-	-	-	-	-	1680	-	-	1520	-	-	-	-
d/ft	-	-	-	-	-	134.4	-	-	121.6	-	-	-	-
Li, g	-	-	11.93	-	-	-	-	-	-	-	-	33.83	-
g/ft	-	-	0.90	-	-	-	-	-	-	-	-	2.48	-
Gross-sectional area, in. <sup>2</sup>	0.670	0.628	0.342	0.970	0.374	0.900	1.474	0.488	0.813	1.301	0.250	0.586	0.834
Channel flow area, in. <sup>2</sup>		Outer	Outer Middle	Inner Middle	Inner	Dead Space							
Total assembly		1.840	1.740	2.142	1.092	1.198							
Volume displacement, in. <sup>3</sup>			1145										
Weight, lb <sup>e</sup>			118.8										

Figure X-15  
MARK 22 ACTUAL CASK LOADED

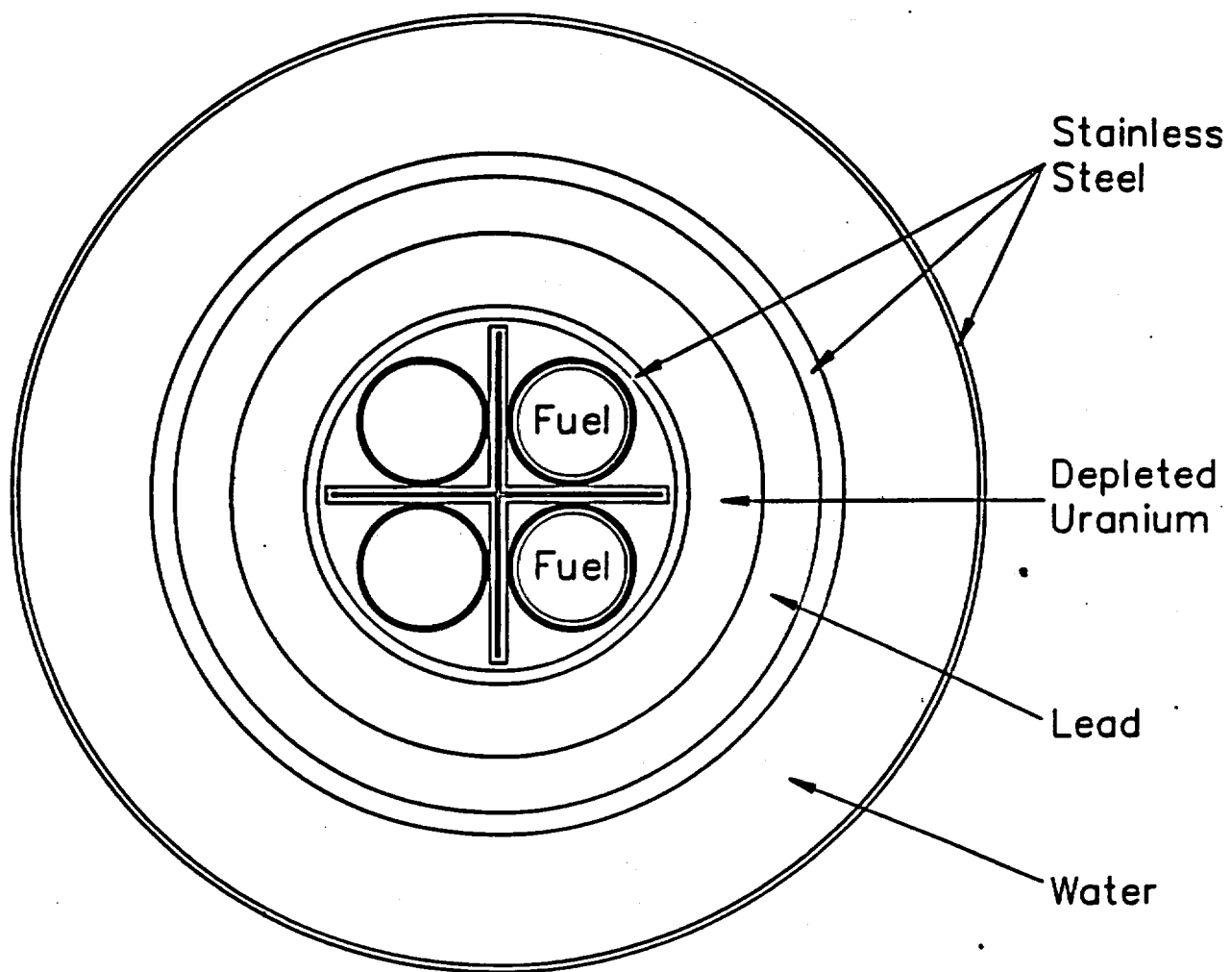


Figure X-16  
MARK 22 KENO Model

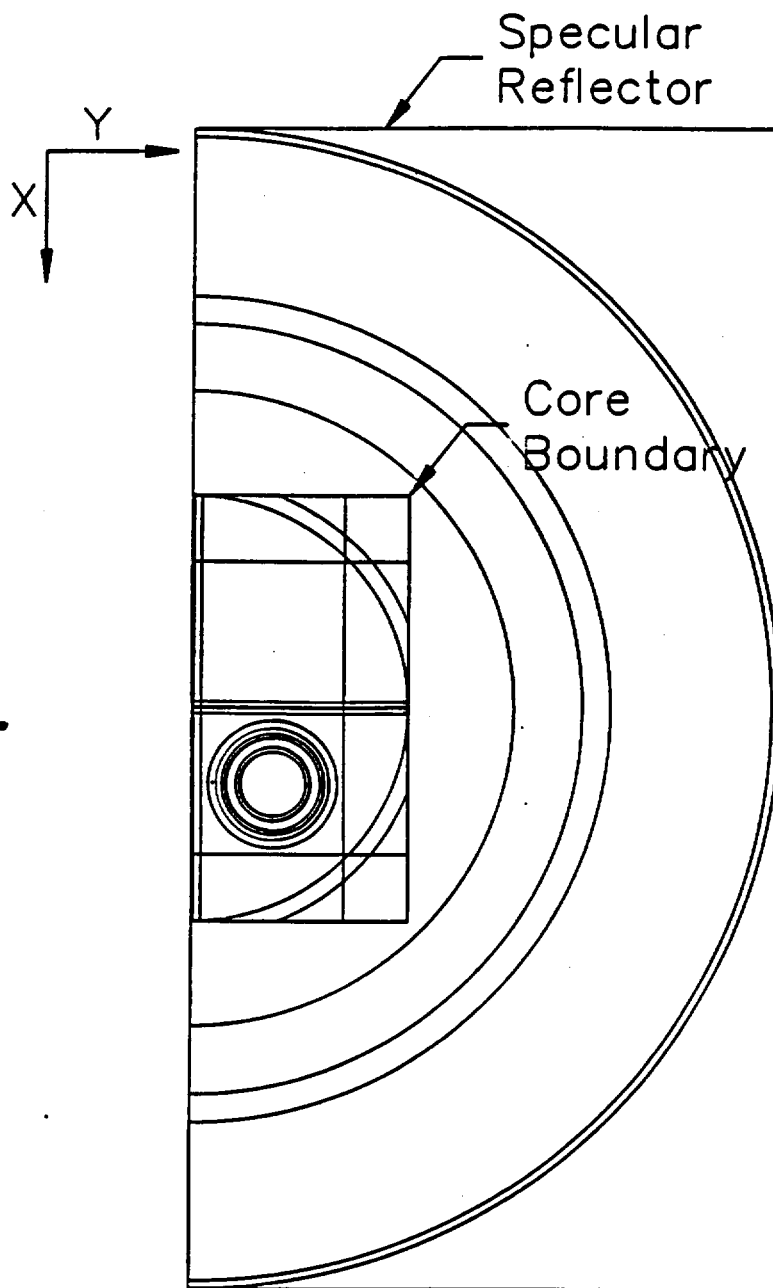
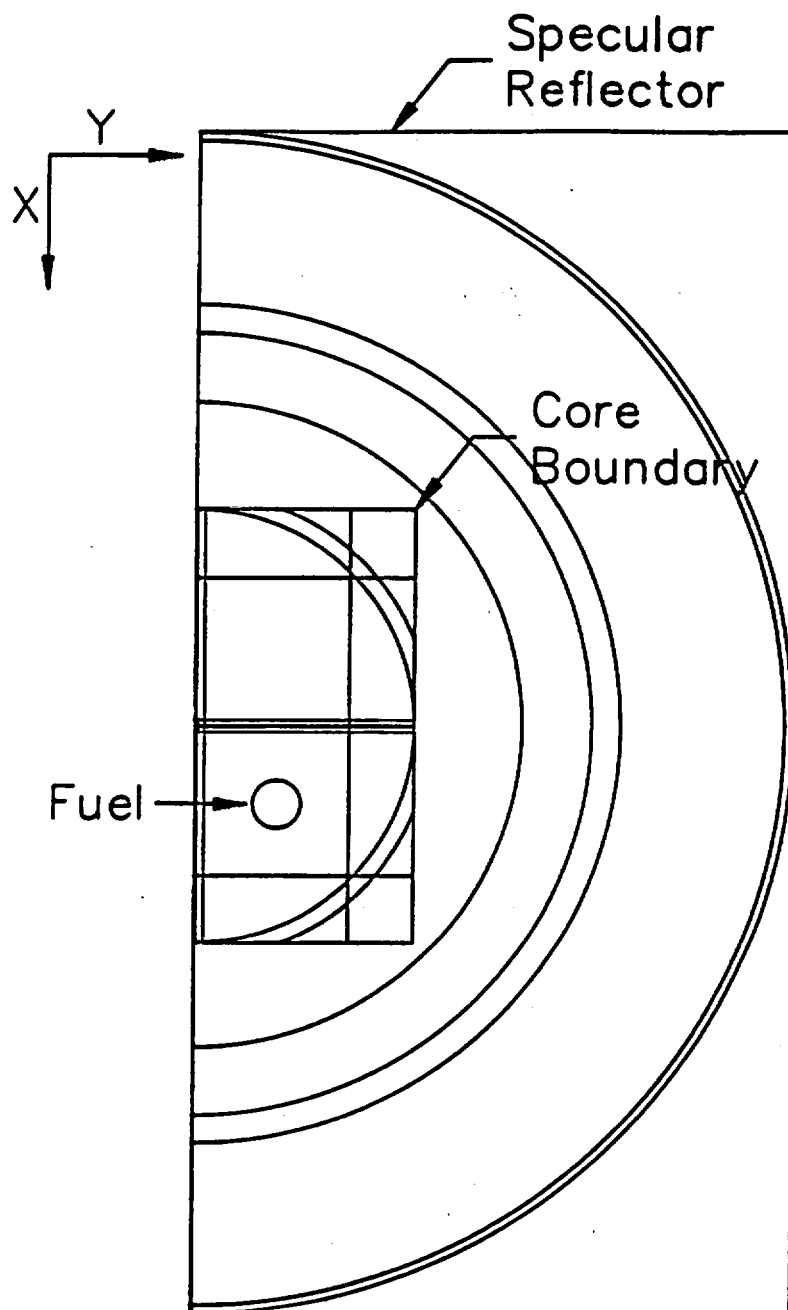


Figure X-17  
MARK 22 KENO Model  
Hypothetical Accident



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## 10.8 CRITICALITY EVALUATION FOR FERMI-1 AND EBR-II FUELS

### Introduction

The AMPX/KENO-IV computer system was used in conjunction with a 27 energy group SCALE nuclear data library to calculate k-effectives for both fuel types in normal operation and hypothetical accident scenarios. The NULIF computer code maintained by Babcock and Wilcox was used to determine the optimum pitches of the fuel types within the cans containing them. NULIF also calculates the Dancoff coefficient and effective moderator cross-section required by the NITAWL module of AMPX. The fuel region was "homogenized" using the XDRNPM module of AMPX and the resulting fuel was modeled using the KENO-IV mixed box geometry. The NLI-1/2 cask was modeled as concentric cylinders of Uranium (depleted), lead, steel, water, and steel using the actual cask dimensions except for the inner Uranium layer. This layer intersects with the core boundary of the mixed box representation and the inside Uranium radius was adjusted accordingly. This results in excess water at the outside corners of the core region and a small reduction in the depleted Uranium shield of the cask. All analyses were performed with an "infinite" fuel length. The longest actual active fuel length (156.8 inches for the EBR-II) is less than the Boral plate length (167 inches), so that the four fuel regions are separated by Boral at any axial location.

# FERMI-1 FUEL PARAMETERS

1. Fuel assembly consists of 140 rods arranged in a 2.4" by 2.4" array. Outer channel is 2.693" square. Some assemblies are in cans that are 2.928" square. They are stored in a water pool so that all Na has been removed.
2. The rods are U/Mo alloy (10% Molybdenum) with 25.6% U-235 enrichment. They are clad with Zr 5 mils thick, metalurgically bonded to the rod.

	<u>Unirradiated</u>	<u>Per Rod</u> <u>Irradiated</u>
Total U	133.9g	132g
U-235	34.4g	33.6g
w/o	25.7	25.5
Burnup	0	1600 max., 410 avg. MWD/MTU

## Per Assembly (Unirradiated)

U	18.746 kgU
U-235	4.816 kgU-235

3. Each rod is 0.158" O.D. with a 5 mil cladding

$$\begin{aligned} R_{\text{fuel}} &= 0.1880\text{cm} \\ R_{\text{rod}} &= 0.2007\text{cm} \end{aligned}$$

$$\begin{aligned} \text{Length of Assembly} &= 36.62" \\ \text{Active fuel length} &= 30.50" \end{aligned}$$

4. Densities

The alloy density is 17.3 g/cm<sup>3</sup> with 90 w/o U and 10 w/o Molybdenum

$$N_x = \rho N_A / A_x \cdot w/o_x$$

$$N_{238} = \frac{(17.3)(6.024 \times 10^{23})}{238} \times 0.90 \times (1-0.256) = 2.932 \times 10^{22} \text{ atom/cm}^3$$

$$\begin{aligned} N_{25} &= 1.0218 \cdot 10^{22} \text{ atoms/barn-cm} \\ N_{28} &= 2.932 \cdot 10^{22} \end{aligned}$$

$$N_{\text{Mo}} = 1.087 \cdot 10^{22} \text{ (} A_{\text{Mo}} = 95.9 \text{)}$$

$$\text{Also } \sigma_3(\text{Mo}) = 6 \text{ barns; for NITAWL, } \sigma_3 = \frac{N_{\text{Mo}}}{N_{28}} \sigma_3(\text{Mo}) = 2.22 \text{ Barns}$$

5. Rod Arrangement

Assuming a 3" square hole for the assembly, the rods would have a square pitch of 0.635 cm. This equally allocates the water area to a 12 by 12 square lattice. Including the 4 water rod locations (distributing the area equally to each of the 140 rods) yields a slightly larger pitch of 0.644 cm. The rod cell on this case has a radius of 0.3633 cm. This pitch is used for the normal operation analysis, the no-moderator analysis and the boron sensitivity analysis. In the Hypothetical Accident scenario the fuel separates to a pitch of 0.856 cm, the optimum pitch.

The 0.856 cm optimum pitch is the maximum pitch permitted by the structural tubes containing the fuel, which have a 4.5" I.D. Using the B & W NULIF program, the optimum pitch of the rods is found by computing  $k_{oo}$  versus pitch.

Pitch(cm)	$k_{oo}$
0.500	1.4736
0.600	1.5389
0.644	1.5702 (Maximum Hypothetical Attainable)
0.700	1.6069 in 3" can
0.800	1.6591
0.856	1.6803
0.900	1.6932
1.000	1.7113
1.100	1.7162
1.200	1.7102
1.300	1.6955

6. Data (from NULIF) for AMPX/KENO  
Normal Operation:

$$\begin{aligned} \Sigma_{(G_m)}^{po} &= 0.4879 & \bar{T} &= 0.5753 \\ (G_m)_{eff} &= 76.34 & C &= 0.3464 \end{aligned}$$

Hypothetical Accident

$$\begin{aligned} \Sigma_{(G_m)}^{po} &= 0.4879 & \bar{T} &= 0.4553 \\ (G_m)_{eff} &= 92.06 & C &= 0.1741 \end{aligned}$$

"Homogenized" Fuel Densities

Normal Operation:

Nu235	=	2.146-3
Nu238	=	6.157-3
Nmo	=	2.286-3
Nzr	=	1.242-3
N <sub>H</sub>	=	5.089-2
No	=	2.545-2

Hypothetical Accident

Nu235	=	1.5484-3
Nu238	=	4.4430-3
Nmo	=	1.6472-3
Nzr	=	8.9465-4
N <sub>H</sub>	=	5.5379-2
No	=	2.7690-2

7. KENO Model

The geometry of the KENO Model is illustrated in Figures X-18 and X-19. Four different fuel locations were investigated: a normal operation case (Figure X-20) with the fuel located by the non-structural aluminum tube of the basket, and a hypothetical accident scenario (Figure X-21) in which the tubes vanish and the fuel is free to cluster at the center of the basket. In this scenario, the Boral at the very center of the basket is assumed to disappear because it is not supported by the steel of the basket. An additional calculation was performed for the normal operation geometry in which all moderator was removed from the fuel region. This case is necessary to demonstrate that the fuel is subcritical for the fast spectrum present during dry shipment. This unmoderated case used the cross-sections without the cell-weighting performed by XSDRNPM. The sensitivity of the basket to neutron channeling between boron carbide grains was evaluated by re-performing the normal operation case with 75% of the boron concentration.

Assumptions for Rockwell Basket Geometry (see Figure X-19)

#### A. Boral Locations:

1. Treat all 4 legs of cruciform the same. The Boral plates extend 6.3" to the outer part of the cruciform legs except on the side with the drain line channel, which extends 4.81" from the center. The Boral has been extended to 6" for conservation.

#### B. The Total cruciform thickness is:

$$T = \text{Boral plate thickness} + 2t = 0.2882 \text{ cm} + 1.27 \text{ cm} \\ (0.1135") \quad (0.50") \\ = 1.5582 \text{ cm}$$

The half width is thus 0.7791 cm.

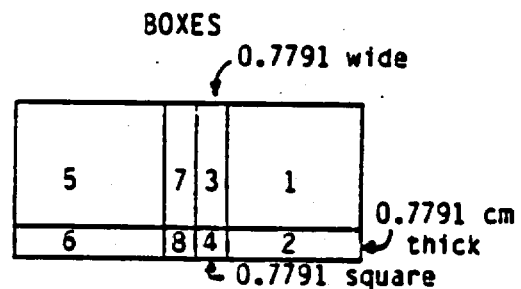
#### C. Fuel Locations:

1. Fermi-1: The Fermi fuel is a 2.936" square centered in a 5" OD tube. The center of the fuel square is thus 2.5" (6.35cm) from the surface of the stainless steel cruciform. The tube around the fuel is not part of the license drawings and is treated as water for the criticality analysis, it just centers the fuel in normal operation.
2. EBR II fuel: The fuel is a 4.875" OD can that is free to contact the cruciform walls.

#### KENO GEOMETRY

##### Materials

- 1-Fuel
- 2-Boral
- 3-Water
- 4-SS
- 5-Al
- 6-Pb
- 7-depleted U



##### 8 Box Types

Box Type 1	Fermi, Normal Operation (Al Tube Ignored)			
CUBOID 1	7.62	0.00	7.62	0.00
CUBOID 3	10.16	-2.54	10.16	-2.54
		5"		

Box Type 2					
CUBOID 2	13.015	0.00	0.1441	0.00	1000.-1000. 27±0.5
CUBOID 4	13.015	0.00	0.7791	0.00	"
(5")					
Box Type 3					
CUBOID 2	0.1441	0.00	13.015	0.00	"
CUBOID 4	0.7791	0.00	13.015	0.00	"
Box Type 4					
CUBOID 4	0.00	-0.635	0.00	-0.635	"
CUBOID 2	0.00	-0.7791	0.00	-0.7791	"
Box Type 5					
CUBOID 1	7.62	0.00	7.62	0.00	"
CUBOID 3	10.16	-2.54	10.16	-2.54	"
Box Type 6					
CUBOID 2	0.00	-13.015	0.1441	0.00	"
CUBOID 4	0.00	-13.015	0.7791	0.00	"
Box Type 7					
CUBOID 2	0.00	-0.1441	13.015	0.00	"
CUBOID 4	0.00	-0.7791	13.015	0.00	"
Box Type 8					
CUBOID 4	0.635	0.0	0.00	-0.635	"
CUBOID 2	0.7791	0.0	0.00	-0.7791	"

#### 8. Computer Results

The computer inputs and outputs are provided in Appendix F. The results for the AMPX/KENO analyses are provided below. The results of the analyses are summarized here along with the results corrected for bias and uncertainties ( $k_s$ ).

Case	Calculated $K_e$	$k_s$
Normal Operation, fuel centered in tubes	0.80637±0.00480	0.827
Hypothetical Accident	0.93662±0.00313 0.93720±0.00397	0.956
Boron Sensitivity: 75% of 8-10	0.81949±0.00492	0.841 ( $\Delta k_s = 1.7\%$ )
No Moderator	0.65500±0.00477	0.676

$$k_s = k_{\text{calculated}} + \underset{\text{(bias)}}{0.00981} + \underset{\text{(experimental uncertainty)}}{0.001711} + \underset{\text{(calculation uncertainty)}}{(1.645\sigma^2 + 0.00722^2)^{1/2}} \underset{\text{(benchmark calcs)}}{\text{Uncertainty of}} \quad \text{Uncertainty of}$$

FIGURE X-18

NLI 1/2 KENO MODEL (FERMI-1 FUEL SHOWN)

$+ \gamma$

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE X-19  
KENO GEOMETRY

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE X-20  
FERNI-I  
NORMAL OPERATION

FIGURE WITHHELD UNDER 10 CFR 2.390



**FIGURE X-21**  
**FERHI-I**  
**HYPOTHETICAL ACCIDENT**

**FIGURE WITHHELD UNDER 10 CFR 2.390**

# EBRII FUEL PARAMETERS

1. Fuel consists of a circular canister containing 41 rods. The arrangement of these rods is random so the optimum spacing is determined (via the NULIF program) and the can is treated as if it contained fuel all of which is at the optimum spacing. The can itself is not considered in the criticality analysis except to define the boundary of the fuel.
2. The fuel slugs are of depleted Uranium plus Plutonium. The canister contains 3.876 kg Pu and 287.9 kgU (0.21% U-235). The fuel density is 19.3 g/cm<sup>3</sup>. All Pu is treated as Pu-239, given its fissile nature.
3. Rod Dimensions

$$R_{\text{fuel}} = 0.5499 \text{ cm}$$

$$R_{\text{rod}} = 0.79375 \text{ cm Aluminum clad}$$

$$\text{Active Fuel Length} = 156.8 \text{ inches}$$

## 4. Densities

The alloy is 0.01328 w/o Pu in Uranium.

$$N_U = 19.3 \times \frac{N_0}{238} (1-0.01328) = 4.820 \cdot 10^{-2} \text{ atoms/barn-cm}$$

$$N_{28} = 4.810 \cdot 10^{-2}$$

$$N_{25} = 1.025 \cdot 10^{-4}$$

$$N_{\text{pu}} = 6.460 \cdot 10^{-4}$$

For NITAWL, the U-238 is treated without a scattering nuclide present. The Pu-239 is affected by the U-238 (even though the energy transfer for a neutron colliding with U-238 is small), so the  $\sigma_s$  for the Pu-239 resonance calculation is:

$$\sigma_s(\text{U-238}) = 12 \text{ barns}; \quad \sigma_s = 893.5 \text{ barns per Pu atom.}$$

5. The optimum pitch is determined by the NULIF program:

<u>Pitch (cm)</u>	<u>k<sub>∞</sub></u>
1.805	1.2504
1.918	1.3061
2.031	1.3385
2.144	1.3548
2.200	1.3583
2.257	1.3595
2.400	1.3535
2.600	1.3293
2.800	1.2928
3.000	1.2485
3.200	1.1991

$$\begin{aligned} \text{Optimum } C &= 0.07323 \text{ for NITAWL} \\ (\sigma_m)_{\text{eff}} &= 28.09 \text{ for U}_{238} \\ (\sigma_m)_{\text{eff}} &= 2091.6 \text{ for Pu}_{239} \end{aligned}$$

## 6. "Homogenized" Fuel Densities

N <sub>28</sub>	=	8.9701-3	atom / barn-cm
N <sub>25</sub>	=	1.9115-5	
N <sub>49</sub>	=	1.2047-4	Pu-239
N <sub>41</sub>	=	1.2180-2	
N <sub>H</sub>	=	4.0927-2	
N <sub>O</sub>	=	2.0463-2	

## 7. KENO Models

The cask and basket models used to analyze the Fermi-1 fuel were used to analyze the EBR11 fuel. A normal operation case and hypothetical accident case that assumes that the fuel clusters in the center of the basket were analyzed.

## 8. Computer Results

The input and results for the AMPX/KENO calculations are provided below. The results of the analyses are summarized here along with the results corrected for bias and uncertainties ( $k_s$ ).

Case	k calculated	$k_s$
Normal Operation, (See Figure X-22)	0.68167±0.00378	0.702
Hypothetical Accident, fuel clustered in center of basket (See Figure X-23)	0.67571±0.00385	0.696

FIGURE X-22  
EBR-II  
NORMAL OPERATION

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE X-23  
EBR-II  
HYPOTHETICAL ACCIDENT

FIGURE WITHHELD UNDER 10 CFR 2.390

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**APPENDIX A**

**SECTION X**

**Additional Criticality Analysis**

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**APPENDIX A  
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## 1.0 INTRODUCTION

This report provides additional information confirming the validity of the criticality analysis of the NLI 1/2 Shipping Cask. Specifically provided are the details of an analysis of a critical experiment and of the cask with the code KENO<sup>(1)</sup>, comparison of the results with those obtained with the code ANISN<sup>(2)</sup> and the actual number densities of the fuel region for both the 1 FWR and 2 BWR cask loadings.

## 2.0 SUMMARY AND CONCLUSIONS

The KENO Monte Carlo criticality code with the Hansen and Roach<sup>(3)</sup> cross sections has been used to calculate the reactivity of a Yankee critical experiment and of the NLI 1/2 cask with the 1 FWR fuel loading described in the NLI 1/2 SAR.<sup>(4)</sup> The results of these analyses yield a 95% confidence level  $k_{\text{eff}}$  of  $0.929 \pm .014$  for a single isolated cask with water in the can, in the can to cask gap and in the shield jacket. Note that the can in the cask was conservatively assumed to be filled with water even though the cask and can are designed so that even under hypothetical accident conditions, no water would enter the can. The above value includes a correction for the difference between the KENO results for the critical experiment and the measured value. The standard deviation of each KENO run was approximately 0.005. The above result compares favorably with the equivalent ANISN result of 0.944.

Additional analyses were performed to show that for a large array of undamaged casks (but with can filled with water) there is no essential change in reactivity. Analyses were also performed to show that the reactivity of a single cask is insensitive to the amount of external water moderation. The maximum reactivity for a single cask under accident

conditions is essentially the same as that for normal conditions or  $0.929 \pm .014$ .

From the above and the results for the EWR loading presented in the SAR, it is concluded that the NLI 1/2 shipping cask meets the criticality requirements of 10 CFR 71.33 thru 71.37 and 71.40 for Fissile Class III shipments.

### 3.0 METHODS OF ANALYSIS

#### 3.1 The KENO Code

KENO is a multigroup Monte Carlo program for calculating the criticality of a nuclear system. The code treats the neutron motion in the system using a statistics method. In this method, the life histories of a large number of neutrons as specified in the input are followed as they travel from one point to another in the system.

The neutron scattering as treated in KENO assumes that the differential scattering cross section can be represented by the P1 Legendre polynomial. Absorption of neutrons is not allowed. Instead, the weight of a neutron at each collision point is reduced by the absorption probability. If the region in which the collision occurs contains fissile material, a fission weight is generated. Tracking of a neutron is continued until the neutron leaks from the system or until its weight is reduced below a specified value for the region in which the collision occurred. At that time, Russian roulette is played to determine if the neutron survives or is killed. Information based on collision of these neutrons with the materials in the system is used to determine the criticality condition of the system.

The output from KENO consists of the effective multiplication factor of the system plus an estimate of its standard deviation. In addition, the groupwise and the regionwise information on leakage, absorption and fission are included in the output.

### 3.2 Cross Sections

The KENO calculation was performed using the sixteen group Knight-modified Hansen and Roach cross sections.<sup>(5)</sup> The neutron energy group structure for this set of cross sections is given in Table 1.

The Hansen and Roach cross sections were compiled for fast and intermediate neutron critical assemblies. For a well moderated, homogeneous system containing slightly enriched uranium fuel pins such as the one in our case, some adjustments of the cross sections are required in the thermal and resonance energy regions.

#### 3.2.1 Resonance Region

The proper resonance absorber cross sections were chosen from the Knight-modified Hansen and Roach data on the basis of a potential scattering cross section value ( $\sigma_p^*$ ), which includes an "escape" cross section derived from an equivalence relation as discussed in Reference 6. The potential scattering cross section is given by:

$$\sigma_p^* = \frac{\Sigma_p + \Sigma_e^*}{N_o} \quad (1)$$

where  $\Sigma_p$  is the homogeneous potential scattering for the pellet composition,  $N_o$  is the atom density of the resonance absorber, and

$$\Sigma_e^* = \Sigma_e \cdot \frac{a(1-c)}{1+(a-1)c} \quad (2)$$

TABLE 1  
THE 16 ENERGY GROUPS

<u>Group Number</u>	<u>Group lower energy limit, eV</u>
1	$3.0 \times 10^6$
2	$1.4 \times 10^6$
3	$9.0 \times 10^5$
4	$4.0 \times 10^5$
5	$1.0 \times 10^5$
6	$1.7 \times 10^4$
7	$3.0 \times 10^3$
8	$5.5 \times 10^2$
9	$1.0 \times 10^2$
10	$3.0 \times 10^1$
11	$1.0 \times 10^1$
12	3.0
13	1.0
14	0.4
15	0.1
16	0



where

$$\Sigma_e = \frac{S_o}{4V_o} \quad (3)$$

$$c = 1 - \gamma_3 - \gamma_3^4 (1 - \gamma_3) \quad (4)$$

$$\gamma_3 = \frac{\Sigma_1}{\Sigma_1 + \Sigma_{e1}} \quad (5)$$

and

$$\Sigma_{e1} = \frac{S_o}{4V_1} \quad (6)$$

In equation 3, 5, and 6,  $\Sigma_1$  is the total cross section of the outer region (homogenized clad-coolant), and  $S_o$ ,  $V_o$ , and  $V_1$  are respectively the pellet surface, pellet volume and volume of the outer region. Equation 4 is a modified Bell approximation <sup>(7)</sup> for the Dancoff factor suggested by Hummel <sup>(3)</sup>. Reference 6 suggested 1.35 as a typical value for "a" in equation 2.

### 3.2.2 Thermal Region

The fuel pin cells were represented in the KENO geometry as a homogenized mixture of pellet, clad and moderator. The thermal neutron flux in a heterogeneous fuel pin cell is depressed in the absorbing fuel and peaks in the moderator region. To account for this variation across a fuel pin cell, thermal cross sections must be adjusted by thermal disadvantage factors before these cross sections can be accepted for homogeneous calculations. The thermal disadvantage factors for the fuel pin cells were evaluated using the THERMOS <sup>(9)</sup> code. THERMOS solves the one-dimensional multigroup integral transport equation with isotropic scattering. The code computes the scalar thermal neutron flux as a function of position in a lattice. The cell average flux and regionwise

average flux are edited and included in the output.

### 3.3 The LEPARD Code

The LEPARD<sup>(10)</sup> Code was described in the SAR, Amendment 1, pages X-3, X-5 and X-11. As indicated, LEPARD was used in the cask analysis only to determine the effect of varying the fuel pin pitch and the water temperature in order to select the most reactive water to fuel ratio for the fuel region. Nearly all the cross sections compiled in the code are from MUFT and SOFOCATE libraries. The code has been tested by Westinghouse against 49  $\text{UO}_2$  critical experiments and 20 uranium metal exponential lattices. The enrichment varied from approximately 1.3 to 4.0%, the W/U ratio varied from approximately 2 to 10; boron concentrations in the moderator were from zero to 3500 ppm and light water to 76%  $\text{D}_2\text{O}$  served as moderator. Bare, steel and aluminum clad fuel were studied as well as both square and hexagonal lattice arrays. A comparison of experimental and calculated results is reported in Reference 11. The calculations for 49  $\text{UO}_2$  cases result in a mean  $k_{\text{eff}} = 0.9907 \pm .0092$ . If cases containing  $\text{D}_2\text{O}$  in the moderator are excluded, then  $k_{\text{eff}} = 0.9933 \pm .0071$  for 41  $\text{UO}_2$  cases. For the 10 experiments, performed by Westinghouse, which have the most complete physical parameters of the experimental assembly the mean  $k_{\text{eff}}$  is  $0.9964 \pm .0032$ . A bias factor of 0.36% was built into the code. Use of the code was later extended to Zircaloy cores. Good agreement of calculated and measured values was also reported.<sup>(12)</sup>

### 4.0 BENCHMARK PROBLEM

A benchmark problem is included in this report to demonstrate the validity of the method and the neutron cross section data which were

used in the criticality analysis of the cask. The benchmark calculation was performed using the KENO and PICTURE<sup>(13)</sup> codes, and the Hansen and Roach cross section processed as described in the previous section. One of the Yankee critical experiments<sup>(14)</sup> was chosen as a benchmark problem for its similarity in the type of fuel and the water-to-uranium ratio as compared with the design basis fuel used in the cask calculations.

#### 4.1 Yankee Critical Assembly

The Yankee critical assembly was mounted in a stainless steel tank 6 ft in diameter and 7 ft high with a 4 ft bottom extension to accommodate the follower sections of the control rods. The fuel rods used in the core were slightly enriched  $\text{UO}_2$  (2.7 w/o) pellets, clad in AISI-304 stainless steel and with a  $\text{UO}_2$  density of 10.2 gm/cc. The pellet diameter was 0.3000 inch. The inside diameter of the stainless steel tubing was 0.3062 inch with a wall thickness of 0.0161 inch. The active fuel length was 48 inches. The pitch of fuel rods was 0.470 inch which corresponds to a water-to-uranium volume ratio of 3.87:1 at room temperature.

The fuel rods were not grouped into bundles, but uniformly loaded in the core. Figure 1 shows the fuel loading diagram for the case chosen for this calculation. Only the outer ring of rods is shown, the center of the loading diagram being filled with fuel rods. There were 4468 fuel rods, plus 289 additional unit cells occupied by control rods. Control of the core reactivity was provided by nine silver-cadmium control rods (69.83% Ag, 30.15% Cd and 0.02% Zn) located in the core as shown in Figure 2. The control rods had a span of 7.812 inches and a blade thickness of 0.285. The poisoned portion of the control rod was 48 inches long with 53 inches of aluminum follower below the active section.

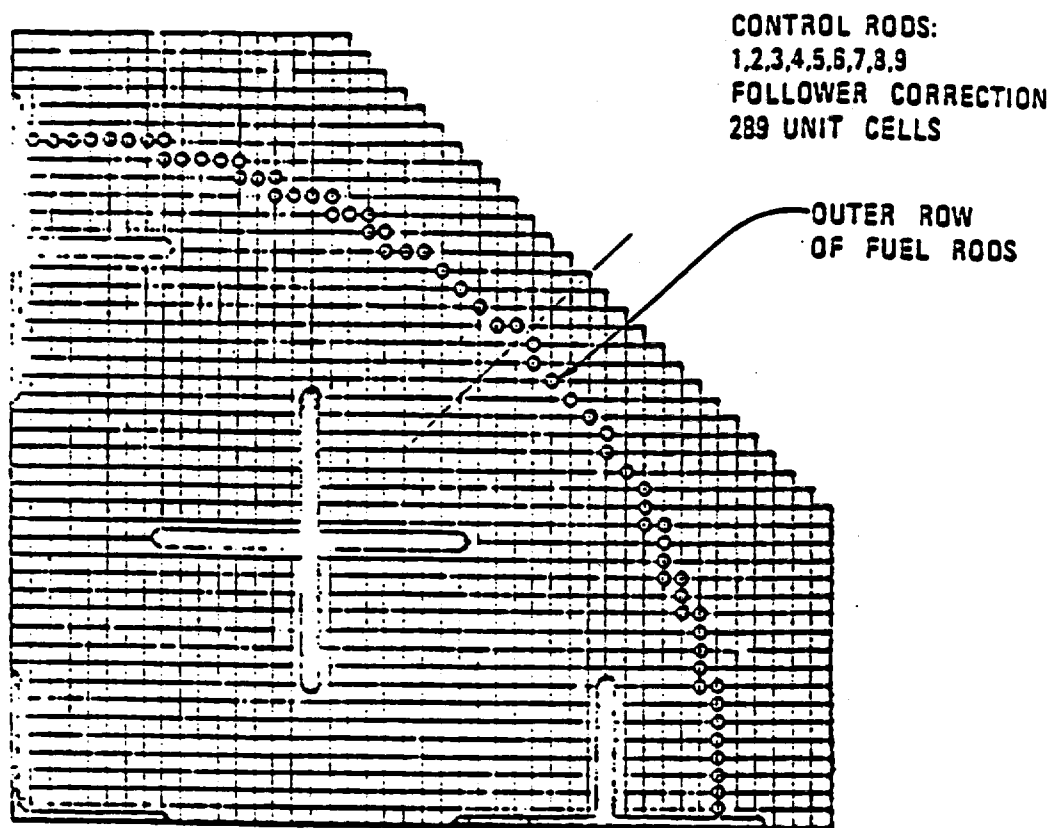


FIGURE 1  
LOADING DIAGRAM YANKEE CRITICAL EXPERIMENT 3.9:1 CORE

FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 2  
YANKEE CRITICAL ASSEMBLY CORE PLATE MATRIX.

The rods were banked at 10.33 inches (or 26.37 cm) from bottom of the fuel.

Light water served both as moderator and reflector. The experiment was conducted with water maintained at or near the room temperature. Soric acid dissolved in water provided an alternate control of the core during the process of measuring the reactivity worth of the control rods. The boron concentration in this case was measured at 12.5 ppm of water as reported on page 82 of Reference 14.

#### 4.2 Input Informations

The geometry which represents the Yankee critical experiment as used in the KENO calculation is shown in Figures 3 and 4. The fuel region was treated as a homogeneous mixture of  $\text{UO}_2$ , clad and moderator. The equivalent diameter of the core is 92.91 cm. Control rods and water slots adjacent to control rods were explicitly represented as shown in Figure 4 and were located as shown in Figure 2. Because of complexity of this geometry, the core was described using a special subroutine built in the code and known as the generalized geometry package (GEOM). The generalized geometry allows any system which can be described by a combination of planes and/or quadric surfaces, arbitrarily oriented and intersecting in any arbitrary fashion. The geometry input cards were checked out with the use of the PICTURE code prior to use in the KENO problem.

There were altogether five material mixtures in the KENO problem, namely:

<u>Mixture</u>	<u>Description</u>
1	fuel
2	water slots
3	follower

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FIGURE WITHHELD UNDER 10 CFR 2.390

FIG. 3 KENO GEOMETRY DESCRIPTION OF THE YANKEE CRITICAL ASSEMBLY

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FIGURE WITHHELD UNDER 10 CFR 2.390

FIGURE 4  
KENO GEOMETRY FOR CONTROL RODS  
YANKEE CRITICAL EXPERIMENT

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<u>Mixture</u>	<u>Description</u>
4	control rod
5	reflector

Table 2 presents the nuclides and atom densities in each mixture. The mixture No. 1 corresponds to medium 1 in GEOM, mixture No. 2 to medium 2, and so on.

Neutron cross sections for U-235 and U-238 were selected from the Hansen and Roach library on basis of the potential scattering cross section of a heterogeneous fuel pin cell. Following the procedures described in Section 3.2,  $\sigma_p^*$  for the Yankee fuel is 75.6 and 2690 barns for U-238 and U-235 respectively.

Thermal disadvantage factors for the Yankee fuel pin cell obtained from THERMOS are as follows:

	<u>Group 15</u>	<u>Group 16</u>
Pellet	0.931	0.876
Clad	0.979	0.957
Moderator	1.040	1.073

The appropriate group 15 and 16 fuel region Hansen and Roach cross sections were multiplied by these factors for input into KENO.

Since silver is not included in the Hansen and Roach library, cross sections of silver were generated from GAM-II and THERMOS. (See the NLI 1/2 SAR) These cross sections were weighted over the fuel spectrum.

TABLE 2

NUCLIDES AND ATOM DENSITIES USED IN YANKEE CRITICAL KENO CALCULATIONS

YANKEE CRITICAL EXPERIMENT  $k = 0.027$ ,  $\rho/\rho_0 = 0.07$ , MUOS 26.37CM FROM BUNION, 1

VOLUME	NUCLIDE	DENSITY	
1	1	3.95720E-02	hydrogen
1	2	4.11725E-07	boron
1	3	1.97440E-02	oxygen in moderator
1	4	1.21441E-03	chromium
1	5	1.29544E-00	manganese
1	6	4.45475E-03	iron
1	7	4.17404E-04	nickel
1	8	1.36741E-04	U-235
1	9	7.67941E-03	U-238
1	10	1.45571E-02	oxygen in $UO_2$
2	1102	6.57443E-02	hydrogen
2	5100	4.94424E-07	boron
2	0100	3.11714E-02	oxygen in water
3	13100	5.79007E-02	aluminum
4	11	3.97440E-02	silver
4	30100	1.47410E-05	zinc
4	09100	1.44740E-02	cadmium
3	1102	6.57440E-02	hydrogen
3	5100	6.94425E-07	boron
5	0100	3.11714E-02	oxygen in water

ALTHOUGH A FISSION SPECTRUM MAY HAVE BEEN ASSOCIATED WITH ONE OR MORE INPUT NUCLIDES,  
A FISSION SPECTRUM WILL BE READ FROM CARDS BECAUSE ALL NUCLIDE IDS ARE POSITIVE

# YANKEE CRITICAL KENO RESULTS

TABLE 3

YANKEE CRITICAL EXPERIMENT E=0.027, K/U=1.07, R005 24.57CM FROM BOTTOM, 1

NO. OF INITIAL  
GEYERATIONS  
SKIPPED

AVERAGE  
K-EFFECTIVE

DEVIATION

67 PER CENT  
CONFIDENCE INTERVAL

95 PER CENT  
CONFIDENCE INTERVAL

99 PER CENT  
CONFIDENCE INTERVAL

NUMBER OF  
MISSTAKES

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3	0.96304	+ DR - 0.00541	0.96164	TO 0.97445	0.95425	TO 0.97946	0.95242	TO 0.98456	17166
4	0.96374	+ DR - 0.00546	0.96424	TO 0.97520	0.95483	TO 0.98046	0.95117	TO 0.98412	16876
5	0.97056	+ DR - 0.00549	0.96507	TO 0.97606	0.95957	TO 0.98155	0.95408	TO 0.98665	16566
6	0.97141	+ DR - 0.00553	0.96540	TO 0.97694	0.96035	TO 0.98247	0.95442	TO 0.98700	16256
7	0.97143	+ DR - 0.00562	0.96621	TO 0.97745	0.96040	TO 0.98307	0.95494	TO 0.98764	15946
8	0.97209	+ DR - 0.00572	0.96637	TO 0.97781	0.96064	TO 0.98353	0.95492	TO 0.98766	15636
9	0.97367	+ DR - 0.00561	0.96904	TO 0.97420	0.96245	TO 0.98489	0.95644	TO 0.98950	15326
10	0.97557	+ DR - 0.00534	0.97019	TO 0.98044	0.96401	TO 0.98434	0.95743	TO 0.99172	15016
11	0.97702	+ DR - 0.00529	0.97173	TO 0.98231	0.96444	TO 0.98760	0.96114	TO 0.98794	14706
12	0.97764	+ DR - 0.00517	0.97220	TO 0.98401	0.96491	TO 0.98837	0.96155	TO 0.98917	14400
17	0.98033	+ DR - 0.00565	0.97440	TO 0.98574	0.96902	TO 0.99163	0.96517	TO 0.99724	12700
22	0.97794	+ DR - 0.00630	0.97344	TO 0.98424	0.96344	TO 0.98246	0.96107	TO 0.98944	11400
27	0.98225	+ DR - 0.00474	0.97541	TO 0.98490	0.96477	TO 0.98572	0.96204	TO 0.98245	9900
32	0.98544	+ DR - 0.00761	0.97905	TO 0.98426	0.97144	TO 0.98147	0.96344	TO 0.98947	8400
37	0.98585	+ DR - 0.00716	0.98460	TO 0.98401	0.98252	TO 0.98117	0.97535	TO 0.98135	6900
42	0.98942	+ DR - 0.00660	0.98342	TO 0.98402	0.97723	TO 0.98052	0.97542	TO 0.98142	5400
47	0.99116	+ DR - 0.00446	0.98250	TO 0.98994	0.97303	TO 0.98048	0.96517	TO 0.98175	3900
52	0.99132	+ DR - 0.01239	0.97843	TO 0.98171	0.96654	TO 0.98140	0.95915	TO 0.98440	2400
57	0.99249	+ DR - 0.01208	0.98040	TO 0.98474	0.98243	TO 0.98644	0.98445	TO 0.98492	900

### 4.3 Results

The effective neutron multiplication factor obtained from this KENO calculation is  $0.977 \pm 0.011$  at 95% confidence level. Detailed KENO output is presented in Table 3. The above result yields a bias factor of 0.023 as compared with unity in the critical experiment.

Similar experiment-theory discrepancies, where Monte Carlo calculations with Hansen and Roach cross sections were used, have been reported by Dickinson<sup>(15)</sup> and Carter<sup>(16)</sup>. Monte Carlo calculations with ENDF/B-II and ENDF/B-III cross sections also result in discrepancy as reported by Bierman and Clayton.<sup>(17)</sup>

After reviewing a large number and variety of comparisons between critical experiment data and the corresponding calculated results, Crume<sup>(18)</sup> concluded with the following comments:

"For our purposes, neutron multiplication factor values of 0.98 from ANISN and DOT calculations and 0.97 from KENO calculations using Hansen-Roach cross sections are considered to correspond to actual criticality for systems containing highly enriched uranium. The corresponding values for low enriched systems may have to be taken somewhat smaller.

It should be pointed out that differences from unity such as these are usually quite acceptable for criticality safety purposes whereas they might not be nearly so acceptable for purposes of reactor design. This acceptability occurs for the following reason. If a system is analyzed using extrapolations of experimental criticality data or less sophisticated calculational techniques than those just discussed it may be necessary to use considerable conservatism in applying the results of the analysis. Often, the amount of conservatism required will be so great as to be equivalent to taking a much smaller value for the critical multiplication factor than the 0.98 or 0.97 indicated above".

In light of the above discussions, a computation bias factor of +0.023 was established and later was introduced into the criticality calculation of the cask (Section 5.2).

## 5.0 CASK ANALYSIS

The methods of analysis as described in Section 3.0 were followed in determining the neutron multiplication factor of the cask using KENO. Additional ANISN analyses were also performed using the methods described in the SAR.

### 5.1 Input Information

#### 5.1.1 KENO Analysis

Figure 5 shows the 1 PWR cask as modeled in KENO. The actual geometry input for KENO is presented in Table 4. There are altogether six mixtures representing explicitly the following regions:

<u>Mixture</u>	<u>Description</u>
1	Homogenized fuel with the most reactive water/fuel ratio
2	Depleted uranium
3	95% aluminum and 5% water
4	Stainless steel
5	Lead
6	Water

A reflection boundary was imposed at the top and bottom of the fuel and, therefore, any neutron leakage in the axial direction was neglected.

The atom density of nuclides appearing in various mixtures are given in Table 5. The depleted uranium is present in the cask to serve as one of the shielding materials. The U-235 content of the depleted uranium was taken as 0.22%

FIGURE WITHHELD UNDER 10 CFR 2.390

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FIGURE 5  
MODEL - I PWVR LOADING

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NIC PWR E=3.35, ACCIDENT PITCH 5949 INCH, 100F

GEOMETRY DESCRIPTION

GEOMETRY INPUT IN KENO FOR NII PWR CASK

TABLE 1

CUBOID	1	X = 1.1277E+01	Y = 1.1277E+01	Z = 1.1277E+01	X = 1.1277E+01	Y = 1.1277E+01	Z = 1.1277E+01
CYLINDER	3	RADIUS = 1.6034E+01	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02
CYLINDER	4	RADIUS = 1.6669E+01	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02
CYLINDER	6	RADIUS = 1.6986E+01	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02
CYLINDER	4	RADIUS = 1.6256E+01	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02
CYLINDER	6	RADIUS = 1.0328E+01	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02
CYLINDER	2	RADIUS = 2.5309E+01	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02
CYLINDER	5	RADIUS = 3.0706E+01	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02
CYLINDER	4	RADIUS = 3.2929E+01	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02
CYLINDER	6	RADIUS = 4.0000E+01	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02
CYLINDER	6	RADIUS = 4.5627E+01	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02
CYLINDER	4	RADIUS = 4.6264E+01	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02	Z = 1.0208E+02
CUBOID	0	X = 4.6264E+01	Y = 4.6264E+01	Z = 4.6264E+01	X = 4.6264E+01	Y = 4.6264E+01	Z = 4.6264E+01

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TABLE 5  
KENO CASK ATOM DENSITIES

WTC PWR E=3.35, ACCIDENT PITCH .5949 INCH, 100F

MIXTURE	NUCLIDE	DENSITY	
1	1	3.64848E-02	H in moderator
1	2	1.83424E-02	O in moderator
1	3	1.40800E-04	Ni in moderator
1	4	3.37611E-03	Zr
1	5	2.10432E-04	U-235
1	6	5.97462E-03	U-238
1	7	1.24101E-02	O in UO <sub>2</sub>
1	8	5.05936E-03	H in non-lattice
1	9	2.52568E-03	O in non-lattice
1	10	2.64358E-05	Fe in non-lattice
1	11	2.40760E-05	Ni in non-lattice
1	12	7.43157E-06	Cr in non-lattice
1	13	7.52270E-07	Mn in non-lattice
1	14	3.10051E-04	Zr in non-lattice
2	92501	1.05230E-04	U-235
2	92801	4.77250E-02	U-238
3	1102	3.32120E-03	H
3	0100	1.66060E-03	O
3	13100	5.68100E-02	Al
4	24100	1.67433E-02	Cr
4	25100	1.76140E-03	Mn
4	26100	6.04160E-02	Fe
4	28100	8.36665E-03	Ni
5	82100	3.30000E-02	Pb
6	1102	6.54239E-02	H
6	0100	3.32119E-02	O

ALTHOUGH A FISSION SPECTRUM MAY HAVE BEEN ASSOCIATED WITH ONE OR MORE INPUT NUCLIDES,  
A FISSION SPECTRUM WILL BE READ FROM CARDS BECAUSE ALL NUCLIDE IDS ARE POSITIVE

X-A20



The potential scattering cross sections for U-235 and U-238 in the most reactive fuel pin cell were found to be 1990 and 69.8 barns respectively for the PWR fuel. Based on these potential scattering cross sections, a proper set of cross sections was chosen for U-235 and U-238 from the Hansen and Roach library. The thermal disadvantage factors for the fuel pin cell determined from THERMOS are:

	<u>Group 15</u>	<u>Group 16</u>
Pellet	0.888	0.837
Clad	0.982	0.962
<u>Moderator</u>	1.058	1.086

These were applied to the thermal cross sections for nuclides appearing in the fuel region. For nuclides which appear in regions other than the homogenized fuel, cross sections were taken directly from the Hansen and Roach library. Infinite dilution cross sections were chosen for U-235 and U-238 in the region of depleted uranium.

#### 5.1.2 ANISN Analyses

To examine the expected small effect of cask boundary conditions and external reflector thickness several ANISN problems were run. These were run using the methods described in the SAR. The atom densities used in the analyses are given in Table 6.

### 5.2 Results

#### 5.2.1 Single Isolated Undamaged Cask

This calculation was for the cask filled with 100°F water, the neutron shield jacket filled with water, and no neutrons returning from outside

TABLE 6  
 ATOM DENSITY OF NUCLIDES USED IN ANISN CALCULATIONS  
 (atoms/barn - cm)

PWR fuel:		95% Al Plus 5% Water:	
H	0.041985	H	0.0033212
O	0.033413	O	0.0016606
SS	0.000039150	Al	0.05681
Ni	0.00016112		
Zr	0.0037078	Stainless Steel	
U-235	0.00021061	SS	0.08807
U-238	0.0059996		
		Depleted Uranium	
		U-235	0.00010523
		U-238	0.047725
BWR fuel:		Lead	
H	0.040761	Pb	0.0330
O	0.034404		
SS	0.00032531	Water	
Zr	0.0035599	- H	0.06622
U-235	0.00018811	O	0.03311
U-238	0.0068234		

of the shield jacket. Table 7 presents the KENO output. At a 95% confidence level the effective neutron multiplication factor is  $0.906 \pm .008$ . To this a computation bias factor of  $0.023 \pm 0.011$  which was established in Section 4.3 from a direct comparison of experiment and calculated  $k_{eff}$  values should be applied. Thus the corrected effective multiplication factor of the PWR cask is  $0.929 \pm .014$  at 95% confidence level. The uncertainty is the combined value for the two (critical experiment and cask) KENO analyses.

#### 5.2.2 An Infinite Array of Undamaged Casks

To conservatively determine the reactivity of two adjacent casks, an ANISN problem similar to those described in the NLI 1/2 SAR was run with full reflection at the outer edge of the filled neutron shield jacket. The result is 0.944 which is the same as that for a single isolated cask with the shield jacket full of water. The ANISN result shows that the above KENO result for a single cask is also applicable to an infinite array of undamaged casks.

#### 5.2.3 Single Damaged Cask

The only effect of the hypothetical accident conditions on the cask as far as criticality is concerned is the potential loss of the external neutron shield water. The effect of varying the amount of water external to the cask shell has been examined with a series of ANISN calculations assuming the can is filled with water and zero neutron return at the outer surface of several different thicknesses of water surrounding the cask. The results of the analyses are given in Table 8.

Revised  
Oct. 1990

X-A24

TABLE 7  
KENO  $k_{eff}$  OF NLI 1 PWR CASK

WTC PWR E=3.39, ACCIDENT PITCH .5949 INCH, 100F

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.90613	+ DR = 0.00398	0.90215 TO 0.91011	0.89817 TO 0.91409	0.89419 TO 0.91807	24139
4	0.90655	+ DR = 0.00402	0.90253 TO 0.91057	0.89851 TO 0.91458	0.89449 TO 0.91860	19600
5	0.90615	+ DR = 0.00406	0.90209 TO 0.91021	0.89803 TO 0.91427	0.89397 TO 0.91834	19500
6	0.90639	+ DR = 0.00412	0.90227 TO 0.91051	0.89815 TO 0.91463	0.89404 TO 0.91874	19260
7	0.90629	+ DR = 0.00418	0.90211 TO 0.91047	0.89793 TO 0.91466	0.89374 TO 0.91884	12900
8	0.90607	+ DR = 0.00424	0.90183 TO 0.91032	0.89750 TO 0.91456	0.89334 TO 0.91881	12500
9	0.90554	+ DR = 0.00429	0.90225 TO 0.91083	0.89797 TO 0.91512	0.89360 TO 0.91941	16300
10	0.90604	+ DR = 0.00433	0.90171 TO 0.91037	0.89730 TO 0.91471	0.89305 TO 0.91904	16000
11	0.90704	+ DR = 0.00429	0.90275 TO 0.91132	0.89846 TO 0.91561	0.89417 TO 0.91990	17700
12	0.90612	+ DR = 0.00426	0.90186 TO 0.91030	0.89760 TO 0.91465	0.89333 TO 0.91891	17400
17	0.90336	+ DR = 0.00437	0.89900 TO 0.90773	0.89463 TO 0.91210	0.89026 TO 0.91647	15900
22	0.90310	+ DR = 0.00469	0.89045 TO 0.90702	0.89376 TO 0.91251	0.88907 TO 0.91730	14400
27	0.90304	+ DR = 0.00504	0.89000 TO 0.90008	0.89295 TO 0.91312	0.88791 TO 0.91816	12900
32	0.90592	+ DR = 0.00531	0.90061 TO 0.91123	0.89530 TO 0.91654	0.88999 TO 0.92105	11400
37	0.90994	+ DR = 0.00521	0.90477 TO 0.91519	0.89956 TO 0.92039	0.89436 TO 0.92560	9900
42	0.91145	+ DR = 0.00570	0.90575 TO 0.91713	0.90005 TO 0.92205	0.89435 TO 0.92855	8400
47	0.91131	+ DR = 0.00602	0.90530 TO 0.91733	0.89924 TO 0.92335	0.89326 TO 0.92937	6900
52	0.90697	+ DR = 0.00704	0.89791 TO 0.91404	0.89205 TO 0.92110	0.88570 TO 0.92817	5400
57	0.90707	+ DR = 0.00803	0.90024 TO 0.91790	0.89141 TO 0.92674	0.88257 TO 0.93557	3900
62	0.91209	+ DR = 0.01209	0.89946 TO 0.92413	0.88787 TO 0.93622	0.87970 TO 0.94831	2400
67	0.90569	+ DR = 0.00235	0.90313 TO 0.90824	0.90050 TO 0.91079	0.89503 TO 0.915	900

TABLE 3

$k_{eff}$  OF AN ISOLATED PWR CASK  
VERSUS THICKNESS OF WATER REFLECTOR

<u>Thickness of Water Reflector, inch</u>	$k_{eff}$	
	<u>KENO</u>	<u>ANISN</u>
0	--	0.9438
5 (design thickness - shield jacket full)	0.929 $\pm$ .014	0.9442
7	--	0.9443

## 6.0 DISCUSSION OF RESULTS

The pertinent results of the criticality analysis of the NLI 1/2 spent fuel shipping cask for the reference PWR fuel loading are summarized in Table 9. Results for both KENO and ANISN analyses are included. The KENO results were obtained using the Hansen and Roach cross sections and include the calculational bias obtained from the benchmark problem. The ANISN results are all from a P1-S8 calculation using cross sections from GAM-II and THERMOS. The cask reactivities determined by the two independent methods are in good agreement. The difference may be easily accounted for by differences in cross sections and differences due to the 3 dimensional treatment in KENO versus the 1 dimensional treatment in ANISN. The comparison between the benchmarked KENO results and the ANISN results indicate the validity of the ANISN results in the SAR.

The ANISN results for an isolated cask and for an infinite array of casks (zero leakage) indicate that there is no difference in reactivity between the two conditions; hence, the isolated cask KENO result is also applicable to the array of casks. The maximum reactivity of an array of undamaged casks is therefore less than  $0.929 \pm .014$  with 95% confidence.

The ANISN results for different amounts of water external to a single cask indicate that the cask body effectively isolates the fuel region from thermal neutron effects external to the cask. The reactivity of the single cask under hypothetical accident condition is therefore no more than that given above for normal conditions.

TABLE 9  
SUMMARY OF RESULTS OF CRITICALITY ANALYSIS  
NLI 1/2 CASK 1 PWR LOADING

	KENO	ANISN
<u>Undamaged Cask</u>		
Single Cask	$.929 \pm .014^*$	0.944
Infinite Array of Casks	--	0.944
<u>Damaged Cask</u>		
Single Cask		
0" Surrounding Water	--	0.944
5" Surrounding Water (Neutron shield full)	$.929 \pm 0.014$	0.944
7" Surrounding Water	--	0.944

\*95% confidence level

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**APPENDIX B**

**SECTION X**

**Mark 42 Fuel Assembly KENO Input and Output**

10ALP  
10100 1988 Nov 16 Wed 1158:33  
MLI-1/2: ROCKWELL BASKET: MARK42 FUEL: NO POISON OR AL: INF ARRAY  
200- B6 424 6 27 27 16 7 19 41 8 4 2 1 -16 1 0 2000 0 1 82  
-1 -1 38-1  
1 94238 2.061-6 1 -94239 1.071-3 1 -94241 3.080-5 1 8016 2.733-3  
2 94240 1.0-20 1 94242 1.0-20 1 13027 1.0-20  
3 5010 8.361-3 2 6012 1.083-2 2 13027 3.013-2  
4 8016 3.3461-2 3 1001 6.6822-2  
5 24000 1.839-2 4 28000 1.815-3 6 26000 5.994-2  
6 13027 6.026-2  
7 82000 3.299-2  
7 92238 4.773-2 7 -92235 1.052-4  
BOX TYPE 1  
CYLINDER 3 2.182 1000. -1000. 27\*0.5  
CYLINDER 5 2.286 1000. -1000. 27\*0.5  
CYLINDER 1 2.570 1000. -1000. 27\*0.5  
CYLINDER 5 2.647 1000. -1000. 27\*0.5  
CYLINDER 3 3.289 1000. -1000. 27\*0.5  
CYLINDER 5 3.366 1000. -1000. 27\*0.5  
CYLINDER 1 3.653 1000. -1000. 27\*0.5  
CYLINDER 3 3.729 1000. -1000. 27\*0.5  
CYLINDER 3 4.361 1000. -1000. 27\*0.5  
CYLINDER 5 4.437 1000. -1000. 27\*0.5  
CYLINDER 1 4.623 1000. -1000. 27\*0.5  
CYLINDER 5 4.699 1000. -1000. 27\*0.5  
CYLINDER 3 5.093 1000. -1000. 27\*0.5  
CYLINDER 5 5.220 1000. -1000. 27\*0.5  
CYLINDER 5 5.715 1000. -1000. 27\*0.5  
CYLINDER 3 6.191 1000. -1000. 27\*0.5  
CUBOID 3 6.5075 -6.5075 6.5075 -6.5075 1000. -1000. 27\*0.5  
BOX TYPE 2  
CUBOID 2 13.015 0.000 0.1441 0.000 1000. -1000. 27\*0.5  
CUBOID 4 13.015 0.000 0.7791 0.000 1000. -1000. 27\*0.5  
BOX TYPE 3  
CUBOID 2 0.1441 0.000 13.015 0.000 1000. -1000. 27\*0.5  
CUBOID 4 0.7791 0.000 13.015 0.000 1000. -1000. 27\*0.5  
BOX TYPE 4  
CUBOID 4 0.000 -0.635 0.000 -0.635 1000. -1000. 27\*0.5  
CUBOID 2 0.000 -0.7791 0.000 -0.7791 1000. -1000. 27\*0.5  
BOX TYPE 5  
CYLINDER 3 5.715 1000. -1000. 27\*0.5  
CYLINDER 5 6.191 1000. -1000. 27\*0.5  
CUBOID 3 6.5075 -6.5075 6.5075 -6.5075 1000. -1000. 27\*0.5  
BOX TYPE 6  
CUBOID 2 0.000 13.015 0.1441 0.000 1000. -1000. 27\*0.5  
CUBOID 4 0.000 13.015 0.7791 0.000 1000. -1000. 27\*0.5  
BOX TYPE 7  
CUBOID 2 0.000 -0.1441 13.015 0.000 1000. -1000. 27\*0.5  
CUBOID 4 0.000 -0.7791 13.015 0.000 1000. -1000. 27\*0.5  
BOX TYPE 8  
CUBOID 4 0.635 0.000 0.000 -0.635 1000. -1000. 27\*0.5  
CUBOID 2 0.7791 0.000 0.000 -0.7791 1000. -1000. 27\*0.5  
CORE BDY 0 13.7941 -13.7941 13.7941 0.00 1000. -1000. 27\*0.5  
ZENICCYL-V 3 19.509 1000. -1000. 27\*0.5  
ZENICCYL-V 4 19.600 1000. -1000. 27\*0.5  
ZENICCYL-V 7 25.309 1000. -1000. 27\*0.5

X-B2

ZNERICTL+Y	6	30.706	1000.	-1000.	27*0.5
ZNERICTL+Y	4	32.93	1000.	-1000.	27*0.5
ZNERICTL+Y	3	45.629	1000.	-1000.	27*0.5
ZNERICTL+Y	4	46.264	1000.	-1000.	27*0.5
CUBOID	3	46.27	-46.27	0.00	1000. -1000. 27*0.5
1	4	4	1	1	1
2	4	4	1	1	1
3	3	3	1	1	1
4	3	3	1	1	1
5	1	1	1	1	1
6	1	1	1	1	1
7	2	2	1	1	1
8	2	2	1	1	1

END KENO.

MLT-1/2: ROCKWELL BASKET: MARK42 FUEL: NO POISON ON AL: INF ARRAY

NUMBER OF GENERATIONS	86	START TYPE	1
NUMBER PER GENERATION	424	GENERATIONS BETWEEN CHECKPOINTS	0
NUMBER OF GENERATIONS TO BE SKIPPED	6	LIST INPUT X <sup>2</sup> SECTIONS READ FROM TAPE	NO
NUMBER OF ENERGY GROUPS	27	LIST 1 <sup>st</sup> MIXTURE X SECTIONS	NO
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2 <sup>nd</sup> MIXTURE X <sup>2</sup> SECTIONS	NO
NUMBER OF INPUT NUCLIDES	16	LIST FISS. AND ABS. BY REGION	NO
NUMBER OF MIXTURES	7	USE X <sup>2</sup> SECTIONS FROM PREVIOUS CASE	NO
NUMBER OF MIXING TABLE ENTRIES	19	USE GEOMETRY FROM PREVIOUS CASE	NO
NUMBER OF GEOMETRY CARDS	41	USE VELOCITIES FROM PREVIOUS CASE	NO
NUMBER OF BOX TYPES	8	COMPUTE MATRIX K <sup>2</sup> EFFECTIVE BY UNIT	NO
NUMBER OF UNITS IN X DIRECTION	4	COMPUTE MATRIX K <sup>2</sup> EFFECTIVE BY BOX TYPE	NO
NUMBER OF UNITS IN Y DIRECTION	2	LIST FISS PROD MATRIX BY UNIT	NO
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALCULATION	NO
NUMBER OF NUCLIDES READ FROM TAPE	16	USE EXPONENTIAL TRANSFORM	NO
ALBEDO TYPE	1	CALCULATE FLUX	YES
SEARCH TYPE	0	CALCULATE FISSION DENSITIES	YES

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE  $\alpha_X = 1.00000 \times 10^0$   $\alpha_Y = 1.00000 \times 10^0$   $\alpha_Z = 1.00000 \times 10^0$   $\alpha_X = 1.00000 \times 10^0$   $\alpha_Y = 1.00000 \times 10^0$   $\alpha_Z = 1.0$

MAXIMUM TIME = 200.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 29621  
REMAINING AVAILABLE LOCATIONS = 40379

MIXTURE	NUCLIDE	DENSITY
1	94238	2.06100E+006
1	=94239	1.07100E+003
1	=94241	3.08000E+003
2	94240	2.73300E+003
2	94242	1.00000E+020
2	13027	1.00000E+020
2	5010	2.38100E+003
2	6012	1.08300E+002
2	13027	3.01300E+002
2	8016	3.34610E+002
3	1001	6.69220E+002
3	26000	1.83900E+002
3	28000	1.81300E+003
3	26000	3.99400E+002
3	13027	6.02600E+002
3	82000	3.29900E+002
3	92238	4.77300E+002
3	=92235	1.05280E+004

```

NUCLIOE = 1001      N 1259 F, 1002 T 218 GP 032475(2)
NUCLIOE = 5010      0-10 1273 218NGP 062375 P=3 293K
NUCLIOE = 6012      C=12 12745 10657 218 GP 030476(7)
NUCLIOE = 8016      0-16 1276 218 GP 030476(7)
NUCLIOE = 13027     AL-27 1193 218 GP 040375(5)
NUCLIOE = 16000     CR 1191 218NGP VT 1/E P=3 293K SIGP=5+4 RE042375)
NUCLIOE = 26000     FE 218GP RE 5-17-78(1)
NUCLIOE = 28000     NI 1190 218NGP VT 1/E P=3 293K SIGP=5+4 RE042375)
NUCLIOE = 82000     PB 1288 218NGP 062375 P=3 293K
NUCLIOE = 92235     U=235 1261 SIGP=5+4 NEWKLACS 218NGP P=3 293K(S)
NUCLIOE = 92238     U=238 218GP RE 5-17-78(1)
NUCLIOE = 94238     PU=238 1050 SIGP=5+4 NEWKLACS 218NGP P=3 293K
NUCLIOE = 94239     PU=239 1264 SIGP=5+4 NEWKLACS 218NGP P=3 293K
NUCLIOE = 94240     PU=240 1265 SIGP=5+4 NEWKLACS 218NGP P=3 293K
NUCLIOE = 94241     PU=241 1266 SIGP=5+4 NEWKLACS 218NGP P=3 293K
NUCLIOE = 94242     PU=242 1161 SIGP=5+4 NEWKLACS 218NGP P=3 293K

```

WL1-1/2: ROCKWELL BASKET: MARK42 FUEL: NO POISON OR AL: INF ARRAY

ARRAY DESCRIPTION

2 = 1

3 7 3 1

6 8 4 2

X-B6

Page added  
December 1988



NLI-1/2: ROCKWELL BASKET: MARK42 FUEL: NO POISON OR AL: INF ARNAV  
 LIFETIME = 1.20888-004 + OR = 1.01291-006  
 GENERATION 121

NO. OF INITIAL  
 GENERATIONS  
 SKIPPED  
 AVERAGE  
 K-EFFECTIVE  
 DEVIATION  
 67 PER CENT  
 CONFIDENCE INTERVAL

6	61216	+ OR =	.00358	60858 TO	61575
7	61268	+ OR =	.00361	60887 TO	61610
8	61254	+ OR =	.00366	60888 TO	61620
9	61266	+ OR =	.00371	60895 TO	61637
10	61286	+ OR =	.00375	60911 TO	61661
11	61288	+ OR =	.00380	60908 TO	61669
12	61369	+ OR =	.00377	60992 TO	61745
13	61361	+ OR =	.00382	60979 TO	61742
14	61332	+ OR =	.00386	60946 TO	61718
15	61345	+ OR =	.00391	60954 TO	61736
20	61431	+ OR =	.00393	61039 TO	61824
25	61564	+ OR =	.00413	61151 TO	61977
30	61618	+ OR =	.00417	61202 TO	62035
35	61766	+ OR =	.00419	61347 TO	62185
40	61761	+ OR =	.00422	61339 TO	62183
45	62112	+ OR =	.00440	61672 TO	62552
50	62367	+ OR =	.00430	61937 TO	62797
55	62588	+ OR =	.00471	62118 TO	63059
60	62796	+ OR =	.00501	62295 TO	63297
65	62815	+ OR =	.00590	62225 TO	63405
70	62771	+ OR =	.00737	62015 TO	63528
75	61645	+ OR =	.00721	60925 TO	62566
80	60626	+ OR =	.00942	59684 TO	61568

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**APPENDIX C**

**SECTION X**

**Mark 42 Fuel Assembly NITAWL Output**

13 ARRAY 12 ENTRIES READ

CT

MSCM	NUMBER OF EXTRA CROSS SECTIONS	0
MNT	NUMBER OF NUCLIDES FROM MASTER LIBRARY	16
MWT	NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LOG 2)	0
MXT	NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LOG 7)	0
MCR	ANISN/DOT/MORSE OUTPUT TRIGGER	0
HXX	TOTAL CROSS SECTION POSITION	0
MS	WITHIN-GROUP SCATTERING CROSS SECTION POSITION	0
IRES	NUMBER OF RESONANCE CALCULATIONS	0
IGN	TABLE LENGTH FOR CROSS SECTIONS	0
IPM	IS AN OLD ANISN LIBRARY MOUNTED ? (0/1:NO/YES)	0
IPP	OUTPUT OPTION TRIGGER	-1
IFG	PRINT CONTROL - ANISN OUTPUT	0

THE STORAGE ALLOCATED FOR THIS CASE IS 13000 WORDS

23 ARRAY 16 ENTRIES READ

CT

GENERAL INFORMATION CONCERNING CROSS SECTION LIBRARY

TAPE IDENTIFICATION NUMBER	4321
NUMBER OF NUCLIDES ON TAPE	32
NUMBER OF NEUTRON ENERGY GROUPS	27
FIRST THERMAL NEUTRON ENERGY GROUP	15
NUMBER OF GAMMA ENERGY GROUPS	0

XSDRN TAPE 4321

27 NEUTRON GROUP LIBRARY  
BASED ON ENDF/B VERSION 4 DATA  
COMPILED FOR NRC  
8/3/81  
L.M.PETRIE ORNL

NUCLIDES FROM XSDRN TAPE

1	H 1267 F, 1002 T 21P GP 032475(2)	1001
2	R-10 1273 218NGP 042375 P-3 293K	3010
3	C-12 1274F, 1065T 218 GP 030476(7)	6012
4	O-16 1276 218 GP 030476(7)	8016
5	AL-27 1193 218 GP 040375(5)	13027
6	CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	24000
7	FE 212GP RE 5-17-78(1)	26000
8	NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	28000
9	PR 1228 218NGP 042375 P-3 293K	82000
10	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)	92235
11	U-238 218GP RE 5-17-78(1)	92238
12	PU-239 1050 SIGO=5+4 NEWXLACS P-3 293K F-1/E-W(1.+5)	94238
13	PU-239 1264 SIGP=5+4 NEWXLACS 218NGP P-3 293K	94239
14	PU-240 1265 SIGP=5+4 NEWXLACS 218NGP P-3 273K	94240

15 PU-241 1266 SIGP=5+4 NEWXLACS 218NGP P-3 293K  
16 PU-242 1161 SIGP=5+4 NEWXLACS 218NGP P-3 293K

94241  
94242

H 1269 F, 1002 T 218 GP 032475(2)	1001
B-10 1273 218NGP 042375 P-3 293K	5010
C-12 1274F, 1065T 218 GP 030476(7)	6012
D-16 1276 218 GP 030476(7)	8016
AL-27 1103 218 GP 040375(5)	13027
CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	24000
FE 218GP RE 5-17-78(1)	26000

\*\*\*\*\*  
NORESONANCE DATA SUPPLIED FOR 26000  
INFINITE DILUTION VALUES WILL BE USED  
\*\*\*\*\*

NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	28000
PB 1280 218NGP 042375 P-3 293K	82000
U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)	92235

\*\*\*\*\*  
NORESONANCE DATA SUPPLIED FOR 92235  
INFINITE DILUTION VALUES WILL BE USED  
\*\*\*\*\*

U-238 218GP RE 5-17-78(1)	92238
---------------------------	-------

\*\*\*\*\*  
NORESONANCE DATA SUPPLIED FOR 92238  
INFINITE DILUTION VALUES WILL BE USED  
\*\*\*\*\*

PU-238 1050 SIGP=5+4 NEWXLACS P-3 293K F-1/E-4(1+5)	94238
-----------------------------------------------------	-------

\*\*\*\*\*  
NORESONANCE DATA SUPPLIED FOR 94238  
INFINITE DILUTION VALUES WILL BE USED  
\*\*\*\*\*

PU-239 1264 SIGP=5+4 NEWXLACS 218NGP P-3 293K	94239
-----------------------------------------------	-------

\*\*\*\*\*  
NORESONANCE DATA SUPPLIED FOR 94239  
INFINITE DILUTION VALUES WILL BE USED  
\*\*\*\*\*

PU-240 1265 SIGP=5+4 NEWXLACS 218NGP P-3 273K	94240
-----------------------------------------------	-------

\*\*\*\*\*

NORESONANCE DATA SUPPLIED FOR 94240  
INFINITE DILUTION VALUES WILL BE USED

\*\*\*\*\*  
PU-241 1266 SIGP=5+4 NEWXLACS 212NGP P-3 293K

94241

\*\*\*\*\*  
NORESONANCE DATA SUPPLIED FOR 94241  
INFINITE DILUTION VALUES WILL BE USED

\*\*\*\*\*  
PU-242 1161 SIGP=5+4 NEWXLACS 212NGP P-3 293K

94242

\*\*\*\*\*  
NORESONANCE DATA SUPPLIED FOR 94242  
INFINITE DILUTION VALUES WILL BE USED

\*\*\*\*\*  
ELAPSED TIME 13.39664996 MIN.

THIS XSDRM WORKING TAPE WAS CREATED  
THE TITLE OF THE PARENT CASE IS AS FOLLOWS  
2- NEUTRON GROUP LIBRARY

BASED ON ENDF/R VERSION 4 DATA  
COMPILED FOR NRC

TAPE ID 4321  
NUMBER OF NEUTRON GROUPS 27  
FIRST THERMAL GROUP 15

NUMBER OF NUCLIDES 16  
NUMBER OF GAMMA GROUPS 0

TABLE OF CONTENTS

M 1267 F, 1002 T 218 GP 032475(2)	ID	1001
B-10 1273 218NGP 042375 P-3 293K	ID	5010
C-12 1274F, 1065T 218 GP 030476(7)	ID	6012
O-16 1276 218 GP 030476(7)	ID	8016
AL-27 1193 218 GP 040375(5)	ID	13027
CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	ID	24000
FE 218GP RE 5-17-78(1)	ID	26000
NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	ID	28000
PD 1208 218NGP 042375 P-3 293K	ID	82000
U-235 1261 SIGP=5+4 NEWLACS 218NGP P-3 293K(3)	ID	92235
U-238 218GP RE 5-17-78(1)	ID	92238
PU-239 1050 SIGP=5+4 NEWLACS P-3 293K F-1/E-M(1.+5)	ID	94238
PU-239 1264 SIGP=5+4 NEWLACS 218NGP P-3 293K	ID	94239
PU-240 1265 SIGP=5+4 NEWLACS 218NGP P-3 273K	ID	94240
PU-241 1266 SIGP=5+4 NEWLACS 218NGP P-3 293K	ID	94241
PU-242 1161 SIGP=5+4 NEWLACS 218NGP P-3 293K	ID	94242

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**APPENDIX D**

**SECTION X**

**Mark 22 Fuel Assembly KENO Input and Output**

DELTA STE\*MARK22.KENLI

ELT 8R2B (871020 0900:40) 1990 Jan 26 Fri 1515:13

1.	05	ML1-1/2: ROCKWELL BASKET: MARK22 FUEL: NO POISON : INF ARRAY
2.	05	200. 51 624 6 27 27 12 8 20 51 16 6 3 1 -12 1 0 2000 0 1 82
3.	05	6R-1
4.	05	1 -92235 1.9887-3 1 92236 2.33-4 1 92238 2.1426-4 1 13027 5.6357-2
5.	05	2 -92235 2.0288-3 2 92236 2.3275-4 2 92238 2.1391-4 2 13027 5.6363-2
6.	05	3 5010 8.361-3 3 6012 1.083-2 3 13027 3.013-2
7.	05	4 8016 3.3456-2 4 1001 6.6912-2
8.	05	5 24000 1.821-2 5 26000 6.140-2 5 28000 7.773-3
9.	05	6 13027 6.051-2
10.	05	7 82000 3.296-2
11.	05	8 92238 4.773-2 8 -92235 1.052-4
12.	05	BOX TYPE 1
13.	05	CYLINDER 4 2.53365 1000. -1000. 27*0.5
14.	05	CYLINDER 6 2.60985 1000. -1000. 27*0.5
15.	05	CYLINDER 1 2.91211 1000. -1000. 27*0.5
16.	05	CYLINDER 6 2.98831 1000. -1000. 27*0.5
17.	05	CYLINDER 4 3.67284 1000. -1000. 27*0.5
18.	05	CYLINDER 6 3.74904 1000. -1000. 27*0.5
19.	05	CYLINDER 2 3.98780 1000. -1000. 27*0.5
20.	05	CYLINDER 6 4.06400 1000. -1000. 27*0.5
21.	05	CYLINDER 4 4.44500 1000. -1000. 27*0.5
22.	05	CYLINDER 6 5.08000 1000. -1000. 27*0.5
23.	05	CUBOID 4 5.612 -5.612 5.612 -5.612 1000. -1000. 27*0.5
24.	05	BOX TYPE 2
25.	05	CUBOID 5 0.000 -0.635 0.000 -0.635 1000. -1000. 27*0.5
26.	05	CUBOID 3 0.000 -0.7874 0.000 -0.7874 1000. -1000. 27*0.5
27.	05	BOX TYPE 3
28.	05	CUBOID 3 11.224 0.000 0.1524 0.000 1000. -1000. 27*0.5
29.	05	CUBOID 5 11.224 0.000 0.7874 0.000 1000. -1000. 27*0.5
30.	05	BOX TYPE 4
31.	05	CUBOID 3 4.752 0.000 0.1524 0.000 1000. -1000. 27*0.5
32.	05	CUBOID 5 4.752 0.000 0.7874 0.000 1000. -1000. 27*0.5
33.	05	BOX TYPE 5
34.	05	CUBOID 3 0.1524 0.000 11.224 0.000 1000. -1000. 27*0.5
35.	05	CUBOID 5 0.7874 0.000 11.224 0.000 1000. -1000. 27*0.5
36.	05	BOX TYPE 6
37.	05	CUBOID 8 0.000 -1.7447 0.000 -3.4894 1000. -1000. 27*0.5
38.	05	CUBOID 5 0.000 -2.8134 0.000 -5.6270 1000. -1000. 27*0.5
39.	05	CUBOID 4 0.000 -4.7520 0.000 -11.224 1000. -1000. 27*0.5
40.	05	BOX TYPE 7
41.	05	CUBOID 3 0.1524 0.000 4.7520 0.000 1000. -1000. 27*0.5
42.	05	CUBOID 5 0.7874 0.000 4.7520 0.000 1000. -1000. 27*0.5
43.	05	BOX TYPE 8
44.	05	CUBOID 8 0.000 -1.5140 0.000 -1.5140 1000. -1000. 27*0.5
45.	05	CUBOID 5 0.000 -2.4700 0.000 -2.4700 1000. -1000. 27*0.5
46.	05	CUBOID 4 0.000 -11.224 0.000 -4.7520 1000. -1000. 27*0.5
47.	05	BOX TYPE 9
48.	05	CUBOID 5 1.2580 0.000 1.2580 0.000 1000. -1000. 27*0.5
49.	05	CUBOID 8 4.7520 0.000 4.7520 0.000 1000. -1000. 27*0.5
50.	05	BOX TYPE 10
51.	05	CUBOID 4 5.612 -5.612 5.612 -5.612 1000. -1000. 27*0.5
52.	05	BOX TYPE 11
53.	05	CUBOID 5 0.635 0.000 0.000 -0.635 1000. -1000. 27*0.5
54.	05	CUBOID 3 0.7874 0.000 0.000 -0.7874 1000. -1000. 27*0.5
55.	05	BOX TYPE 12
56.	05	CUBOID 3 0.000 -0.1524 11.224 0.000 1000. -1000. 27*0.5
57.	05	CUBOID 5 0.000 -0.7874 11.224 0.000 1000. -1000. 27*0.5
58.	05	BOX TYPE 13
59.	05	CUBOID 8 1.7447 0.000 0.000 -3.4894 1000. -1000. 27*0.5
60.	05	CUBOID 5 2.8134 0.000 0.000 -5.6270 1000. -1000. 27*0.5
61.	05	CUBOID 4 4.7520 0.000 0.000 -11.224 1000. -1000. 27*0.5
62.	05	BOX TYPE 14
63.	05	CUBOID 3 0.000 -0.1524 4.7520 0.000 1000. -1000. 27*0.5
64.	05	CUBOID 5 0.000 -0.7874 4.7520 0.000 1000. -1000. 27*0.5
65.	05	BOX TYPE 15

```

66.      05      CUBOID  8  1.5140 0.000  0.000 -1.5140 1000. -1000. 27*0.5
67.      05      CUBOID  5  2.4700 0.000  0.000 -2.4700 1000. -1000. 27*0.5
68.      05      CUBOID  4 11.224 0.000  0.000 -4.7520 1000. -1000. 27*0.5
69.      05      BOX TYPE 16
70.      05      CUBOID  5  0.000 -1.2580 1.2580 0.000 1000. -1000. 27*0.5
71.      05      CUBOID  8  0.000 -4.7520 4.7520 0.000 1000. -1000. 27*0.5
72.      05      CORE BODY 0 16.7634 -16.7634 16.7634 0.00 1000. -1000. 27*0.5
73.      05      ZHENICYL+Y 8 25.309 1000. -1000. 27*0.5
74.      05      ZHENICYL+Y 7 30.706 1000. -1000. 27*0.5
75.      05      ZHENICYL+Y 5 32.929 1000. -1000. 27*0.5
76.      05      ZHENICYL+Y 4 45.629 1000. -1000. 27*0.5
77.      05      ZHENICYL+Y 5 46.264 1000. -1000. 27*0.5
78.      05      CUBOID  4 46.27 -46.27 46.27 0.00 1000. -1000. 27*0.5
79.      05      4 1 1 1 1 1 1 1 0
80.      05      3 2 2 1 1 1 1 1 0
81.      05      11 3 3 1 1 1 1 1 0
82.      05      2 4 4 1 1 1 1 1 0
83.      05      3 5 5 1 1 1 1 1 0
84.      05      4 6 6 1 1 1 1 1 0
85.      05      13 1 1 1 2 2 1 1 1 0
86.      05      10 2 2 1 2 2 1 1 1 0
87.      05      12 3 3 1 2 2 1 1 1 0
88.      05      5 4 4 1 2 2 1 1 1 0
89.      05      1 5 5 1 2 2 1 1 1 0
90.      05      6 6 6 1 2 2 1 1 1 0
91.      05      16 1 1 1 3 3 1 1 1 0
92.      05      15 2 2 1 3 3 1 1 1 0
93.      05      14 3 3 1 3 3 1 1 1 0
94.      05      7 4 4 1 3 3 1 1 1 0
95.      05      8 5 5 1 3 3 1 1 1 0
96.      05      9 6 6 1 3 3 1 1 1 1
97.      05      END KENO.
END ELT.  ERRORS: NONE.  TIME: 1.777 SEC.  IMAGE COUNT: 97
BXQT,B 421000*KENO.KENO

```

MLI-1/2: ROCKWELL BASKET: MARK22 FUEL: NO POISON : INF ARRAY

NUMBER OF GENERATIONS	51
NUMBER PER GENERATION	624
NUMBER OF GENERATIONS TO BE SKIPPED	6
NUMBER OF ENERGY GROUPS	27
MAX. NUMBER OF ENERGY TRANSFERS	27
NUMBER OF INPUT NUCLIDES	12
NUMBER OF MIXTURES	8
NUMBER OF MIXING TABLE ENTRIES	20
NUMBER OF GEOMETRY CARDS	51
NUMBER OF BOX TYPES	16
NUMBER OF UNITS IN X DIRECTION	6
NUMBER OF UNITS IN Y DIRECTION	3
NUMBER OF UNITS IN Z DIRECTION	1
NUMBER OF NUCLIDES READ FROM TAPE	-12
ALBEDO TYPE	1
SEARCH TYPE	0

START TYPE	1
GENERATIONS BETWEEN CHECKPOINTS	0
LIST INPUT X-SECTIONS READ FROM TAPE	NO
LIST 1-D MIXTURE X SECTIONS	NO
LIST 2-D MIXTURE X-SECTIONS	NO
LIST FISSION AND ABS. BY REGION	NO
USE X-SECTIONS FROM PREVIOUS CASE	NO
USE GEOMETRY FROM PREVIOUS CASE	NO
USE VELOCITIES FROM PREVIOUS CASE	NO
COMPUTE MATRIX K-EFFECTIVE BY UNIT	NO
COMPUTE MATRIX K-EFFECTIVE BY BOX TYPE	NO
LIST FISSION PROB MATRIX BY UNIT	NO
ADJOINT CALCULATION	NO
USE EXPONENTIAL TRANSFORM	NO
CALCULATE FLUX	YES
CALCULATE FISSION DENSITIES	YES

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE +X = 1.00000+000 -X = 1.00000+000 +Y = 1.00000+000 -Y = 1.00000+000 +Z = 1.00000+000 -Z = 1.00000+000

MAXIMUM TIME = 200.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 37083

REMAINING AVAILABLE LOCATIONS= 32917

NLI-1/2: ROCKWELL BASKET: MARK22 FUEL: NO POISON : INF ARRAY

MIXTURE	NUCLIDE	DENSITY
1	-92235	1.98870-003
1	92236	2.33000-004
1	92238	2.14260-004
1	13027	5.63570-002
2	-92235	2.02880-003
2	92236	2.32750-004
2	92238	2.13910-004
2	13027	5.63630-002
3	5010	8.36100-003
3	6012	1.08300-002
3	13027	3.01300-002
4	8016	3.34560-002
4	1001	6.69120-002
5	24000	1.82100-002
5	26000	6.14000-002
5	28000	7.77300-003
6	13027	6.05100-002
7	82000	3.29600-002
8	92238	4.77300-002
8	-92235	1.05200-004

CROSS SECTIONS READ FROM TAPE

NUCLIDE =	1001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	5010	B-10 1273 218NGP 042375 P-3 293K
NUCLIDE =	6012	C-12 1274F, 1065T 218 GP 030476(7)
NUCLIDE =	8016	O-16 1276 218 GP 030476(7)
NUCLIDE =	13027	AL-27 1193 218 GP 040375(5)
NUCLIDE =	24000	CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	26000	FE 218GP RE 5-17-78(1)
NUCLIDE =	28000	NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	82000	PB 1288 218NGP 042375 P-3 293K
NUCLIDE =	92235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	92236	U-236 1163 SIGO=5+4 NEWXLACS P-3 293K F-1/E-M(1.+5)
NUCLIDE =	92238	U-238 218GP RE 5-17-78(1)

NLI-1/2: ROCKWELL BASKET: MARK22 FUEL: NO POISON : INF ARRAY  
ARRAY DESCRIPTION

Z = 1  
16 15 14 7 8 9  
13 10 12 5 1 6  
4 3 11 2 3 4

NLI-1/2: ROCKWELL BASKET: MARK22 FUEL: NO POISON : INF ARRAY

LIFETIME = 1.07860-004 + OR - 7.38088-007

GENERATION TIME = 5.89191-005 + OR - 5.07176-007

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL		95 PER CENT CONFIDENCE INTERVAL		99 PER CENT CONFIDENCE INTERVAL		NUMBER OF HISTORIES
6	.53257	+ OR - .00373	.52884 TO	.53631	.52511 TO	.54004	.52137 TO	.54378	28080
7	.53257	+ OR - .00382	.52875 TO	.53639	.52493 TO	.54021	.52111 TO	.54403	27456
8	.53186	+ OR - .00384	.52802 TO	.53571	.52418 TO	.53955	.52034 TO	.54339	26832
9	.53123	+ OR - .00388	.52735 TO	.53512	.52347 TO	.53900	.51959 TO	.54288	26208
10	.53151	+ OR - .00397	.52755 TO	.53548	.52358 TO	.53945	.51961 TO	.54342	25584
11	.53088	+ OR - .00402	.52686 TO	.53489	.52285 TO	.53891	.51883 TO	.54292	24960
12	.53220	+ OR - .00389	.52831 TO	.53609	.52442 TO	.53998	.52053 TO	.54387	24336
13	.53118	+ OR - .00385	.52733 TO	.53504	.52347 TO	.53889	.51962 TO	.54275	23712
14	.53242	+ OR - .00375	.52867 TO	.53617	.52492 TO	.53992	.52117 TO	.54367	23088
15	.53193	+ OR - .00382	.52810 TO	.53575	.52428 TO	.53958	.52046 TO	.54340	22464
20	.53289	+ OR - .00434	.52856 TO	.53723	.52422 TO	.54156	.51988 TO	.54590	19344
25	.53443	+ OR - .00507	.52936 TO	.53950	.52430 TO	.54457	.51923 TO	.54964	16224
30	.53689	+ OR - .00565	.53124 TO	.54254	.52559 TO	.54819	.51994 TO	.55384	13104
35	.53354	+ OR - .00671	.52683 TO	.54026	.52012 TO	.54697	.51340 TO	.55368	9984
40	.53186	+ OR - .00908	.52277 TO	.54094	.51369 TO	.55002	.50461 TO	.55910	6864
45	.53520	+ OR - .01370	.52150 TO	.54890	.50780 TO	.56260	.49410 TO	.57630	3744

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**APPENDIX E**

**SECTION X**

**Mark 22 Fuel Assembly NITAWL Output**

QADD,P STE\*MARK22.NITINDUL  
 1S ARRAY 12 ENTRIES READ  
 OT  
 MSCM NUMBER OF EXTRA CROSS SECTIONS 0  
 MMT NUMBER OF NUCLIDES FROM MASTER LIBRARY 12  
 MWT NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LOG 2) 0  
 MXT NUMBER OF NUCLIDES FROM X-SECT LIBRARY (LOG 3) 0  
 MCR ANISM/DOT/MORSE OUTPUT TRIGGER 0  
 MXX TOTAL CROSS SECTION POSITION 0  
 MS WITHIN-GROUP SCATTERING CROSS SECTION POSITION 0  
 IRES NUMBER OF RESONANCE CALCULATIONS 0  
 IQM TABLE LENGTH FOR CROSS SECTIONS 0  
 IPM IS AN OLD ANISM LIBRARY MOUNTED ? (0/1:NO/YES) 0  
 IPP OUTPUT OPTION TRIGGER -1  
 IFG PRINT CONTROL - ANISM OUTPUT 0

THE STORAGE ALLOCATED FOR THIS CASE IS 13000 WORDS

2S ARRAY 12 ENTRIES READ.

OT

# GENERAL INFORMATION CONCERNING CROSS SECTION LIBRARY

TAPE IDENTIFICATION NUMBER 4321

NUMBER OF NUCLIDES ON TAPE 82

NUMBER OF NEUTRON ENERGY GROUPS 27

FIRST THERMAL NEUTRON ENERGY GROUP 15

NUMBER OF GAMMA ENERGY GROUPS 0

XSDRN TAPE 4321

## 27 NEUTRON GROUP LIBRARY

BASED ON ENDF/B VERSION 4 DATA

COMPILED FOR NRC

8/3/81

L.M.PETRIE ORNL

## NUCLIDES FROM XSDRN TAPE

1	H 1269 F, 1002 T 218 GP 032475(2)	1001
2	B-10 1273 218NGP 042375 P-3 293K	5010
3	C-12 1274F,1065T 218 GP 030476(7)	6012
4	O-16 1276 218 GP 030476(7)	8016
5	AL-27 1193 218 GP 040375(5)	13027
6	CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	24000
7	FE 218GP RE 5-17-78(1)	26000
8	NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	28000
9	PB 1288 218NGP 042375 P-3 293K	82000
10	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)	92235
11	U-236 1163 SIGO=5+4 NEWXLACS P-3 293K F-1/E-M(1.+5)	92236
12	U-238 218GP RE 5-17-78(1)	92238

H 1269 F, 1002 T 218 GP 032475(2)	1001
B-10 1273 218NGP 042375 P-3 293K	5010
C-12 1274F, 1065T 218 GP 030476(7)	6012
O-16 1276 218 GP 030476(7)	8016
AL-27 1193 218 GP 040375(5)	13027
CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	24000
FE 218GP RE 5-17-78(1)	26000
*****	
NORESONANCE DATA SUPPLIED FOR 26000	
INFINITE DILUTION VALUES WILL BE USED	
*****	
NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	28000
PB 1288 218NGP 042375 P-3 293K	82000
U-235 1261 SIGP=5+4 NEWLACS 218NGP P-3 293K(3)	92235
*****	
NORESONANCE DATA SUPPLIED FOR 92235	
INFINITE DILUTION VALUES WILL BE USED	
*****	
U-236 1163 SIGO=5+4 NEWLACS P-3 293K F-1/E-M(1+5)	92236
*****	
NORESONANCE DATA SUPPLIED FOR 92236	
INFINITE DILUTION VALUES WILL BE USED	
*****	
U-238 218GP RE 5-17-78(1)	92238
*****	
NORESONANCE DATA SUPPLIED FOR 92238	
INFINITE DILUTION VALUES WILL BE USED	
*****	
ELAPSED TIME 10.13243330 MIN.	

THIS XSDRM WORKING TAPE WAS CREATED  
 THE TITLE OF THE PARENT CASE IS AS FOLLOWS  
 27 NEUTRON GROUP LIBRARY  
 BASED ON ENDF/B VERSION 4 DATA  
 COMPILED FOR NRC

TAPE ID	4321	NUMBER OF NUCLIDES	12
NUMBER OF NEUTRON GROUPS	27	NUMBER OF GAMMA GROUPS	0
FIRST THERMAL GROUP	15		

TABLE OF CONTENTS

N 1269 F, 1002 T 218 GP 032475(2)	ID	1001
B-10 1273 218NGP 042375 P-3 293K	ID	5010
C-12 1274F,1065T 218 GP 030476(7)	ID	6012
O-16 1276 218 GP 030476(7)	ID	8016
AL-27 1193 218 GP 040375(5)	ID	13027
CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	ID	24000
FE 218GP RE 5-17-78(1)	ID	26000
NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)	ID	28000
PB 1288 218NGP 042375 P-3 293K	ID	82000
U-235 1261 SIGP=5+4 NEWLACS 218NGP P-3 293K(3)	ID	92235
U-236 1163 SIGO=5+4 NEWLACS P-3 293K F-1/E-M(1.+5)	ID	92236
U-238 218GP RE 5-17-78(1)	ID	92238

28BKPT PRINTS

**APPENDIX F**

**SECTION X**

**Computer Input and Output for  
Fermi-1 Fuel and EBR-II Blanket Fuel**

# NITAWL - FERMI-1 NORMAL OPERATION

\*KEMO.N27

10 07/17/86 10:50:17 (22)

19 1SS 0 17 52 2 22 -1 3 T

19 2SS 92238 -592233 92235 -592235 8016 -555081 1001 -555011 13027

13 40000 24000 28000 26000 82000 5010 6012 42000

22 3\*\* 92238 294. 2 .1880 .3464 76.34 2.932-2 1 96 2.22 1 32 1.0

19 592238 294. 3 0.0 0.00 20.0 4.773-2 1 32 32 1.0 T

ERRORS: NONE. TIME: 0.302 SEC. IMAGE COUNT: 5

- IN CONTROL MODE

NITAWL.NITAWL

# NITAWL - FERMI-1 NORMAL OPERATION (Continued)

THIS XSDRN WORKING TAPE WAS CREATED  
THE TITLE OF THE PARENT CASE IS AS FOLLOWS  
27 NEUTRON GROUP LIBRARY

BASED ON ENDF/B VERSION 4 DATA

COMPILED FOR NRC

TAPE ID

4321

NUMBER OF NUCLIDES

NUMBER OF NEUTRON GROUPS

27

NUMBER OF GAMMA GROUPS

FIRST THERMAL GROUP

15

## TABLE OF CONTENTS

H 1269 F, 1002 T 212 GP 032475(2)  
H 1269 F, 1002 T 218 GP 032475(2)  
S-10 1273 218NGP 042375 P-3 293K  
C-12 1274F,1065T 218 GP 030476(7)  
O-16 1276 218 GP 030476(7)  
O-16 1276 218 GP 030476(7)  
AL-27 1193 218 GP 040375(5)  
CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
FE 218GP RE 5-17-78(1)  
NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
ZR(NAT) 7141 21 NGP WT FIS(0.1T020)-1/E-MAX P-3  
MO (1227) SIGP=5+4 NEWXLACS 218NGP F-1/E-M P-3 293K  
PB 1223 218NGP 042375 P-3 293K  
U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)  
U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)  
U-238 218GP RE 5-17-78(1)  
U-238 218GP RE 5-17-78(1)

KPT PRINTS

# XSDRNPM - FERMI-1 NORMAL OPERATION

.ENO.X27

7/17/86 11:19:19 (19)

```

15 XSDRNPM FOR FERMI-1 METAL FUEL
17 1SS 2 3 20 1 3 3 39 8 3 1 2R10 FO
15 2SS -2 FO
15 3SS 1 32 1000 22 1 FJ
15 4SS -1 27 0 -2 E T
17 13SS 3R1 2 2R3 11R1 11R2 11R3
15 14SS 92235 92238 42C00 40000 555081 555011
15 8016 1001 82000 24000 28000 26000
17 13027 5010 6012 592238 592235 2011
19 15** 1.0218-2 2.932-2 1.087-2 4.227-2 3.3461-2 6.6922-2 F1.-15 T
15 33** F1.0 T
16 35** 910.0 .188 .189 71.2007 .3633
15 36SS 10R1 2R2 8R3
15 38** 10R1.0 0.0 F1.0
15 39SS 1 2 3
15 40SS F3
15 51SS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
15 13 19 20 21 22 23 24 25 26 27 T

```

:: NONE. TIME: 0.278 SEC. IMAGE COUNT: 18

.NPM.XSDRNPM



# XSDRNPM - FERMI-1 NORMAL OPERATION (Continued)

3ADD,DEP 998CC4\*KENO.X27

XSDRNPM FOR FERMI-1 METAL FUEL

1S ARRAY 15 ENTRIES READ

2S ARRAY 10 ENTRIES READ

3S ARRAY 12 ENTRIES READ

4S ARRAY 9 ENTRIES READ

QT

## DIRECT ACCESS FILES ASSIGNED

3000 WORDS PER RECORD ON UNIT 8

880 WORDS PER RECORD ON UNIT 9

3000 WORDS PER RECORD ON UNIT 10

1 PHYSICAL RECORDS PER LOGICAL

10 PHYSICAL RECORDS PER LOGICAL

1 PHYSICAL RECORDS PER LOGICAL

## GENERAL PROBLEM DESCRIPTION DATA BLOCK

### GENERAL PROBLEM DATA

IGE 1/2/3 = PLANE/CYLINDER/SPHERE 2  
 IZM NUMBER OF ZONES 3  
 IM NUMBER OF SPACIAL INTERVALS 20  
 IBL C/1/2/3 = VACUUM/REFL/PER/WHITE 1  
 IBR RIGHT BOUNDARY CONDITION 3  
 MXM NUMBER OF MIXTURES 3  
 MS MIXING TABLE LENGTH 39  
 IGM NUMBER OF ENERGY GROUPS 27  
 NNG NUMBER OF NEUTRON GROUPS 27  
 NGG NUMBER OF GAMMA GROUPS 3  
 IFTG NUMBER OF FIRST THERMAL GROUP 15

ISN QUADRATURE ORDER  
 ISCT ORDER OF SCATTERING  
 IEVT 0/1/2/3/4/5/6=2/K/ALPHA  
 IIM INNER ITERATION MAXIMUM  
 ICM OUTER ITERATION MAXIMUM  
 ICLC -1/0/N=FLAT RES/SN/OPT  
 ITH 0/1 = FORWARD/ADJOINT  
 IFLU 0/1/2/3/4=L-S/L/S/L-L-W  
 IPRT -2/-1/0/N=MIXTURE XSEC  
 ID1 0/1/2/3=NO/PRT ND/PCH N  
 IPBT -1/0/1=NONE/FIVE/ALL 2A

### SPECIAL OPTIONS

IFG 0/1 = NONE/WEIGHTING CALCULATION 1  
 IQM VOLUMETRIC SOURCES (0/N=NO/YES) 3  
 IPM BOUNDARY SOURCES (0/N=NO/YES) 3  
 IFN 0/1/2 = INPUT 33=34=USE LAST 3  
 ITMX MAXIMUM TIME (MINUTES) 1000  
 IDT1 0/1/2/3=NO/XSECT/SRCE/FLUX=OUT 3

IPN DUMMY PARAMETER  
 IDFM 0/1 = NONE/DENSITY FACT  
 IAZ 0/N = NONE/N ACTIVITIES  
 IAI 0/1=NONE/ACTIVITIES BY  
 IFCT 0/1=NO/YES UPSCATTER SC  
 IPVT 0/1/2=NO/K/ALPHA PARAME

### WEIGHTING DATA (IFG=1)

ICON -1/0/1=CELL/ZONE/REGION WEIGHT -1  
 IGMF NUMBER OF BROAD GROUPS 27  
 ITP 0/10/20/30/40 0/C/E/AC/A 3  
 IPP -2/-1/0/N=WGTED XSECT PRINT -2  
 IAP -1/N ANISN XSECT PRINT -1

INTF TOTAL XSECT PSN IN BRD  
 NDSF PSN G-G OR FILE NUMBER  
 NUSF TABLE LENGTH OR MAX ORD  
 MSCM EXTRA 1-D X-SECT POSITI

### FLOATING POINT PARAMETERS

# XSDRNPM - FERMI-1 NORMAL OPERATION (Continued)

XSDRNPM FOR FERMI-1 METAL FUEL

AY 39 ENTRIES READ

AY 39 ENTRIES READ

AY 39 ENTRIES READ

## DATA BLOCK 2 (MIXING TABLE, ETC.)

DES  
CCCC  
IDENTIFICATION

MIXTURE  
MIXING TABLE  
COMPONENT

1001	1	92235	.10219-001
5011	1	92233	.29320-001
5010	1	42000	.10870-001
5012	2	40000	.42270-001
5016	3	555081	.33461-001
5081	3	555011	.66922-001
5027	1	8016	.10000-016
4000	1	1001	.10000-016
0000	1	92000	.10000-016
0000	1	24000	.10000-016
0000	1	28000	.10000-016
0000	1	26000	.10000-016
0000	1	13027	.10000-016
2235	1	5010	.10000-016
2235	1	6012	.10000-016
2238	1	592238	.10000-016
2238	1	592235	.10000-016
2238	2	8016	.10000-016
2238	2	1001	.10000-016
2238	2	62000	.10000-016
2238	2	24000	.10000-016
2238	2	28000	.10000-016
2238	2	26000	.10000-016
2238	2	13027	.10000-016
2238	2	5010	.10000-016
2238	2	6012	.10000-016
2238	2	592238	.10000-016
2238	2	592235	.10000-016
2238	3	8016	.10000-016
2238	3	1001	.10000-016
2238	3	82000	.10000-016
2238	3	24000	.10000-016
2238	3	28000	.10000-016
2238	3	26000	.10000-016
2238	3	13027	.10000-016
2238	3	5010	.10000-016
2238	3	6012	.10000-016
2238	3	592238	.10000-016
2238	3	592235	.10000-016

MIXING CROSS SECTIONS  
TIME .00000000 MIN.  
Page Added  
Oct. 1990

X-F6

# XSDRNPM - FERMI-1 NORMAL OPERATION (Continued)

OUTER	INNER	BALANCE	UPSCATTER	RATIO	EIGENVALUE	LAMBDA1	
1	254	1.0000026+000	7.7642534-001		1.1001459+000	1.0798629+000	
2	491	1.0000027+000	1.0707040+000		1.4294742+000	1.3276672+000	
3	701	1.0000028+000	1.0299312+000		1.5103499+000	1.3552144+000	
4	874	1.0000029+000	1.0113186+000		1.5285615+000	1.3115772+000	
5	995	1.0000028+000	1.0033013+000		1.5323223+000	1.3022611+000	
6	1058	1.0000028+000	1.0006182+000		1.5326419+000	1.3001417+000	
7	1026	1.0000028+000	1.0000592+000		1.5327520+000	1.3000579+000	
GRP.	1	REQUIRED	1	ITERATIONS. MFD OF	8.30392-005	OCCURRED IN INT.	20 CO.
GRP.	2	REQUIRED	1	ITERATIONS. MFD OF	6.64191-005	OCCURRED IN INT.	20 CO.
GRP.	3	REQUIRED	1	ITERATIONS. MFD OF	6.49530-005	OCCURRED IN INT.	20 CO.
GRP.	4	REQUIRED	1	ITERATIONS. MFD OF	6.97308-005	OCCURRED IN INT.	20 CO.
GRP.	5	REQUIRED	1	ITERATIONS. MFD OF	5.86760-005	OCCURRED IN INT.	20 CO.
GRP.	6	REQUIRED	1	ITERATIONS. MFD OF	5.87569-005	OCCURRED IN INT.	20 CO.
GRP.	7	REQUIRED	1	ITERATIONS. MFD OF	4.98808-005	OCCURRED IN INT.	20 CO.
GRP.	8	REQUIRED	1	ITERATIONS. MFD OF	4.92717-005	OCCURRED IN INT.	20 CO.
GRP.	9	REQUIRED	1	ITERATIONS. MFD OF	5.06186-005	OCCURRED IN INT.	17 CO.
GRP.	10	REQUIRED	1	ITERATIONS. MFD OF	5.01321-005	OCCURRED IN INT.	16 CO.
GRP.	11	REQUIRED	1	ITERATIONS. MFD OF	4.89183-005	OCCURRED IN INT.	15 CO.
GRP.	12	REQUIRED	1	ITERATIONS. MFD OF	5.66715-005	OCCURRED IN INT.	15 CO.
GRP.	13	REQUIRED	1	ITERATIONS. MFD OF	5.63124-005	OCCURRED IN INT.	15 CO.
GRP.	14	REQUIRED	1	ITERATIONS. MFD OF	5.10950-005	OCCURRED IN INT.	15 CO.
GRP.	15	REQUIRED	1	ITERATIONS. MFD OF	1.91663-005	OCCURRED IN INT.	1 CO.
GRP.	16	REQUIRED	1	ITERATIONS. MFD OF	2.11288-005	OCCURRED IN INT.	1 CO.
GRP.	17	REQUIRED	1	ITERATIONS. MFD OF	2.56110-005	OCCURRED IN INT.	1 CO.
GRP.	18	REQUIRED	1	ITERATIONS. MFD OF	2.64325-005	OCCURRED IN INT.	1 CO.
GRP.	19	REQUIRED	1	ITERATIONS. MFD OF	2.36228-005	OCCURRED IN INT.	1 CO.
GRP.	20	REQUIRED	1	ITERATIONS. MFD OF	2.44632-005	OCCURRED IN INT.	1 CO.
GRP.	21	REQUIRED	1	ITERATIONS. MFD OF	3.77428-005	OCCURRED IN INT.	1 CO.
GRP.	22	REQUIRED	1	ITERATIONS. MFD OF	2.86500-005	OCCURRED IN INT.	1 CO.
GRP.	23	REQUIRED	1	ITERATIONS. MFD OF	1.86630-005	OCCURRED IN INT.	1 CO.
GRP.	24	REQUIRED	1	ITERATIONS. MFD OF	3.30656-005	OCCURRED IN INT.	20 CO.
GRP.	25	REQUIRED	1	ITERATIONS. MFD OF	5.13642-005	OCCURRED IN INT.	20 CO.
GRP.	26	REQUIRED	1	ITERATIONS. MFD OF	2.80517-005	OCCURRED IN INT.	20 CO.
GRP.	27	REQUIRED	1	ITERATIONS. MFD OF	1.71842-005	OCCURRED IN INT.	17 CO.
1113		1.0000028+000	1.0000476+000		1.5328507+000	1.3000611+000	
FINAL MINITOR		LAMBDA		1.5328135+000		ANGULAR FLUX ON	
ELAPSED TIME		2.90218329 MIN.					

# KENO - FERMI-1 NORMAL OPERATION

KENO-KB040FER

C7/17/86 11:31:10 (13)

14 FOUR ASBL BASKET FOR FERMI-1 FUEL, -040 BORON

15 200. 56 403 6 27 27 17 7 15 25 8 4 2 1 -17 1 3 2000 0 1 82

16 -1 0 0 3R-1

17 1 -92235 2.7362-3 1 92238 7.8491-3 1 42030 2.91C-3

18 1 40C00 1.5806-3 1 55311 4.6515-2 1 55328 1 2.3253-2

19 2 5010 8.361-3 2 5012 1.083-2 2 13027 3.013-2

20 3 8016 3.1461-2 3 1001 6.6922-2

21 4 24C00 1.839-2 4 28C00 1.815-3 4 26C00 5.994-2

22 5 13027 6.026-2

23 6 82C00 3.299-2

24 7 592238 4.773-2 7 -592235 1.352-4

25 BOX TYPE 1

26 CUBOID 1 3.81C -3.81C 3.810 -3.810 1303. -1000. 27\*0.5

27 CUBOID 3 6.5075 -6.5075 6.5075 -6.5075 1303. -1000. 27\*0.5

28 DOX TYPE 2

29 CUBOID 2 13.015 0.300 0.1441 0.300 1303. -1000. 27\*0.5

30 CUBOID 4 13.015 0.300 0.7791 0.000 1003. -1000. 27\*0.5

31 BOX TYPE 3

32 CUBOID 2 0.1441 0.300 13.015 0.000 1003. -1000. 27\*0.5

33 CUBOID 4 0.7791 0.300 13.015 0.000 1003. -1000. 27\*0.5

34 BOX TYPE 4

35 CUBOID 4 0.000 -0.535 0.000 -0.635 1303. -1000. 27\*0.5

36 CUBOID 2 0.000 -0.7791 0.000 -0.7791 1303. -1000. 27\*0.5

37 BOX TYPE 5

38 CUBOID 1 3.81C -3.81C 3.810 -3.810 1303. -1000. 27\*0.5

39 CUBOID 3 6.5075 -6.5075 6.5075 -6.5075 1303. -1000. 27\*0.5

40 BOX TYPE 6

41 CUBOID 2 0.300 -13.015 0.1441 0.300 1003. -1000. 27\*0.5

42 CUBOID 4 0.300 -13.015 0.7791 0.300 1003. -1000. 27\*0.5

43 BOX TYPE 7

44 CUBOID 2 0.300 -0.1441 13.015 0.300 1003. -1000. 27\*0.5

45 CUBOID 4 0.300 -0.7791 13.015 0.000 1003. -1000. 27\*0.5

46 BOX TYPE 8

47 CUBOID 4 0.635 0.300 0.000 -0.635 1303. -1000. 27\*0.5

48 CUBOID 2 0.7791 0.300 0.000 -0.7791 1003. -1000. 27\*0.5

49 CORE BDY 3 13.7941 -13.7941 13.7941 0.000 1303. -1000. 27\*0.5

50 ZHEMICYL+Y 3 19.509 1000. -1000. 27\*0.5

51 ZHEMICYL+Y 4 19.600 1000. -1000. 27\*0.5

52 ZHEMICYL+Y 7 25.309 1000. -1000. 27\*0.5

53 ZHEMICYL+Y 6 30.706 1000. -1000. 27\*0.5

54 ZHEMICYL+Y 4 32.93 1000. -1000. 27\*0.5

55 ZHEMICYL+Y 3 45.629 1000. -1000. 27\*0.5

56 ZHEMICYL+Y 4 46.264 1000. -1000. 27\*0.5

57 CUBOID 3 53. -63. 63. 0.300 1000. -1000. 27\*0.5

58 1 4 4 1 2 2 1 1 1 1 3

59 2 4 4 1 1 1 1 1 1 3

60 3 3 3 1 2 2 1 1 1 3

61 4 3 3 1 1 1 1 1 1 3

62 5 1 1 1 2 2 1 1 1 3

63 6 1 1 1 1 1 1 1 1 3

64 7 2 2 1 2 2 1 1 1 3

65 8 2 2 1 1 1 1 1 1 1

66 END KENO.

ORS: NONE. TIME: 0.526 SEC. IMAGE COUNT: 53

# KENO - FERMI-1 NORMAL OPERATION (Continued)

FOUR ASBL BASKET FOR FERMI-1 FUEL, .040 BORON

NUMBER OF GENERATIONS	56	START TYPE
NUMBER PER GENERATION	403	GENERATIONS BE
NUMBER OF GENERATIONS TO BE SKIPPED	5	LIST INPUT X-S
NUMBER OF ENERGY GROUPS	27	LIST 1-D MIXTU
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2-D MIXTU
NUMBER OF INPUT NUCLIDES	17	LIST FISS. AND
NUMBER OF MIXTURES	7	USE X-SECTIONS
NUMBER OF MIXING TABLE ENTRIES	15	USE GEOMETRY F
NUMBER OF GEOMETRY CARDS	25	USE VELOCITIES
NUMBER OF BOX TYPES	8	COMPUTE MATRIX
NUMBER OF UNITS IN X DIRECTION	4	COMPUTE MATRIX
NUMBER OF UNITS IN Y DIRECTION	2	LIST FISS PROE
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALCUL
NUMBER OF NUCLIDES READ FROM TAPE	-17	USE EXPONENTIAL
ALBEDO TYPE	1	CALCULATE FLUX
SEARCH TYPE	3	CALCULATE FISS

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE +X = 1.00000+000 -X = .33000 +Y = .33000 -Y = 1.00000+

MAXIMUM TIME = 200.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 24763  
 REMAINING AVAILABLE LOCATIONS = 375237

# KENO - FERMI-1 NORMAL OPERATION (Continued)

## FOUR ASBL BASKET FOR FERMI-1 FUEL, .040 30R3V

MIXTURE	NUCLIDE	DENSITY
1	-92235	2.73620-003
1	92238	7.84910-003
1	42000	2.91000-003
1	40000	1.58060-003
1	555011	4.65150-002
1	555081	2.32580-002
2	5010	8.36100-003
2	6012	1.08300-002
2	13027	3.01300-002
3	8016	3.34610-002
3	1001	6.69220-002
4	24000	1.83900-002
4	28000	1.81500-003
4	26000	5.99400-002
5	13027	6.02600-002
6	82000	3.29900-002
7	592238	4.77300-002
7	-592235	1.05200-004

## CROSS SECTIONS READ FROM TAPE

NUCLIDE =	1001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	555011	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	5010	B-10 1273 218NGP 042375 P-3 293K
NUCLIDE =	6012	C-12 1274F, 1065T 218 GP 030476(7)
NUCLIDE =	8016	O-16 1276 218 GP 030475(7)
NUCLIDE =	555081	O-16 1276 218 GP 030475(7)
NUCLIDE =	13027	AL-27 1193 218 GP 040375(5)
NUCLIDE =	24000	CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	26000	FE 218GP RE 5-17-73(1)
NUCLIDE =	23000	NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	40000	ZR(NAT) 7141 21 NGP WT FIS(0.1T020)-1/E-MAX P-3
NUCLIDE =	42000	MO (1287) SIGP=5+4 NEWXLACS 218NGP F-1/E-M P-3 293K
NUCLIDE =	32000	PB 1288 218NGP 042375 P-3 293K
NUCLIDE =	92235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	592235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	92238	U-238 218GP RE 5-17-73(1)
NUCLIDE =	592238	U-238 218GP RE 5-17-73(1)

KENO - FERMI-1 NORMAL OPERATION (Continued)

FOUR ASBL BASKET FOR FERMI-1 FUEL, .040 BORON

ARRAY DESCRIPTION

Z = 1

5 7 3 1

6 8 4 2

# KENO - FERMI 1 NORMAL OPERATION (Continued)

FOUR ASBL BASKET FOR FERMI-1 FUEL, .040 BORON

LIFETIME = 9.71350-005 + OR - 1.02707-036

GENERATION TIME = 4.07517

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	57 PER CENT CONFIDENCE INTERVAL	95 PER CONFIDENCE
6	<u>.80637 + OR - .00480</u>		.80158 TO .81117	.79678 TO
7	.80684 + OR - .00487		.80197 TO .81171	.79710 TO
8	.80659 + OR - .00497		.80162 TO .81156	.79666 TO
9	.80613 + OR - .00505		.80108 TO .81118	.79603 TO
10	.80702 + OR - .00508		.80193 TO .81210	.79685 TO
11	.80606 + OR - .00510		.80096 TO .81117	.79585 TO
12	.80641 + OR - .00521		.80120 TO .81162	.79599 TO
13	.80763 + OR - .00518		.80245 TO .81281	.79726 TO
14	.80725 + OR - .00529		.80196 TO .81255	.79666 TO
15	.80831 + OR - .00532		.80300 TO .81363	.79758 TO
20	.80765 + OR - .00533		.80232 TO .81299	.79699 TO
25	.80640 + OR - .00599		.80041 TO .81238	.79442 TO
30	.80738 + OR - .00695		.80043 TO .81434	.79368 TO
35	.80975 + OR - .00740		.80235 TO .81716	.79494 TO
40	.81444 + OR - .00900		.80544 TO .82344	.79644 TO
45	.80389 + OR - .01150		.79238 TO .81539	.79088 TO
50	.80858 + OR - .01406		.79451 TO .82264	.79045 TO



# KENO - FERMI-1 - NO MODERATOR

```

.KB040FER1
17/86 15:55:52 (19)
    FOUR ASBL BASKET FOR FERMI-1 FUEL, .040 BORON, NO MODERATOR IN FUEL
200. 56 403 6 27 27 17 7 18 25 8 4 2 1 -17 1 3 2000 0 1 52
-1 0 0 3R-1
1 -92235 2.7362-3 1 92238 7.8471-3 1 42030 2.910-3 NO WATER
1 40000 1.5806-3 1 555011 1.-15 1 555081 1.-15 IN FUEL
2 5010 8.361-3 2 6012 1.083-2 2 13027 3.013-2
3 8016 3.3461-2 3 1001 6.6922-2
4 24000 1.839-2 4 28000 1.815-3 4 26000 5.994-2
5 13027 6.026-2
6 82000 3.299-2
7 592238 6.773-2 7 -592235 1.052-4
BOX TYPE 1
CUBOID 1 3.810 -3.810 3.810 -3.810 1303. -1000. 27*0.5
CUBOID 3 6.5075 -6.5075 6.5075 -6.5075 1303. -1000. 27*0.5
BOX TYPE 2
CUBOID 2 13.015 0.000 0.1441 0.000 1003. -1000. 27*0.5
CUBOID 4 13.015 0.000 0.7791 0.000 1003. -1000. 27*0.5
BOX TYPE 3
CUBOID 2 0.1441 0.000 13.015 0.000 1003. -1000. 27*0.5
CUBOID 4 0.7791 0.000 13.015 0.000 1003. -1000. 27*0.5
BOX TYPE 4
CUBOID 4 0.000 -0.635 0.000 -0.635 1003. -1000. 27*0.5
CUBOID 2 0.000 -0.7791 0.000 -0.7791 1003. -1000. 27*0.5
BOX TYPE 5
CUBOID 1 3.810 -3.810 3.810 -3.810 1303. -1000. 27*0.5
CUBOID 3 6.5075 -6.5075 6.5075 -6.5075 1303. -1000. 27*0.5
BOX TYPE 6
CUBOID 2 0.000 -13.015 0.1441 0.000 1003. -1000. 27*0.5
CUBOID 4 0.000 -13.015 0.7791 0.000 1003. -1000. 27*0.5
BOX TYPE 7
CUBOID 2 0.000 -0.1441 13.015 0.000 1003. -1000. 27*0.5
CUBOID 4 0.000 -0.7791 13.015 0.000 1303. -1000. 27*0.5
BOX TYPE 8
CUBOID 4 0.635 0.000 0.000 -0.635 1303. -1000. 27*0.5
CUBOID 2 0.7791 0.000 0.000 -0.7791 1303. -1000. 27*0.5
CORE BODY C 13.7941 -13.7941 13.7941 0.000 1003. -1000. 27*0.5
ZHEMICYL+Y 3 19.509 1000. -1000. 27*0.5
ZHEMICYL+Y 4 19.600 1000. -1000. 27*0.5
ZHEMICYL+Y 7 25.309 1000. -1000. 27*0.5
ZHEMICYL+Y 6 30.706 1000. -1000. 27*0.5
ZHEMICYL+Y 4 32.93 1000. -1000. 27*0.5
ZHEMICYL+Y 3 45.629 1000. -1000. 27*0.5
ZHEMICYL+Y 4 46.264 1000. -1000. 27*0.5
CUBOID 3 63. -63. 63. 0.000 1000. -1000. 27*0.5
1 4 4 1 2 2 1 1 1 1 3
2 4 4 1 1 1 1 1 1 1 3
3 3 3 1 2 2 1 1 1 1 3
4 3 3 1 1 1 1 1 1 1 3
5 1 1 1 2 2 1 1 1 1 3
6 1 1 1 1 1 1 1 1 1 3
7 2 2 1 2 2 1 1 1 1 3
8 2 2 1 1 1 1 1 1 1 1
END KENO.

```

NONE. TIME: 0.531 SEC. IMAGE COUNT: 53

X-F13

# KENO - FERMI-1 - NO MODERATOR (Continued)

FOUR ASBL BASKET FOR FERMI-1 FUEL, .040 BORON, NO MODERATOR IN FUEL

LIFETIME = 1.12881-004 + OR - 1.16662-006

GENERATION TIME = 5.35320-

NO. OF INITIAL  
GENERATIONS  
SKIPPED

AVERAGE  
K-EFFECTIVE

DEVIATION

67 PER CENT  
CONFIDENCE INTERVAL

95 PER C  
CONFIDENCE I

6	.65500 + OR - .00477	.65023 TO .65977	.64546 TO
7	.65515 + OR - .00486	.65029 TO .66002	.64542 TO
8	.65463 + OR - .00494	.64969 TO .65957	.64475 TO
9	.65521 + OR - .00501	.65020 TO .66022	.64519 TO
10	.65415 + OR - .00500	.64915 TO .65916	.64414 TO
11	.65294 + OR - .00496	.64797 TO .65790	.64301 TO
12	.65205 + OR - .00500	.64706 TO .65705	.64206 TO
13	.65332 + OR - .00493	.64845 TO .65831	.64352 TO
14	.65180 + OR - .00478	.64702 TO .65658	.64224 TO
15	.65266 + OR - .00482	.64784 TO .65748	.64302 TO
20	.65525 + OR - .00513	.65012 TO .66038	.64499 TO
25	.65111 + OR - .00557	.64554 TO .65667	.63997 TO
30	.64524 + OR - .00524	.64000 TO .65048	.63476 TO
35	.64595 + OR - .00534	.64061 TO .65129	.63527 TO
40	.64900 + OR - .00665	.64236 TO .65365	.63571 TO
45	.65082 + OR - .00803	.64279 TO .65835	.63476 TO
50	.64331 + OR - .01152	.63179 TO .65482	.62027 TO

J.K8030FER

## KENO - FERMI-1 BORON SENSITIVITY

/17/86 20:13:12 (0)

00 FOUR ASBL BASKET FOR FERMI-1 FUEL, .030 BORON

00 200. 50 403 6 27 27 17 7 18 25 8 4 2 1 -17 1 3 2000 0 1 82

00 -1 0 0 3R-1

00 1 -92235 2.180-3 1 92238 6.124-3 1 42000 2.286-3

00 1 40000 1.242-3 1 555011 5.089-2 1 555081 2.545-2

00 2 5010 6.271-3 2 6012 1.083-2 2 13027 3.013-2

00 3 8016 3.3461-2 3 1001 6.6922-2

00 4 24000 1.839-2 4 28303 1.815-3 4 26000 5.994-2

00 5 13027 6.026-2

00 6 82000 3.299-2

00 7 592238 4.773-2 7 -592235 1.052-4

00 BOX TYPE 1

00 CUBOID 1 7.620 0.000 7.620 0.000 1000. -1000. 27\*0.5

00 CUBOID 3 10.160 -2.54 10.160 -2.54 1000. -1000. 27\*0.5

00 BOX TYPE 2

00 CUBOID 2 11.438 0.000 0.1441 0.000 1000. -1000. 27\*0.5

00 CUBOID 4 12.700 0.000 0.7791 0.000 1000. -1000. 27\*0.5

00 BOX TYPE 3

00 CUBOID 2 0.1441 0.000 11.438 0.000 1000. -1000. 27\*0.5

00 CUBOID 4 0.7791 0.000 12.700 0.000 1000. -1000. 27\*0.5

00 BOX TYPE 4

00 CUBOID 4 0.000 -0.635 0.000 -0.635 1000. -1000. 27\*0.5

00 CUBOID 2 0.000 -0.7791 0.000 -0.7791 1000. -1000. 27\*0.5

00 BOX TYPE 5

00 CUBOID 1 7.620 0.000 7.620 0.000 1000. -1000. 27\*0.5

00 CUBOID 3 10.160 -2.54 10.160 -2.54 1000. -1000. 27\*0.5

00 BOX TYPE 6

00 CUBOID 2 0.000 -11.438 0.1441 0.000 1000. -1000. 27\*0.5

00 CUBOID 4 0.000 -12.700 0.7791 0.000 1000. -1000. 27\*0.5

00 BOX TYPE 7

00 CUBOID 2 0.000 -0.1441 11.438 0.000 1000. -1000. 27\*0.5

00 CUBOID 4 0.000 -0.7791 12.700 0.000 1000. -1000. 27\*0.5

00 BOX TYPE 8

00 CUBOID 4 0.635 0.000 0.000 -0.635 1000. -1000. 27\*0.5

00 CUBOID 2 0.7791 0.000 0.000 -0.7791 1000. -1000. 27\*0.5

00 CORE BDY C 13.4791 -13.4791 13.4791 0.00 1000. -1000. 27\*0.5

00 ZHEMICYL+Y 3 19.326 1000. -1000. 27\*0.5

00 ZHEMICYL+Y 4 19.394 1000. -1000. 27\*0.5

00 ZHEMICYL+Y 7 25.309 1000. -1000. 27\*0.5

00 ZHEMICYL+Y 6 30.706 1000. -1000. 27\*0.5

00 ZHEMICYL+Y 4 32.93 1000. -1000. 27\*0.5

00 ZHEMICYL+Y 3 45.629 1000. -1000. 27\*0.5

00 ZHEMICYL+Y 4 46.264 1000. -1000. 27\*0.5

00 CUBOID 3 63. -63. 63. 0.00 1000. -1000. 27\*0.5

00 1 4 4 1 2 2 1 1 1 1 0

00 2 4 4 1 1 1 1 1 1 1 0

00 3 3 3 1 2 2 1 1 1 1 0

00 4 3 3 1 1 1 1 1 1 1 0

00 5 1 1 1 2 2 1 1 1 1 0

00 6 1 1 1 1 1 1 1 1 1 0

00 7 2 2 1 2 2 1 1 1 1 0

00 8 2 2 1 1 1 1 1 1 1 1

00 END KENO.

: NONE. TIME: 0.402 SEC. IMAGE COUNT: 53

- X-F15

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# KENO - FERMI-1 BORON SENSITIVITY (Continued)

FOUR ASBL BASKET FOR FERMI-1 FUEL, .030 BORON

LIFETIME = 1.02514-004 + OR - 1.13177-036

GENERATION TIME = 4.32614

NO. OF INITIAL  
GENERATIONS  
SKIPPED

AVERAGE  
K-EFFECTIVE

DEVIATION

67 PER CENT  
CONFIDENCE INTERVAL

95 PER  
CONFIDENCE

6	.81949 + OR - .00492	.81457 TO .82441	.80965 TO
7	.82057 + OR - .00491	.81565 TO .82548	.81074 TO
8	.82040 + OR - .00503	.81537 TO .82543	.81034 TO
9	.81883 + OR - .00489	.81393 TO .82372	.80904 TO
10	.81780 + OR - .00491	.81289 TO .82270	.80799 TO
11	.81714 + OR - .00499	.81215 TO .82212	.80716 TO
12	.81782 + OR - .00507	.81275 TO .82289	.80768 TO
13	.81746 + OR - .00520	.81226 TO .82266	.80707 TO
14	.81727 + OR - .00534	.81193 TO .82261	.80659 TO
15	.81605 + OR - .00535	.81070 TO .82140	.80535 TO
20	.81514 + OR - .00573	.80941 TO .82087	.80368 TO
25	.81403 + OR - .00505	.80898 TO .81908	.80393 TO
30	.81795 + OR - .00497	.81297 TO .82292	.80800 TO
35	.81894 + OR - .00602	.81292 TO .82496	.80690 TO
40	.82306 + OR - .00839	.81467 TO .83145	.80627 TO
45	.81852 + OR - .00593	.81259 TO .82445	.80666 TO

NITAWL - FERMI-1 HYPOTHETICAL ACCIDENT

RECC4\*KENO.N27HA

74Q1C C7/16/86 12:37:01 (24)

20	1SS	0	17	52	2	22	-1	0	T										
20	2SS	92238	-592238	92235	-592235	8016	-555081	1001	-555011	13027									
20		40000	24000	28000	24000	82000	5010	6012	42000										
24	3**	92238	294.	2	.1880	.1741	92.06	2.932-2	1	96	2.22	1	32	1.0					
20		592238	294.	0	0.0	0.00	20.0	4.773-2	1	32	32	1.0	T						

ERRORS: NONE. TIME: 0.253 SEC. IMAGE COUNT: 5

.RED - IN CONTROL MODE

.CC=NITAWL.NITAWL

# NITAWL - FERMI-1 HYPOTHETICAL ACCIDENT (Continued)

THIS XSDRN WORKING TAPE WAS CREATED  
THE TITLE OF THE PARENT CASE IS AS FOLLOWS  
27 NEUTRON GROUP LIBRARY

BASED ON ENDF/B VERSION 4 DATA  
COMPILED FOR NRC

TAPE ID

4321

NUMBER OF NUCLIDES

NUMBER OF NEUTRON GROUPS

27

NUMBER OF GAMMA GROUPS

FIRST THERMAL GROUP

15

## TABLE OF CONTENTS

H 1269 F, 1002 T 218 GP 032475(2)  
H 1269 F, 1002 T 218 GP 032475(2)  
B-10 1273 218NGP 042375 P-3 293K  
C-12 1274F, 1065T 218 GP 030476(7)  
U-16 1276 218 GP 030476(7)  
O-16 1276 218 GP 030476(7)  
AL-27 1193 218 GP 040375(5)  
CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
FE 218GP RE 5-17-78(1)  
NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
ZR(NAT) 7141 21 NGP WT FIS(0.1T020)-1/E-MAX P-3  
MO (1237) SIGP=5+4 NEWXLACS 218NGP F-1/E-M P-3 293K  
PS 1238 218NGP 042375 P-3 293K  
U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)  
U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)  
U-232 213GP RE 5-17-78(1)  
U-232 213GP RE 5-17-78(1)

.PT PRINTS

# XSDRNPM - FERMI-1 HYPOTHETICAL ACCIDENT

\*KENO.X27HA

07/16/86 13:38:10 (22)

```

21 XSDRNPM FOR FERMI-1 METAL FUEL, HYPOTHETICAL ACCIDENT, .356 CM PITCH
18 1SS 2 3 20 1 3 3 39 8 3 1 2R10 F0
18 2SS -2 F0
18 3SS 1 32 1000 22 1 F0
18 4SS -1 27 C -2 E T
18 13SS 3R1 2 2R3 11R1 11R2 11R3
18 14SS 92235 92238 42000 40000 555081 555011
18 8016 1001 82000 24000 28000 26000
18 13027 5010 6012 592238 592235 2011
22 15** 1.0216-2 2.932-2 1.087-2 4.227-2 3.3461-2 6.6922-2 F1.-15 T
18 33** F1.0 T
21 35** 910.0 .188 .189 71.2007 .4830
18 36SS 10R1 2R2 8R3
18 38** 10R1.0 0.0 F1.0
18 39SS 1 2 3
18 40SS F3
18 51SS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
18 18 19 20 21 22 23 24 25 26 27 T

```

R3: NCNE. TIME: 0.229 SEC. IMAGE COUNT: 18

DRNPM.XSDRNPM

# XSDRNPM - FERMI-1 HYPOTHETICAL ACCIDENT (Continued)

SADD,DEP 998CC4=KENO.X27HA

XSDRNPM FOR FERMI-1 METAL FUEL, HYPOTHETICAL ACCIDENT

1S ARRAY 15 ENTRIES READ  
2S ARRAY 10 ENTRIES READ  
3S ARRAY 12 ENTRIES READ  
4S ARRAY 9 ENTRIES READ

CT

## DIRECT ACCESS FILES ASSIGNED

3000 WORDS PER RECORD ON UNIT 8  
320 WORDS PER RECORD ON UNIT 9  
3000 WORDS PER RECORD ON UNIT 10

1 PHYSICAL RECORDS PER LOGICAL  
10 PHYSICAL RECORDS PER LOGICAL  
1 PHYSICAL RECORDS PER LOGICAL

## GENERAL PROBLEM DESCRIPTION DATA BLOCK

### GENERAL PROBLEM DATA

IGE 1/2/3 = PLANE/CYLINDER/SPHERE	2	ISN QUADRATURE ORDER
IZM NUMBER OF ZONES	3	ISCT ORDER OF SCATTERING
IM NUMBER OF SPACIAL INTERVALS	20	IEVT 0/1/2/3/4/5/6=1/K/ALPHA/
IBL 0/1/2/3 = VACUUM/REFL/PER/WHITE	1	IIM INNER ITERATION MAXI
IBR RIGHT BOUNDARY CONDITION	3	ICM OUTER ITERATION MAXI
MXM NUMBER OF MIXTURES	3	ICLC -1/0/N=FLAT RES/S/1/OPT
MS MIXING TABLE LENGTH	39	ITH 0/1 = FORWARD/ADJOINT
IGM NUMBER OF ENERGY GROUPS	27	IFLU 0/1/2/3/4=L-S/L/S/W/L-W
NNG NUMBER OF NEUTRON GROUPS	27	IPRT -2/-1/0/N=MIXTURE XSEC P
NGG NUMBER OF GAMMA GROUPS	0	ID1 0/1/2/3=NO/PRT NO/PCN N/
IFTG NUMBER OF FIRST THERMAL GROUP	15	IPBT -1/0/1=NONE/FINE/ALL BAL

### SPECIAL OPTIONS

IFG 0/1 = NONE/WEIGHTING CALCULATION	1	IPN DUMMY PARAMETER
IGH VOLUMETRIC SOURCES (0/N=NO/YES)	0	IDFM 0/1 = NONE/DENSITY FACTO
IPM BOUNDARY SOURCES (0/N=NO/YES)	0	IAZ 0/4 = NONE/N ACTIVITIES
IFN 0/1/2 = INPUT 33*/34*/USE LAST	0	IAI 0/1=NONE/ACTIVITIES BY 1
ITMX MAXIMUM TIME (MINUTES)	1000	IFCT 0/1=NO/YES UPSCATTER SCA
IDT1 0/1/2/3=NO/XSECT/SRCE/FLUX--OUT	0	IPVT 0/1/2=NO/K/ALPHA PARAMET

### WEIGHTING DATA (IFG=1)

ICON -1/0/1=CELL/ZONE/REGION WEIGHT	-1	IHTF TOTAL XSECT PSN IN BRD G
IGMF NUMBER OF BROAD GROUPS	27	NDSF PSN G-G OR FILE NUMBER
ITP 0/10/20/30/40 0/C/E/AC/A	0	NUSF TABLE LENGTH OR MAX ORDE
IPP -2/-1/0/N=WGTD XSECT PRINT	-2	MSCM EXTRA 1-D X-SECT POSITIC
IAP -1/N ANISH XSECT PRINT	-1	

### FLOATING POINT PARAMETERS

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# XSDRNP - FERMI-1 HYPOTHETICAL ACCIDENT (Continued)

XSDRNP FOR FERMI-1 METAL FUEL, HYPOTHETICAL ACCIDENT, .8

125 ARRAY 39 ENTRIES READ  
 143 ARRAY 39 ENTRIES READ  
 15+ ARRAY 39 ENTRIES READ  
 .T

## DATA BLOCK 2 (MIXING TABLE, ETC.)

NUCLIDES	CCCC	MIXTURE	MIXING TABLE	ATOM DENSITY
CN TAPE	IDENTIFICATION		COMPONENT	
1 15C1		1	92235	.10218-001
2 55011		1	92238	.49723-001
3 5010		1	42000	.10875-001
4 6012		2	40000	.42270-001
5 8016		3	55081	.33461-001
6 55081		3	55011	.66922-001
7 12027		1	8016	.10000-014
8 24000		1	1001	.10000-014
9 28000		1	22000	.10000-014
10 26000		1	24000	.10000-014
11 40000		1	28000	.10000-014
12 42000		1	26000	.10000-014
13 92235		1	13027	.10000-014
14 92235		1	5010	.10000-014
15 92235		1	6012	.10000-014
16 92235		1	592238	.10000-014
17 92235		1	592235	.10000-014
18 92235		2	8016	.10000-014
19 92235		2	1001	.10000-014
20 92235		2	22000	.10000-014
21 92235		2	24000	.10000-014
22 92235		2	26000	.10000-014
23 92235		2	28000	.10000-014
24 92235		2	13027	.10000-014
25 92235		2	5010	.10000-014
26 92235		2	6012	.10000-014
27 92235		2	592238	.10000-014
28 92235		2	592235	.10000-014
29 92235		2	8016	.10000-014
30 92235		2	1001	.10000-014
31 92235		2	32000	.10000-014
32 92235		2	24000	.10000-014
33 92235		2	28000	.10000-014
34 92235		2	26000	.10000-014
35 92235		2	13027	.10000-014
36 92235		2	5010	.10000-014
37 92235		2	6012	.10000-014
38 92235		2	592238	.10000-014
39 92235		2	592235	.10000-014

ASHED MIXING CROSS SECTIONS  
 ELAPSED TIME .00000000 MIN.

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# XSDRNPM - FERMI-1 HYPOTHETICAL ACCIDENT (Continued)

RP.	22	REQUIRED	1	ITERATIONS.	MFD OF	7.12005-006	OCCURRED IN INT.	20	COAF
RP.	23	REQUIRED	1	ITERATIONS.	MFD OF	6.49970-006	OCCURRED IN INT.	17	COAF
RP.	24	REQUIRED	1	ITERATIONS.	MFD OF	1.56342-005	OCCURRED IN INT.	2	COAF
RP.	25	REQUIRED	1	ITERATIONS.	MFD OF	2.46674-005	OCCURRED IN INT.	20	COAF
RP.	26	REQUIRED	1	ITERATIONS.	MFD OF	1.36202-005	OCCURRED IN INT.	20	COAF
RP.	27	REQUIRED	1	ITERATIONS.	MFD OF	2.16312-005	OCCURRED IN INT.	20	COAF
<p>97U 1.0000015+000 1.0000419+000 1.6506742+000 1.0000723+000 1.</p>									
FINAL MINITOR					LAMBDA 1.6506527+000		ANGULAR FLUX ON		
ELAPSED TIME		7.58923328 MIN.							

# KENO - FERMI-1 HYPOTHETICAL ACCIDENT

C.KBC40FERHA

7/16/86 13:48:35 (29)

25 FERMI-1 FOUR ASBL BASKET , .040 BORON, H.A.

22 200. 56 603 6 27 27 17 7 19 27 8 4 2 1 -17 1 0 2000 0 1 82

25 32 3R-1

19 1 -92235 1.5484-3 1 92238 4.4430-3 1 42000 1.6472-3

25 1 40000 3.9465-4 1 555011 5.5379-2 1 555081 2.7690-2

25 2 5010 8.361-3 2 6012 1.083-2 2 13027 3.013-2

25 3 8016 3.3461-2 3 1001 6.6922-2

25 4 24000 1.839-2 4 28000 1.815-3 4 26000 5.994-2

25 5 13027 6.026-2

25 6 82000 3.299-2

25 7 592238 4.773-2 7 -592235 1.052-4

25 BOX TYPE 1

25 CYLINDER 1 5.715 38.735 -38.735 27\*0.5

25 CYLINDER 5 6.350 38.735 -38.735 27\*0.5

27 CUBOID 3 6.5075 -6.5075 6.5075 -6.5075 46.507 -46.507 27\*0.5

25 BOX TYPE 2

26 CUBOID 2 13.015 0.000 0.1441 0.000 46.507 -46.507 27\*0.5

25 CUBOID 4 13.015 0.000 0.7791 0.000 46.507 -46.507 27\*0.5

25 BOX TYPE 3

26 CUBOID 2 0.1441 0.000 13.015 0.000 46.507 -46.507 27\*0.5

25 CUBOID 4 0.7791 0.000 13.015 0.000 46.507 -46.507 27\*0.5

25 BOX TYPE 4

25 CUBOID 4 0.000 -0.635 0.000 -0.635 46.507 -46.507 27\*0.5

25 CUBOID 2 0.000 -0.7791 0.000 -0.7791 46.507 -46.507 27\*0.5

25 BOX TYPE 5

25 CYLINDER 1 5.715 38.735 -38.735 27\*0.5

25 CYLINDER 5 6.350 38.735 -38.735 27\*0.5

27 CUBOID 3 6.5075 -6.5075 6.5075 -6.5075 46.507 -46.507 27\*0.5

25 BOX TYPE 6

26 CUBOID 2 0.000 -13.015 0.1441 0.000 46.507 -46.507 27\*0.5

25 CUBOID 4 0.000 -13.015 0.7791 0.000 46.507 -46.507 27\*0.5

25 BOX TYPE 7

26 CUBOID 2 0.000 -0.1441 13.015 0.000 46.507 -46.507 27\*0.5

25 CUBOID 4 0.000 -0.7791 13.015 0.000 46.507 -46.507 27\*0.5

25 BOX TYPE 8

25 CUBOID 4 0.635 0.000 0.000 -0.635 46.507 -46.507 27\*0.5

25 CUBOID 2 0.7791 0.000 0.000 -0.7791 46.507 -46.507 27\*0.5

25 CORE BODY 0 13.7941 -13.7941 13.7941 0.00 46.507 -46.507 27\*0.5

25 ZHEMICYL+Y 3 19.509 46.507 -46.507 27\*0.5

25 ZHEMICYL+Y 4 19.600 46.507 -46.507 27\*0.5

25 ZHEMICYL+Y 7 25.309 46.507 -46.507 27\*0.5

25 ZHEMICYL+Y 6 30.706 46.507 -46.507 27\*0.5

25 ZHEMICYL+Y 4 32.93 46.507 -46.507 27\*0.5

25 ZHEMICYL+Y 3 45.629 46.507 -46.507 27\*0.5

25 ZHEMICYL+Y 4 46.264 46.507 -46.507 27\*0.5

25 CUBOID 3 63. -63. 63. 0.00 46.507 -46.507 27\*0.5

25 1 4 4 1 2 2 1 1 1 1 0

25 2 4 4 1 1 1 1 1 1 1 0

25 3 3 3 1 2 2 1 1 1 1 0

25 4 3 3 1 1 1 1 1 1 1 0

25 5 1 1 1 2 2 1 1 1 1 0

25 6 1 1 1 1 1 1 1 1 1 0

25 7 2 2 1 2 2 1 1 1 1 0

25 8 2 2 1 1 1 1 1 1 1 1

25 END KENO.

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# KENO - FERMI-1 HYPOTHETICAL ACCIDENT (Continued)

FERMI-1 FOUR ASBL BASKET , .040 BORON, H.A.

NUMBER OF GENERATIONS	55	START TYPE
NUMBER PER GENERATION	503	GENERATIONS BE
NUMBER OF GENERATIONS TO BE SKIPPED	5	LIST INPUT X-S
NUMBER OF ENERGY GROUPS	27	LIST 1-D MIXTU
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2-D MIXTU
NUMBER OF INPUT NUCLIDES	17	LIST FISS. AND
NUMBER OF MIXTURES	7	USE X-SECTIONS
NUMBER OF MIXING TABLE ENTRIES	12	USE GEOMETRY F
NUMBER OF GEOMETRY CARDS	27	USE VELOCITIES
NUMBER OF BOX TYPES	3	COMPUTE MATRIX
NUMBER OF UNITS IN X DIRECTION	4	COMPUTE MATRIX
NUMBER OF UNITS IN Y DIRECTION	2	LIST FISS. 3
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALCUL
NUMBER OF NUCLIDES READ FROM TAPE	-17	USE EXPONENTIAL
ALBEDO TYPE	1	CALCULATE FLUX
SEARCH TYPE	2	CALCULATE FISS

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION .

THE ALBEDOS ARE +X = .00000 -X = .00000 +Y = .00000 -Y = 1.00000+

MAXIMUM TIME = 100.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 29331  
REMAINING AVAILABLE LOCATIONS= 371669

# KENO - FERMI-1 HYPOTHETICAL ACCIDENT (Continued)

FERMI-1 FOUR ASBL BASKET , .040 BORON, H.A.

MIXTURE	NUCLIDE	DENSITY
1	-92235	1.54840-003
1	92238	4.44300-003
1	42000	1.64720-003
1	40000	8.94650-004
1	555011	5.53790-002
1	555021	2.76900-002
2	5010	8.36100-003
2	6012	1.08300-002
2	13027	3.01300-002
2	0016	3.34610-002
3	1001	6.69220-002
4	24000	1.23900-002
4	28000	1.81500-003
4	26000	5.99400-002
5	13027	6.02600-002
6	82000	3.29900-002
7	592238	4.77300-002
7	-592235	1.05200-004

## CROSS SECTIONS READ FROM TAPE

NUCLIDE =	1001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	555011	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	5010	B-10 1273 218NGP 042375 P-3 293K
NUCLIDE =	6012	C-12 1274F, 1065T 218 GP 030476(7)
NUCLIDE =	0016	O-16 1276 218 GP 030476(7)
NUCLIDE =	555021	O-16 1276 218 GP 030476(7)
NUCLIDE =	13027	AL-27 1193 218 GP 040375(5)
NUCLIDE =	24000	CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(C42375)
NUCLIDE =	26000	FE 218GP RE 5-17-78(1)
NUCLIDE =	28000	NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(C42375)
NUCLIDE =	40000	ZR(NAT) 7141 21 NGP WT FIS(C.1T020)-1/E-MAX P-3
NUCLIDE =	42000	MO (1257) SIGP=5+4 NEWXLACS 218NGP F-1/E-M P-3 293K
NUCLIDE =	02000	PB 1288 218NGP 042375 P-3 293K
NUCLIDE =	92235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	592235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	92238	U-238 218GP RE 5-17-78(1)
NUCLIDE =	592238	U-238 218GP RE 5-17-78(1)

**KENO - FERMI-1 HYPOTHETICAL ACCIDENT (Continued)**

**FERMI-1 FOUR ASBL BASKET , .040 BORON, H.A.**

**ARRAY DESCRIPTION**

**Z =        1**

<b>5</b>	<b>7</b>	<b>3</b>	<b>1</b>
<b>6</b>	<b>8</b>	<b>4</b>	<b>2</b>

# KENO - FERMI-1 HYPOTHETICAL ACCIDENT (Continued)

FERMI-1 FOUR ASBL BASKET , .C40 BORON, H.A.

LIFETIME = 8.32585-005 + OR - 8.71476-007

GENERATION TIME = 3.20629-

NO. OF INITIAL  
GENERATIONS  
SKIPPED

AVERAGE  
K-EFFECTIVE

DEVIATION

67 PER CENT  
CONFIDENCE INTERVAL

95 PER C  
CONFIDENCE I

6	.93720 + OR - .00397	.93323 TO .94116	.92926 TO
7	.93691 + OR - .00404	.93287 TO .94095	.92884 TO
8	.93732 + OR - .00410	.93322 TO .94142	.92912 TO
9	.93675 + OR - .00415	.93260 TO .94090	.92846 TO
10	.93624 + OR - .00421	.93204 TO .94045	.92783 TO
11	.93628 + OR - .00430	.93198 TO .94058	.92767 TO
12	.93618 + OR - .00440	.93178 TO .94058	.92738 TO
13	.93622 + OR - .00450	.93171 TO .94072	.92721 TO
14	.93562 + OR - .00457	.93104 TO .94019	.92647 TO
15	.93601 + OR - .00467	.93134 TO .94067	.92667 TO
20	.93703 + OR - .00515	.93188 TO .94218	.92673 TO
25	.93900 + OR - .00557	.93342 TO .94457	.92725 TO
30	.93907 + OR - .00651	.93255 TO .94558	.92604 TO
35	.93310 + OR - .00738	.92573 TO .94048	.91835 TO
40	.92873 + OR - .00815	.92058 TO .93688	.91243 TO
45	.92694 + OR - .00943	.91750 TO .93437	.90937 TO
50	.91873 + OR - .01109	.90763 TO .92982	.89654 TO

# SECOND KENO RUN OF FERMI-1 HYPOTHETICAL ACCIDENT

-NO. KBU40FERMA1  
 7/10/36 20:44:42 (27) ~~CHANGED~~ RANDOM NUMBER SEQUENCE  
 FERMI-1 FOUR ASBL BASKET, 040 BORON, H.A.  
 200. 56 601 6 27 27 17 7 18 27 8 4 2 1 -17 1 3 2000 0 1 32  
 32 3R-1  
 1 -92235 1.5484-3 1 92238 4.4430-3 1 42030 1.6472-3  
 1 40000 8.9463-4 1 555011 5.5379-2 1 555081 2.7593-2  
 2 5010 3.361-3 2 4012 1.083-2 2 13027 3.013-2  
 3 2016 3.3461-2 3 1001 6.0922-2  
 4 24000 1.839-2 4 28000 1.815-3 4 26000 5.994-2  
 5 13027 6.026-2  
 6 82000 3.299-2  
 7 592238 4.773-2 7 -592235 1.052-4  
 BOX TYPE 1  
 CYLINDER 1 5.715 38.735 -38.735 27\*0.5  
 CYLINDER 5 6.350 38.735 -38.735 27\*0.5  
 CUBOID 3 6.5075 -6.5075 6.5075 -6.5075 66.507 -66.507 27\*0.5  
 BOX TYPE 2  
 CUBOID 2 13.015 0.000 0.1441 0.000 46.507 -46.507 27\*0.5  
 CUBOID 4 13.015 0.000 0.7791 0.000 46.507 -46.507 27\*0.5  
 BOX TYPE 3  
 CUBOID 2 0.1441 0.000 13.015 0.000 46.507 -46.507 27\*0.5  
 CUBOID 4 0.7791 0.000 13.015 0.000 46.507 -46.507 27\*0.5  
 BOX TYPE 4  
 CUBOID 4 0.000 -0.635 0.000 -0.635 46.507 -46.507 27\*0.5  
 CUBOID 2 0.000 -0.7791 0.000 -0.7791 46.507 -46.507 27\*0.5  
 BOX TYPE 5  
 CYLINDER 1 5.715 33.735 -38.735 27\*0.5  
 CYLINDER 5 6.350 38.735 -38.735 27\*0.5  
 CUBOID 3 6.5075 -6.5075 6.5075 -6.5075 46.507 -46.507 27\*0.5  
 BOX TYPE 6  
 CUBOID 2 0.000 -13.015 0.1441 0.000 46.507 -46.507 27\*0.5  
 CUBOID 4 0.000 -13.015 0.7791 0.000 46.507 -46.507 27\*0.5  
 BOX TYPE 7  
 CUBOID 2 0.000 -0.1441 13.015 0.000 46.507 -46.507 27\*0.5  
 CUBOID 4 0.000 -0.7791 13.015 0.000 46.507 -46.507 27\*0.5  
 BOX TYPE 8  
 CUBOID 4 0.635 0.000 0.000 -0.635 46.507 -46.507 27\*0.5  
 CUBOID 2 0.7791 0.000 0.000 -0.7791 46.507 -46.507 27\*0.5  
 CORE 30Y 0 13.7941 -13.7941 13.7941 0.00 46.507 -46.507 27\*0.5  
 ZHEMICYL+Y 3 19.509 46.507 -46.507 27\*0.5  
 ZHEMICYL+Y 4 19.600 46.507 -46.507 27\*0.5  
 ZHEMICYL+Y 7 25.309 46.507 -46.507 27\*0.5  
 ZHEMICYL+Y 6 30.706 46.507 -46.507 27\*0.5  
 ZHEMICYL+Y 4 32.93 46.507 -46.507 27\*0.5  
 ZHEMICYL+Y 3 45.629 46.507 -46.507 27\*0.5  
 ZHEMICYL+Y 4 46.264 46.507 -46.507 27\*0.5  
 CUBOID 3 0.000 -63.63 0.000 46.507 -46.507 27\*0.5  
 1 4 4 1 2 2 1 1 1 1 0  
 2 4 4 1 1 1 1 1 1 0  
 3 3 3 1 2 2 1 1 1 1 0  
 4 3 3 1 1 1 1 1 1 0  
 5 1 1 1 2 2 1 1 1 1 0  
 6 1 1 1 1 1 1 1 1 1 0  
 7 2 2 1 2 2 1 1 1 1 0  
 8 2 2 1 1 1 1 1 1 1 1  
 END KENO.



## SECOND KENO RUN OF FERMI-1 HYPOTHETICAL ACCIDENT (Continued)

FERMI-1 FOUR ASBL BASKET , .040 BORON, H.A.

FETIME = 8.29094-005 + OR - 9.55835-007

GENERATION TIME = 3.18678-0

NO OF INITIAL  
GENERATIONS  
SKIPPED

AVERAGE  
K-EFFECTIVE      DEVIATION

67 PER CENT  
CONFIDENCE INTERVAL

95 PER CENT  
CONFIDENCE IN

6	<u>.93662 + OR - .00313</u>	.93350 TO .93975	.93037 TO .
7	.93695 + OR - .00317	.93377 TO .94012	.93060 TO .
8	.93610 + OR - .00312	.93298 TO .93922	.92985 TO .
9	.93624 + OR - .00319	.93305 TO .93942	.92986 TO .
10	.93654 + OR - .00324	.93330 TO .93979	.93006 TO .
11	.93690 + OR - .00329	.93360 TO .94019	.93031 TO .
12	.93715 + OR - .00336	.93379 TO .94051	.93043 TO .
13	.93787 + OR - .00336	.93451 TO .94123	.93115 TO .
14	.93835 + OR - .00341	.93494 TO .94176	.93154 TO .
15	.93834 + OR - .00349	.93485 TO .94183	.93136 TO .
20	.93862 + OR - .00353	.93479 TO .94245	.93096 TO .
25	.93953 + OR - .00428	.93524 TO .94381	.93096 TO .
30	.94039 + OR - .00371	.93668 TO .94410	.93297 TO .
35	.93967 + OR - .00429	.93538 TO .94395	.93109 TO .
40	.93514 + OR - .00475	.93039 TO .93989	.92565 TO .
45	.92837 + OR - .00519	.92318 TO .93356	.91800 TO .
50	.93689 + OR - .00721	.92968 TO .94410	.92243 TO .

NITAWL - EBR-II

NO.NEER

5/31/86 11:48:31 (31)

27 1SS C 16 52 3 22 -1 3 T  
27 2SS 92238 -592238 92235 -592235 3016 -555081 1001 -555011 13027  
27 24000 28000 26000 82000 5010 6012 94239  
29 3\*\* 92238 294. 2 .5499 .07323 28.09 4.81-2 1 32 32 1.0  
27 592238 294. 3 C.3 C.00 20.0 4.773-2 1 32 32 1.0  
31 94239 294. 2 .5499 .07323 2091.6 6.46-4 1 238 893.5 1 32 1.0 T

: NONE. TIME: 0.456 SEC. IMAGE COUNT: 6

% CONTROL MODE

WL.NITAWL

# NITAWL - EBR-II (Continued)

THIS XSDRN WORKING TAPE WAS CREATED  
 THE TITLE OF THE PARENT CASE IS AS FOLLOWS  
 27 NEUTRON GROUP LIBRARY  
 BASED ON ENDF/B VERSION 4 DATA  
 COMPILED FOR NRC  
 TAPE ID  
 NUMBER OF NEUTRON GROUPS  
 FIRST THERMAL GROUP

4321  
 27  
 15

NUMBER OF NUCLIDES  
 NUMBER OF GAMMA GROUPS

## TABLE OF CONTENTS

H 1269 F, 1002 T 213 GP 032475(2)  
 H 1269 F, 1002 T 218 GP 032475(2)  
 E-10 1273 218NGP 042375 P-3 293K  
 C-12 1274F, 1005T 218 GP 030476(7)  
 O-16 1276 218 GP 030476(7)  
 O-16 1276 213 GP 030476(7)  
 AL-27 1193 213 GP 040375(5)  
 CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
 FE 218GP RE 5-17-78(1)  
 NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
 PE 1228 218NGP 042375 P-3 293K  
 U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)  
 U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)  
 U-238 218GP RE 5-17-78(1)  
 U-238 218GP RE 5-17-78(1)  
 PU-239 1264 SIGP=5+4 NEWXLACS 218NGP P-3 293K

.FKPT PRINTS

# XSDRNPM - EBR-II FUEL

NO.XE9R

/31/86 12:10:39 (21)

19 XSDRNPM FOR EBR METAL FUEL

17 1SS 2 3 20 1 3 3 39 3 3 1 2R10 F0

17 2SS -2 F0

17 3SS 1 32 1000 22 1 F0

17 4SS -1 27 0 -2 E T

17 13SS 3R1 2 2R3 11R1 11R2 11R3

19 14SS 92235 92238 94239 13027 555091 555011

17 2016 1001 82000 24000 28000 26000

17 13027 5010 6012 592238 592235 2011

20 15\*\* 1.025-4 4.81-2 5.46-4 6.026-2 3.3461-2 5.5922-2 F1.-15 T

17 33\*\* F1.0 T

21 35\*\* 910.0 .5499 .550 71.7938 1.273

17 36SS 10R1 2R2 3R3

17 38\*\* 10R1.0 0.0 F1.0

17 39SS 1 2 3

17 40SS F3

17 51SS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

17 18 19 20 21 22 23 24 25 26 27 T

: DONE. TIME: 0.349 SEC. IMAGE COUNT: 18

NPM.XSDRNPM

# XSDRNPM - EBR-II FUEL (Continued)

SADD, DEP 998C04=KENO.XEBR

XSDRNPM FOR EBR METAL FUEL

1S ARRAY 15 ENTRIES READ

2S ARRAY 10 ENTRIES READ

3S ARRAY 12 ENTRIES READ

4S ARRAY 9 ENTRIES READ

CT

DIRECT ACCESS FILES ASSIGNED

3000 WORDS PER RECORD ON UNIT 2

280 WORDS PER RECORD ON UNIT 9

3000 WORDS PER RECORD ON UNIT 10

1 PHYSICAL RECORDS PER LOGICAL

10 PHYSICAL RECORDS PER LOGICAL

1 PHYSICAL RECORDS PER LOGICAL

GENERAL PROBLEM DESCRIPTION DATA BLOCK

## GENERAL PROBLEM DATA

IGE	1/2/3 = PLANE/CYLINDER/SPHERE	2	ISN	QUADRATURE ORDER
IZM	NUMBER OF ZONES	3	ISCT	ORDER OF SCATTERING
IM	NUMBER OF SPACIAL INTERVALS	20	IEVT	0/1/2/3/4/5/6=G/K/ALPHA
IBL	0/1/2/3 = VACUUM/REFL/PER/WHITE	1	IIM	INNER ITERATION MAXIMUM
IBR	RIGHT BOUNDARY CONDITION	3	ICM	OUTER ITERATION MAXIMUM
MAX	NUMBER OF MIXTURES	3	ICLC	-1/0/N=FLAT RES/SA/CF
MS	MIXING TABLE LENGTH	39	ITH	0/1 = FORWARD/ADJOINT
IGM	NUMBER OF ENERGY GROUPS	27	IFLU	0/1/2/3/4=L-S/L/S/W/L-W
NGG	NUMBER OF NEUTRON GROUPS	27	IPRT	-2/-1/0/N=MIXTURE XSEC P
GGG	NUMBER OF GAMMA GROUPS	3	ID1	0/1/2/3=NO/PRT NO/PCH N/
IFTG	NUMBER OF FIRST THERMAL GROUP	15	IPBT	-1/0/1=NONE/FIVE/ALL BAL

## SPECIAL OPTIONS

IFG	0/1 = NONE/WEIGHTING CALCULATION	1	IPN	DUMMY PARAMETER
IGM	VOLUMETRIC SOURCES (0/N=NO/YES)	0	IDFM	0/1 = NONE/DENSITY FACTO
IPM	BOUNDARY SOURCES (0/N=NO/YES)	0	IAZ	0/N = NONE/N ACTIVITIES
IFN	0/1/2 = INPUT 33*/34*/USE LAST	0	IAI	0/1=NONE/ACTIVITIES BY 1
ITMX	MAXIMUM TIME (MINUTES)	1000	IFCT	0/1=NO/YES UPSCATTER SCA
IDT1	0/1/2/3=NO/XSECT/SRCE/FLUX--OUT	0	IPVT	0/1/2=NO/K/ALPHA PARAMET

## WEIGHTING DATA (IFG=1)

ICCN	-1/0/1=CELL/ZONE/REGION WEIGHT	-1	INTF	TOTAL XSECT PSN IN BRD G
IGMF	NUMBER OF BROAD GROUPS	27	NDSF	PSN G-G OR FILE NUMBER
ITP	0/10/20/30/40 0/C/E/AC/A	3	NUSF	TABLE LENGTH OR MAX ORDE
IFP	-2/-1/0/N=WGTEO XSECT PRINT	-2	MSCM	EXTRA 1-D X-SECT POSITIO
IAP	-1/N ANISN XSECT PRINT	-1		

## FLOATING POINT PARAMETERS

X-F33

Page Added  
Oct. 1990

# XSDRNP - EBR-II FUEL (Continued)

XSDRNP FOR EBR METAL FUEL

:ES READ  
IES READ  
IES READ

## DATA BLOCK 2 (MIXING TABLE, ETC.)

CC ICATION	MIXTURE	MIXING TABLE COMPONENT	ATOM DENSITY	EXT XSECT
	1	92235	.10250-003	
	1	92238	.48100-001	
	1	94239	.64600-003	
	2	13027	.60260-001	
	2	555081	.33461-001	
	2	555011	.66922-001	
	1	9C16	.10000-014	
	1	1001	.10000-014	
	1	82000	.10000-014	
	1	24000	.10000-014	
	1	28000	.10000-014	
	1	26000	.10000-014	
	1	13027	.10000-014	
	1	5010	.10000-014	
	1	5012	.10000-014	
	1	592238	.10000-014	
	1	592235	.10000-014	
	2	9C16	.10000-014	
	2	1001	.10000-014	
	2	82000	.10000-014	
	2	24000	.10000-014	
	2	28000	.10000-014	
	2	26000	.10000-014	
	2	13027	.10000-014	
	2	5010	.10000-014	
	2	5012	.10000-014	
	2	592238	.10000-014	
	2	592235	.10000-014	
	3	9C16	.10000-014	
	3	1001	.10000-014	
	3	82000	.10000-014	
	3	24000	.10000-014	
	3	28000	.10000-014	
	3	26000	.10000-014	
	3	13027	.10000-014	
	3	5010	.10000-014	
	3	5012	.10000-014	
	3	592238	.10000-014	
	3	592235	.10000-014	

CTIONS  
00000 MIN.

Page Added  
Oct. 1990

X-F34

# XSDRNPM - EBR-II FUEL (Continued)

OUTER	INNER	BALANCE	UPSCATTER	RATIO	EIGENVALUE	LAMBDA1	
1	225	1.0000008+000	1.3643240+000	1.2963255+000	1.3412539+000		
2	400	1.0000008+000	1.0357222+000	1.3441527+000	1.0105986+000	1	
3	492	1.0000007+000	1.0022620+000	1.3546951+000	9.9997327-001	1	
4	563	1.0000008+000	9.9964233-001	1.3557047+000	1.0000948+000	1	
5	610	1.0000008+000	9.9995653-001	1.3557675+000	1.0001246+000	9	
6	638	1.0000008+000	9.9998087-001	1.3556951+000	9.9995275-001	9	
GRP.	1	REQUIRED	1	ITERATIONS. MFD OF	1.29866-005	OCCURRED IN INT.	20 COA
GRP.	2	REQUIRED	1	ITERATIONS. MFD OF	2.06372-006	OCCURRED IN INT.	20 COA
GRP.	3	REQUIRED	1	ITERATIONS. MFD OF	2.15871-006	OCCURRED IN INT.	19 COA
GRP.	4	REQUIRED	1	ITERATIONS. MFD OF	1.54434-006	OCCURRED IN INT.	1 COA
GRP.	5	REQUIRED	1	ITERATIONS. MFD OF	1.11524-006	OCCURRED IN INT.	1 COA
GRP.	6	REQUIRED	1	ITERATIONS. MFD OF	7.90381-007	OCCURRED IN INT.	1 COA
GRP.	7	REQUIRED	1	ITERATIONS. MFD OF	4.63276-007	OCCURRED IN INT.	18 COA
GRP.	8	REQUIRED	1	ITERATIONS. MFD OF	1.25514-006	OCCURRED IN INT.	1 COA
GRP.	9	REQUIRED	1	ITERATIONS. MFD OF	3.37654-006	OCCURRED IN INT.	1 COA
GRP.	10	REQUIRED	1	ITERATIONS. MFD OF	4.78791-006	OCCURRED IN INT.	1 COA
GRP.	11	REQUIRED	1	ITERATIONS. MFD OF	7.37873-006	OCCURRED IN INT.	1 COA
GRP.	12	REQUIRED	1	ITERATIONS. MFD OF	1.20543-005	OCCURRED IN INT.	2 COA
GRP.	13	REQUIRED	1	ITERATIONS. MFD OF	1.50099-005	OCCURRED IN INT.	2 COA
GRP.	14	REQUIRED	1	ITERATIONS. MFD OF	1.72049-005	OCCURRED IN INT.	1 COA
GRP.	15	REQUIRED	1	ITERATIONS. MFD OF	6.39652-005	OCCURRED IN INT.	20 COA
GRP.	16	REQUIRED	1	ITERATIONS. MFD OF	6.91871-005	OCCURRED IN INT.	20 COA
GRP.	17	REQUIRED	1	ITERATIONS. MFD OF	7.67360-005	OCCURRED IN INT.	20 COA
GRP.	18	REQUIRED	1	ITERATIONS. MFD OF	7.58557-005	OCCURRED IN INT.	20 COA
GRP.	19	REQUIRED	1	ITERATIONS. MFD OF	6.73722-005	OCCURRED IN INT.	20 COA
GRP.	20	REQUIRED	1	ITERATIONS. MFD OF	4.76832-005	OCCURRED IN INT.	20 COA
GRP.	21	REQUIRED	1	ITERATIONS. MFD OF	5.25938-005	OCCURRED IN INT.	14 COA
GRP.	22	REQUIRED	1	ITERATIONS. MFD OF	6.68174-005	OCCURRED IN INT.	20 COA
GRP.	23	REQUIRED	1	ITERATIONS. MFD OF	6.18378-006	OCCURRED IN INT.	14 COA
GRP.	24	REQUIRED	1	ITERATIONS. MFD OF	6.40463-006	OCCURRED IN INT.	1 COA
GRP.	25	REQUIRED	1	ITERATIONS. MFD OF	5.30666-006	OCCURRED IN INT.	1 COA
GRP.	26	REQUIRED	1	ITERATIONS. MFD OF	3.19517-006	OCCURRED IN INT.	14 COA
GRP.	27	REQUIRED	1	ITERATIONS. MFD OF	3.24110-006	OCCURRED IN INT.	16 COA
7	665	1.0000008+000	9.9999541-001	1.3556895+000	9.9999935-001	9	
		FINAL MINITOR	LAMBDA 1.3556724+000		ANGULAR FLUX CN		
ELAPSED TIME		2.29266664 MIN.					

# KENO - EBR-II - NORMAL OPERATION

```

J.KB040E3R
/17/86 22:00:06 (19)
15 FOUR ASBL BASKET FOR EBR II FUEL, .040 BORON
16 200. 50 403 6 27 27 15 7 13 25 8 4 2 1 -15 1 3 2000 0 1 32
15 -1 0 0 3R-1
15 1 92235 1.9115-5 1 92239 8.9701-3 1 -94239 1.2047-4
15 1 13027 1.218-2 1 555011 4.0927-2 1 555081 2.0463-2
15 2 5010 8.361-3 2 6012 1.083-2 2 13027 3.013-2
15 3 8016 3.3461-2 3 1001 6.6922-2
15 4 24000 1.839-2 4 28000 1.815-3 4 25000 5.994-2
15 5 13027 6.026-2
15 6 82000 3.299-2
15 7 592238 4.773-2 7 -592235 1.052-4
15 BOX TYPE 1
15 CYLINDER 1 6.191 1000. -1000. 27*0.5
19 CUBOID 3 6.824 -6.191 6.824 -6.191 1000. -1000. 27*0.5
15 BOX TYPE 2
18 CUBOID 2 13.015 0.000 0.1441 0.000 1000. -1000. 27*0.5
18 CUBOID 4 13.015 0.000 0.7791 0.000 1000. -1000. 27*0.5
15 BOX TYPE 3
18 CUBOID 2 0.1441 0.000 13.015 0.000 1000. -1000. 27*0.5
18 CUBOID 4 0.7791 0.000 13.015 0.000 1000. -1000. 27*0.5
15 BOX TYPE 4
15 CUBOID 4 0.000 -0.635 0.000 -0.635 1000. -1000. 27*0.5
15 CUBOID 2 0.000 -0.7791 0.000 -0.7791 1000. -1000. 27*0.5
15 BOX TYPE 5
15 CYLINDER 1 6.191 1000. -1000. 27*0.5
19 CUBOID 3 6.191 -6.824 6.824 -6.191 1000. -1000. 27*0.5
15 BOX TYPE 6
18 CUBOID 2 0.000 -13.015 0.1441 0.000 1000. -1000. 27*0.5
18 CUBOID 4 0.000 -13.015 0.7791 0.000 1000. -1000. 27*0.5
15 BOX TYPE 7
18 CUBOID 2 0.000 -0.1441 13.015 0.000 1000. -1000. 27*0.5
18 CUBOID 4 0.000 -0.7791 13.015 0.000 1000. -1000. 27*0.5
15 BOX TYPE 8
15 CUBOID 4 0.635 0.000 0.000 -0.635 1000. -1000. 27*0.5
15 CUBOID 2 0.7791 0.000 0.000 -0.7791 1000. -1000. 27*0.5
18 CORE ADV 0 13.7941 -13.7941 13.7941 0.00 1000. -1000. 27*0.5
12 ZHEMICYL+Y 3 19.509 1000. -1000. 27*0.5
12 ZHEMICYL+Y 4 19.600 1000. -1000. 27*0.5
15 ZHEMICYL+Y 7 25.309 1000. -1000. 27*0.5
15 ZHEMICYL+Y 6 30.706 1000. -1000. 27*0.5
15 ZHEMICYL+Y 4 32.93 1000. -1000. 27*0.5
15 ZHEMICYL+Y 3 45.629 1000. -1000. 27*0.5
15 ZHEMICYL+Y 4 46.264 1000. -1000. 27*0.5
15 CUBOID 3 63. -63. 63. 0.00 1000. -1000. 27*0.5
15 1 4 4 1 2 2 1 1 1 1 0
15 2 4 4 1 1 1 1 1 1 1 0
15 3 3 3 1 2 2 1 1 1 1 0
15 4 3 3 1 1 1 1 1 1 1 0
15 5 1 1 1 2 2 1 1 1 1 0
15 6 1 1 1 1 1 1 1 1 1 0
15 7 2 2 1 2 2 1 1 1 1 0
15 8 2 2 1 1 1 1 1 1 1 1
15 END KENO.

```

: NONE. TIME: 0.491 SEC. IMAGE COUNT: 53



# KENO - EBR-II - NORMAL OPERATION (Continued)

FOUR ASBL BASKET FOR EBR II FUEL, .040 BORON

NUMBER OF GENERATIONS	50	START TYPE
NUMBER PER GENERATION	403	GENERATIONS BEY
NUMBER OF GENERATIONS TO BE SKIPPED	6	LIST INPUT X-SE
NUMBER OF ENERGY GROUPS	27	LIST 1-D MIXTUF
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2-D MIXTUF
NUMBER OF INPUT NUCLIDES	16	LIST FISS. AND
NUMBER OF MIXTURES	7	USE X-SECTIONS
NUMBER OF MIXING TABLE ENTRIES	18	USE GEOMETRY F
NUMBER OF GEOMETRY CARDS	25	USE VELOCITIES
NUMBER OF BOX TYPES	5	COMPUTE MATRIX
NUMBER OF UNITS IN X DIRECTION	4	COMPUTE MATRIX
NUMBER OF UNITS IN Y DIRECTION	2	LIST FISS PROB
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALCULA
NUMBER OF NUCLIDES READ FROM TAPE	-16	USE EXPONENTIAL
ALBEDO TYPE	1	CALCULATE FLUX
SEARCH TYPE	3	CALCULATE FISS:

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE +X = 1.00000+000 -X = .00000 +Y = .00000 -Y = 1.00000+0

MAXIMUM TIME = 200.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 24763  
REMAINING AVAILABLE LOCATIONS= 375237

# KENO - EBR-II - NORMAL OPERATION (Continued)

## FOUR ASBL BASKET FOR EBR II FUEL, .040 BORON

MIXTURE	NUCLIDE	DENSITY
1	92235	1.91150-005
1	92238	8.97010-003
1	-94239	1.20470-004
1	13027	1.21800-002
1	555011	4.09270-002
1	555081	2.04630-002
2	5010	8.36100-003
2	6012	1.08300-002
2	13027	3.01300-002
3	8016	3.34610-002
3	1001	6.69220-002
4	24000	1.83900-002
4	28000	1.81500-003
4	26000	5.99400-002
5	13027	6.02600-002
6	82000	3.29900-002
7	592238	4.77300-002
7	-592235	1.05200-004

## CROSS SECTIONS READ FROM TAPE

NUCLIDE =	1001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	555011	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	5010	B-10 1273 218NGP 042375 P-3 293K
NUCLIDE =	6012	C-12 1274F, 1065T 218 GP 030476(7)
NUCLIDE =	8016	O-16 1276 218 GP 030476(7)
NUCLIDE =	555081	O-16 1276 218 GP 030476(7)
NUCLIDE =	13027	AL-27 1193 218 GP 040375(5)
NUCLIDE =	24000	CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	26000	FE 218GP RE 5-17-78(1)
NUCLIDE =	28000	NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	82000	PB 1288 218NGP 042375 P-3 293K
NUCLIDE =	92235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	592235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	92238	U-238 218GP RE 5-17-78(1)
NUCLIDE =	592238	U-238 218GP RE 5-17-78(1)
NUCLIDE =	94239	PU-239 1264 SIGP=5+4 NEWXLACS 218NGP P-3 293K

**KENO - EBR-II - NORMAL OPERATION (Continued)**

**FOUR ASBL BASKET FOR EBR II FUEL, .040 BORON**

**ARRAY DESCRIPTION**

<b>Z =</b>	<b>1</b>			
<b>5</b>	<b>7</b>	<b>3</b>	<b>1</b>	
<b>6</b>	<b>8</b>	<b>4</b>	<b>2</b>	

# KENO - EBR-II - NORMAL OPERATION (Continued)

FOUR ASBL BASKET FOR EBR II FUEL, .040 BORON

LIFETIME = 1.09347-004 + OR - 1.46476-006

GENERATION TIME = 5.5724

NO. OF INITIAL  
GENERATIONS  
SKIPPED

AVERAGE  
K-EFFECTIVE

DEVIATION

67 PER CENT  
CONFIDENCE INTERVAL

95 PER  
CONFIDENCE

6	<u>.68167 + OR - .00378</u>	.67789 TO .68545	.67411 TO
7	.68189 + OR - .00386	.67803 TO .68575	.67417 TO
8	.68192 + OR - .00395	.67797 TO .68588	.67432 TO
9	.68171 + OR - .00405	.67766 TO .68575	.67362 TO
10	.68144 + OR - .00414	.67730 TO .68558	.67316 TO
11	.68056 + OR - .00415	.67641 TO .68471	.6727 TO
12	.67933 + OR - .00407	.67526 TO .68339	.67119 TO
13	.67899 + OR - .00416	.67482 TO .68315	.67066 TO
14	.67929 + OR - .00427	.67503 TO .68356	.67076 TO
15	.67952 + OR - .00439	.67513 TO .68391	.67075 TO
20	.67990 + OR - .00438	.67501 TO .68478	.67013 TO
25	.67922 + OR - .00552	.67370 TO .68473	.66819 TO
30	.68111 + OR - .00668	.67443 TO .68779	.66774 TO
35	.68387 + OR - .00834	.67553 TO .69220	.66719 TO
40	.68757 + OR - .01155	.67602 TO .69911	.66447 TO
45	.70838 + OR - .01640	.69197 TO .72473	.67557 TO

# KENO - EBR-II HYPOTHETICAL ACCIDENT

0.KB04CEBRHA

7/18/86 01:33:08 (22)

```

18      FOUR ASBL BASKET FOR EBR II FUEL, .040 BORON, M.A.
20      200. 50 403 6 27 27 16 7 18 25 8 4 2 1 -15 1 3 2000 0 1 82
18      0 0 0 3R-1
18      1 92235 1.9115-5 1 92238 8.9701-3 1 -94239 1.2047-4
18      1 13027 1.218-2 1 555011 4.0927-2 1 555081 2.0463-2
18      2 5010 8.361-3 2 6012 1.083-2 2 13027 3.013-2
18      3 8016 3.3461-2 3 1001 6.6922-2
18      4 24000 1.839-2 4 28000 1.815-3 4 26000 5.994-2
18      5 13027 6.026-2
18      6 82000 3.299-2
18      7 592238 4.773-2 7 -592235 1.052-4
18      BOX TYPE 1
18      CUBOID 1 10.973 0.000 10.973 0.000 1000. -1000. 27*0.5
22      CUBOID 3 13.015 0.000 13.015 0.000 1000. -1000. 27*0.5
18      BOX TYPE 2
22      CUBOID 2 13.015 0.000 0.1441 0.000 1000. -1000. 27*0.5
22      CUBOID 4 13.015 0.000 0.7791 0.000 1000. -1000. 27*0.5
18      BOX TYPE 3
22      CUBOID 2 0.1441 0.000 13.015 0.000 1000. -1000. 27*0.5
22      CUBOID 4 0.7791 0.000 13.015 0.000 1000. -1000. 27*0.5
20      BOX TYPE 4
20      CUBOID 4 0.000 -0.635 0.000 -0.635 1000. -1000. 27*0.5
20      CUBOID 2 0.000 -0.7791 0.000 -0.7791 1000. -1000. 27*0.5
18      BOX TYPE 5
18      CUBOID 1 0.000 -10.973 10.973 0.000 1000. -1000. 27*0.5
22      CUBOID 3 0.000 -13.015 13.015 0.000 1000. -1000. 27*0.5
18      BOX TYPE 6
22      CUBOID 2 0.000 -13.015 0.1441 0.000 1000. -1000. 27*0.5
22      CUBOID 4 0.000 -13.015 0.7791 0.000 1000. -1000. 27*0.5
18      BOX TYPE 7
22      CUBOID 2 0.000 -0.1441 13.015 0.000 1000. -1000. 27*0.5
22      CUBOID 4 0.000 -0.7791 13.015 0.000 1000. -1000. 27*0.5
20      BOX TYPE 8
20      CUBOID 4 0.635 0.000 0.000 -0.635 1000. -1000. 27*0.5
20      CUBOID 2 0.7791 0.000 0.000 -0.7791 1000. -1000. 27*0.5
22      CORE BODY 0 13.7941 -13.7941 13.7941 0.00 1000. -1000. 27*0.5
22      ZHEMICYL+Y 3 19.509 1000. -1000. 27*0.5
22      ZHEMICYL+Y 4 19.600 1000. -1000. 27*0.5
18      ZHEMICYL+Y 7 25.309 1000. -1000. 27*0.5
18      ZHEMICYL+Y 6 30.706 1000. -1000. 27*0.5
18      ZHEMICYL+Y 4 32.93 1000. -1000. 27*0.5
18      ZHEMICYL+Y 3 45.629 1000. -1000. 27*0.5
18      ZHEMICYL+Y 4 46.264 1000. -1000. 27*0.5
18      CUBOID 3 63. -63. 63. 0.00 1000. -1000. 27*0.5
18      1 4 4 1 2 2 1 1 1 1 0
18      2 4 4 1 1 1 1 1 1 1 0
18      3 3 3 1 2 2 1 1 1 1 0
18      4 3 3 1 1 1 1 1 1 1 0
18      5 1 1 1 2 2 1 1 1 1 0
18      6 1 1 1 1 1 1 1 1 1 0
18      7 2 2 1 2 2 1 1 1 1 0
18      8 2 2 1 1 1 1 1 1 1 1
18      END KENO.

```

: NONE. TIME: 0.450 SEC. IMAGE COUNT: 53

# KENO - EBR-II HYPOTHETICAL ACCIDENT (Continued)

FOUR ASBL BASKET FOR EBR II FUEL, .C4C BORON, H.A.

LIFETIME = 1.15041-004 + OR - 1.07736-006

GENERATION TIME = 5.83243

NO. OF INITIAL  
GENERATIONS  
SKIPPED

AVERAGE  
K-EFFECTIVE

DEVIATION

57 PER CENT  
CONFIDENCE INTERVAL

95 PER  
CONFIDENCE

6	<u>.67571 + OR - .00385</u>	.67186 TO .67956	.66802 TO
7	.67518 + OR - .00390	.67128 TO .67908	.66738 TO
8	.67536 + OR - .00399	.67137 TO .67935	.66739 TO
9	.67525 + OR - .00408	.67117 TO .67934	.66708 TO
10	.67485 + OR - .00417	.67068 TO .67901	.66651 TO
11	.67488 + OR - .00428	.67060 TO .67915	.66631 TO
12	.67428 + OR - .00435	.66993 TO .67843	.66559 TO
13	.67585 + OR - .00417	.67168 TO .68001	.66751 TO
14	.67630 + OR - .00426	.67205 TO .68056	.66779 TO
15	.67626 + OR - .00438	.67188 TO .68065	.66750 TO
20	.67896 + OR - .00465	.67431 TO .68361	.66967 TO
25	.67771 + OR - .00524	.67247 TO .68296	.66722 TO
30	.67676 + OR - .00568	.67108 TO .68245	.66540 TO
35	.67724 + OR - .00710	.67014 TO .68435	.66304 TO
40	.67246 + OR - .01025	.66221 TO .68272	.65195 TO
45	.66459 + OR - .01852	.64608 TO .68311	.62756 TO

## SECTION X

### APPENDIX G

#### CRITICALITY ANALYSIS FOR CONNECTICUTT YANKEE STAINLESS CLAD ASSEMBLIES

##### INTRODUCTION:

The design basis fuel for the NLI-1/2 shipping cask is a 3.7 w/o U-235 enrichment PWR fuel assembly with zircalloy cladding. The Connecticut Yankee reactor uses Westinghouse 15x15 fuel with a nominal 4.0 w/o enrichment and stainless steel cladding. This enrichment is greater than the license limit for the NLI-1/2 cask so the reactivity of the stainless clad fuel in the cask must be determined. The procedure used here was to calculate  $k_{eff}$  for the design basis 3.7 w/o zircalloy clad fuel and repeat the calculation for the 4.0 w/o stainless clad fuel. Comparison of  $k_{\infty}$  and  $k_{eff}$  for the design basis and stainless clad fuel would then show if the higher enrichment stainless clad fuel is acceptable in the cask. The other fuel characteristics are all within the cask license limits so no analyses other than criticality are needed.

##### FUEL DATA:

The fuel data parameters used in this analysis are shown in Table I. Both the design basis calculation and stainless clad fuel are for Westinghouse 15x15 assemblies with 204 rods/assembly. There are three Connecticut Yankee assemblies to be shipped, and one of them, H-07M, has been modified by encapsulating 23 rods with stainless steel sleeves. The sleeved rods have a larger diameter than a normal rod, so 15 of them have been inserted into the guide tube locations and 8 have been placed (in pairs) in holes made by removing a 2 by 2 group of rods. Some locations have dummy rods inserted to replace the missing (sleeved) rods. The modified assembly still contains the normal quota of 204 fuel rods, but has only three empty (water-filled) guide tube locations instead of the normal 21 water rod locations. These modifications to H-07M result in a lessened moderator to fuel ratio and an increase in the stainless steel absorber amount, which reduces the  $k_{\infty}$  of the lattice given that the standard assembly is undermoderated.

#### KENO MODEL:

The KENO-IV cask body model is identical to the model previously used in amending the cask license for shipment of Fermi-1 fuel and consists of the steel, depleted uranium, lead, and water neutron shield cylinders which comprise the cask. The model treats the fuel and cask as if it were infinitely long, ignoring neutron leakage from the top and bottom of the fuel. The cross-section sets were prepared for this analysis using the AMPX system modules NITAWL and XSDRNPM, and both Normal Operation and Hypothetical Accident cross-section sets were prepared for zircalloy and stainless steel clad fuel types. The NITAWL resonance data parameters were obtained from the NULIF code development by Babcock and Wilcox and are listed with fuel parameters used by XSDRNPM and KENO-IV in Table II. All calculations were performed for fresh, unirradiated fuel. The computer input and results for each case are included in this Appendix.

#### RESULTS AND DISCUSSION:

The  $k_{inf}$  and  $k_{eff}$  results for the two fuels in Normal Operation and Hypothetical Accident scenarios are shown in Table III. The  $k_{inf}$  values for the stainless clad fuel are significantly less for both scenarios, indicating that the stainless fuel is less reactive than the cask design basis fuel even though it has a higher enrichment. This is confirmed by the KENO-IV calculations of  $k_{eff}$  which determine that the stainless clad fuel is less reactive as it is shipped in the NLI 1/2 cask.

The actual percent of theoretical density and enrichment of each of the three assemblies deviates slightly from the nominal 95% T.D. and 4.0 w/o U-235. The actual values shown in Table IV along with the  $k_{inf}$  results. Comparison of the  $k_{inf}$  of the nominal stainless clad fuel to the actual assemblies shows a negligible difference resulting from the deviations.

#### CONCLUSION:

The  $k_{inf}$  and resulting  $k_{eff}$  in the cask of the stainless steel clad fuel enriched to 4.0 w/o U-235 are lower than the design basis PWR fuel assembly, therefore the shipment of the three Connecticut Yankee fuel assemblies is critically safe in the NLI 1/2 cask.



**Table I**  
**Fuel Data**

<u>Item</u>	<u>Design</u> <u>Basis W15x15</u>	<u>Stainless</u> <u>Clad</u>
Enrichment	3.7 w/o	4.0 w/o
Active length	144"	121.4"
<b>Pellet Data:</b>		
N <sub>25</sub>	8.697-4	9.403-4
N <sub>28</sub>	2.235-2	2.228-2
N <sub>O</sub>	4.642-2	4.642-2
Pellet Radius	0.4647 cm	0.4870 cm
<b>Clad Data:</b>		
Material	Zircalloy	Stainless
N <sub>Material</sub>	4.227-2	8.01-2
Gap Radius	0.4742 cm	0.5010 cm
Clad Radius	0.5360 cm	0.5429 cm
No. of Rods/Assembly	204	204
<b>Normal Operation:</b>		
Cell Pitch	1.430 cm	1.430 cm
Cell Effective Radius	0.8068 cm	0.8068 cm
<b>Hypothetical Accident:</b>		
(204 Rods equally share the 8.88" cask basket cavity area in the Hypothetical Accident Scenario)		
Cell Pitch	1.579 cm	1.579 cm
Cell Effective Radius	0.891 cm	0.891 cm

Table II  
Analysis Parameters

**NORMAL OPERATION:**

<u>Item</u>	<u>Design</u> <u>Basis W15x15</u>	<u>Stainless</u> <u>Clad</u>
Dancoff Coefficient	0.2143	0.2217
$(\sigma_m)_{\text{eff}}$	56.55	54.66
Number Densities in Homogenized Fuel used in KENO-IV		
$N_{25}$	2.616-4	3.107-4
$N_{28}$	6.723-4	7.361-3
$N_O$	3.404-2	3.506-2
$N_{\text{Cladding}}$	3.673-3	4.880-3
$N_H$	4.016-2	3.946-2

**HYPOTHETICAL ACCIDENT:**

<u>Item</u>	<u>Design</u> <u>Basis W15x15</u>	<u>Stainless</u> <u>Clad</u>
Dancoff Coefficient	0.1462	0.1521
$(\sigma_m)_{\text{eff}}$	59.84	57.87
Number Densities in Homogenized Fuel used in KENO-IV		
$N_{25}$	2.146-4	2.548-4
$N_{28}$	5.514-4	6.037-3
$N_O$	3.394-2	3.478-2
$N_{\text{Cladding}}$	3.012-3	4.003-3
$N_H$	4.497-2	4.440-2

Table III  
Analysis Results

NORMAL OPERATION:

<u>Item</u>	Design <u>Basis W15x15</u>	Stainless <u>Clad</u>
$k_{\infty}$	1.4379	1.3630
$k_{eff}$	$0.92666 \pm 0.00523$	$0.90389 \pm 0.00416$

HYPOTHETICAL ACCIDENT:

<u>Item</u>	Design <u>Basis W15x15</u>	Stainless <u>Clad</u>
$k_{\infty}$	1.4463	1.3795
$k_{eff}$	$0.95411 \pm 0.00497$	$0.93540 \pm 0.00477$

Table IV  
Assembly Reactivities

<u>Item</u>	Nominal <u>4.0 w/o fuel</u>	Assembly <u>H07M</u>	Assembly <u>G11</u>	Assembly <u>S04</u>
Enrichment	4.0	3.994	4.007	3.9871
Percent of Theoretical Density	95	95.17	94.85	93.2
NULIP $k_{\infty}$	1.3630	1.3627	1.3634	1.3619

# NITAWL INPUT - ZIRC NORMAL OPERATIONS

STE\*STAINLESS.NW15

75R2Q5 06/17/87 17:05:37 (21)

.	13	1SS	0	14	5Z	2	2Z	-1	0	T										
.	13	2SS	92238	-592238	92235	-592235	8016	-558016	1001	-5510										
.	13		40000	13027	24000	26000	28000	82000												
.	20	3**	92233	294.	2	.4647	.2143	56.55	2.235-2	1	16	7.67	1	3Z						
.	13		592238	294.	0	0.0	0.0	20.	4.773-2	1	3Z	3Z	1.0	T						

7. ERRORS: NONE. TIME: 0.222 SEC. IMAGE COUNT: 5

GNORED - IN CONTROL MODE

01700\*NITAWL.NITAWL

# NITAWL OUTPUT - ZIRC NORMAL OPERATIONS

THIS XSDRN WORKING TAPE WAS CREATED  
THE TITLE OF THE PARENT CASE IS AS FOLLOWS  
2<sup>ND</sup> NEUTRON GROUP LIBRARY

BASED ON ENDF/B VERSION 4 DATA

COMPILED FOR NRC

TAPE ID

4321

NUMBER OF NUCLIDES

NUMBER OF NEUTRON GROUPS

27

NUMBER OF GAMMA GROUPS

FIRST THERMAL GROUP

15

## TABLE OF CONTENTS

H 1269 F, 1002 T 212 GP 032475(2)  
H 1269 F, 1002 T 213 GP 032475(2)  
O-16 1276 218 GP 030476(7)  
O-16 1276 218 GP 030476(7)  
AL-27 1193 218 GP 040375(5)  
CR 1171 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
FE 218GP RE 5-17-73(1)  
NI 1170 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
ZR(NAT) 7141 21 NGP WT FIS(0.1T020)-1/E-MAX P-3  
PB 1233 218NGP 042375 P-3 293K  
U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)  
U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)  
U-233 218GP RE 5-17-73(1)  
U-233 218GP RE 5-17-73(1)

PKPT PRINTS

XSDRNPM INPUT - ZIRC NORMAL OPERATION

.XW15

37 18:17:20 (32)

WEST 15X15 ASBL, 3.7 W/O U-235, 95XT.D., NORMAL OP.

1SS 2 3 20 1 3 3 33 8 3 1 2R20 FO

2SS -2 FO

3SS 1 3Z 1000 2Z 1 FO

4SS -1 27 0 -2 E T

13SS 3R1 2 2R3 9R1 9R2 9R3

14SS 92235 92238 558016 40000 558016 551001

8016 1001 13027 82000 24000 26000 28000

592235 592238 2q9

15\*\* 8.697-4 2.235-2 4.642-2 4.227-2 3.347-2 6.694-2 F1.-15 T

33\*\* F1.0 T

35\*\* 910.0 .4647 .4742 71.5360 0.8069

36SS 10R1 2R2 8R3

38\*\* 10R1.0 0.0 F1.0

39SS 1 2 3

40SS F3

51SS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

21 22 23 24 25 26 27 T

E. TIME: 0.200 SEC. IMAGE COUNT: 18

SDRNPM

# XSDRNPM OUTPUT - ZIRC NORMAL OPERATION

3ADD,DEP STE\*STAINLESS.XW15

WEST 15X15 ASBL, 3.7 W/O U-235, 95%T.O., NORMAL OP.

1S ARRAY 15 ENTRIES READ

2S ARRAY 10 ENTRIES READ

3S ARRAY 12 ENTRIES READ

4S ARRAY 9 ENTRIES READ

BT

## DIRECT ACCESS FILES ASSIGNED

7000 WORDS PER RECORD ON UNIT 3

300 WORDS PER RECORD ON UNIT 9

7000 WORDS PER RECORD ON UNIT 10

1 PHYSICAL RECORDS PER LOGICAL

10 PHYSICAL RECORDS PER LOGICAL

1 PHYSICAL RECORDS PER LOGICAL

## GENERAL PROBLEM DESCRIPTION DATA BLOCK

### GENERAL PROBLEM DATA

IGE	1/2/3 = PLANE/CYLINDER/SPHERE	2	ISN	QUADRATURE ORDER
IZM	NUMBER OF ZONES	3	ISCT	ORDER OF SCATTERING
IM	NUMBER OF SPACIAL INTERVALS	20	IEVT	0/1/2/3/4/5/6=Q/K/ALPHA
IBL	0/1/2/3 = VACUUM/REFL/PER/WHITE	1	IIM	INNER ITERATION MAXIMUM
IBR	RIGHT BOUNDARY CONDITION	3	ICM	OUTER ITERATION MAX
MXM	NUMBER OF MIXTURES	3	ICLC	-1/0/N--FLAT RES/SN/...
MS	MIXING TABLE LENGTH	73	ITH	0/1 = FORWARD/ADJOINT
IGM	NUMBER OF ENERGY GROUPS	27	IFLU	0/1/2/3/4=L-S/L/S/W/L-W
NNG	NUMBER OF NEUTRON GROUPS	27	IPRT	-2/-1/0/N=MIXTURE XSEC
VGG	NUMBER OF GAMMA GROUPS	3	ID1	0/1/2/3=NO/PRT ND/PCH N
IFTG	NUMBER OF FIRST THERMAL GROUP	15	IPBT	-1/0/1=NONE/FINE/ALL BAL

### SPECIAL OPTIONS

IFG	0/1 = NONE/WEIGHTING CALCULATION	1	IPN	DUMMY PARAMETER
IQM	VOLUMETRIC SOURCES (0/N=NO/YES)	0	IDFM	0/1 = NONE/DENSITY FACTO
IPM	BOUNDARY SOURCES (0/N=NO/YES)	0	IAZ	0/N = NONE/N ACTIVITIES
IFN	0/1/2 = INPUT 33*/34*/USE LAST	0	IAI	0/1=NONE/ACTIVITIES BY
ITMX	MAXIMUM TIME (MINUTES)	1000	IFCT	0/1=NO/YES UPSCATTER SC
IDT1	0/1/2/3=NO/XSECT/SRCE/FLUX--OUT	3	IPVT	0/1/2=NO/K/ALPHA PARAME

### WEIGHTING DATA (IFG=1)

ICON	-1/0/1=CELL/ZONE/REGION WEIGHT	-1	IHTF	TOTAL XSECT PSN IN BRD
IGMF	NUMBER OF BROAD GROUPS	27	NDSF	PSN G-G OR FILE NUMBER
ITP	0/1/2/3/4/5/6/7/8/9/10/11/12/13/14/15/16/17/18/19/20/21/22/23/24/25/26/27/28/29/30/31/32/33/34/35/36/37/38/39/40/41/42/43/44/45/46/47/48/49/50/51/52/53/54/55/56/57/58/59/60/61/62/63/64/65/66/67/68/69/70/71/72/73/74/75/76/77/78/79/80/81/82/83/84/85/86/87/88/89/90/91/92/93/94/95/96/97/98/99/100	0	NUSF	TABLE LENGTH OR MAX ORDE
IPP	-1/-1/0/N=WGTE XSECT PRINT	-2	MSCM	EXTRA 1-9 X-SECT POSITIO
IAP	-1/N ANISH XSECT PRINT	-1		

### FLOATING POINT PARAMETERS

Page Added

Oct. 1990

X-G10



# XSDRNPM OUTPUT - ZIRC NORMAL OPERATION (Continued)

X15 ASBL, 3.7 W/O U-235, 95XT.0., NORMAL OP.

## DATA BLOCK 2 (MIXING TABLE, ETC.)

MIXTURE	MIXING TABLE COMPONENT	ATOM DENSITY
1	92235	.86970-003
1	92238	.22350-001
1	553016	.46420-001
2	40000	.42270-001
3	558016	.33470-001
3	551001	.66940-001
1	8016	.10000-014
1	1001	.10000-014
1	13027	.10000-014
1	82000	.10000-014
1	24000	.10000-014
1	26000	.10000-014
1	28000	.10000-014
1	592235	.10000-014
1	592238	.10000-014
2	8016	.10000-014
2	1001	.10000-014
2	13027	.10000-014
2	82000	.10000-014
2	24000	.10000-014
2	26000	.10000-014
2	28000	.10000-014
2	592235	.10000-014
2	592238	.10000-014
2	8016	.10000-014
2	1001	.10000-014
2	13027	.10000-014
2	82000	.10000-014
2	24000	.10000-014
2	26000	.10000-014
2	28000	.10000-014
2	592235	.10000-014
2	592238	.10000-014

EXTRA  
XSECT 10'S

FUEL

# XSDRNPM OUTPUT - ZIRC NORMAL OPERATION (Continued)

OUTER	INNER	BALANCE	UPSCATTER	RATIO	EIGENVALUE	LAMBDA1	
1	279	1.0000014+000	1.1643998+000		1.3689112+000	1.4156068+000	
2	438	1.0000014+000	1.0037007+000		1.4199980+000	1.0040045+000	1
3	521	1.0000014+000	9.9448019-001		1.4233861+000	1.0000900+000	1
4	572	1.0000014+000	9.9855819-001		1.4217595+000	9.9937548-001	9
5	643	1.0000014+000	9.9985803-001		1.4213953+000	1.0000648+000	9
6	633	1.0000014+000	9.9998324-001		1.4213593+000	1.0000052+000	9
GRP.	1	REQUIRED	1	ITERATIONS. MFD OF	2.19266-005	OCCURRED IN INT.	20 COA
GRP.	2	REQUIRED	1	ITERATIONS. MFD OF	1.14907-005	OCCURRED IN INT.	20 COA
GRP.	3	REQUIRED	1	ITERATIONS. MFD OF	1.74324-005	OCCURRED IN INT.	20 COA
GRP.	4	REQUIRED	1	ITERATIONS. MFD OF	2.11005-005	OCCURRED IN INT.	20 COA
GRP.	5	REQUIRED	1	ITERATIONS. MFD OF	1.51664-005	OCCURRED IN INT.	20 COA
GRP.	6	REQUIRED	1	ITERATIONS. MFD OF	1.55552-005	OCCURRED IN INT.	20 COA
GRP.	7	REQUIRED	1	ITERATIONS. MFD OF	1.72174-005	OCCURRED IN INT.	20 COA
GRP.	8	REQUIRED	1	ITERATIONS. MFD OF	2.08914-005	OCCURRED IN INT.	1 COA
GRP.	9	REQUIRED	1	ITERATIONS. MFD OF	2.58451-005	OCCURRED IN INT.	2 COA
GRP.	10	REQUIRED	1	ITERATIONS. MFD OF	2.36221-005	OCCURRED IN INT.	1 COA
GRP.	11	REQUIRED	1	ITERATIONS. MFD OF	2.99193-005	OCCURRED IN INT.	20 COA
GRP.	12	REQUIRED	1	ITERATIONS. MFD OF	3.72575-005	OCCURRED IN INT.	20 COA
GRP.	13	REQUIRED	1	ITERATIONS. MFD OF	3.78544-005	OCCURRED IN INT.	16 COA
GRP.	14	REQUIRED	1	ITERATIONS. MFD OF	3.56158-005	OCCURRED IN INT.	16 COA
GRP.	15	REQUIRED	1	ITERATIONS. MFD OF	5.30689-005	OCCURRED IN INT.	3 COA
GRP.	16	REQUIRED	1	ITERATIONS. MFD OF	5.63336-005	OCCURRED IN INT.	1 COA
GRP.	17	REQUIRED	1	ITERATIONS. MFD OF	4.47040-005	OCCURRED IN INT.	14 COA
GRP.	18	REQUIRED	1	ITERATIONS. MFD OF	4.24325-005	OCCURRED IN INT.	14 COA
GRP.	19	REQUIRED	1	ITERATIONS. MFD OF	3.59833-005	OCCURRED IN INT.	14 COA
GRP.	20	REQUIRED	1	ITERATIONS. MFD OF	4.21391-005	OCCURRED IN INT.	1 COA
GRP.	21	REQUIRED	1	ITERATIONS. MFD OF	4.39209-005	OCCURRED IN INT.	13 COA
GRP.	22	REQUIRED	1	ITERATIONS. MFD OF	2.67022-005	OCCURRED IN INT.	14 COA
GRP.	23	REQUIRED	1	ITERATIONS. MFD OF	1.60542-005	OCCURRED IN INT.	20 COA
GRP.	24	REQUIRED	1	ITERATIONS. MFD OF	1.13174-005	OCCURRED IN INT.	20 COA
GRP.	25	REQUIRED	1	ITERATIONS. MFD OF	6.14099-006	OCCURRED IN INT.	1 COA
GRP.	26	REQUIRED	1	ITERATIONS. MFD OF	2.84598-006	OCCURRED IN INT.	1 COA
GRP.	27	REQUIRED	1	ITERATIONS. MFD OF	2.53511-006	OCCURRED IN INT.	20 COA
	715	1.0000014+000	9.9999557-001		1.4213627+000	1.0000054+000	1
		FINAL MINITOR	LAMBDA	1.4213351+000		ANGULAR FLUX ON	
		ELAPSED TIME	13.64208329	MIN.			

# KENO INPUT - ZIRC NORMAL OPERATION

SS.KW15

18/97 16:51:19 (28)

4 ONE PWR ASSEMBLY, 3.7 W/O U-235, NORMAL OP.

7 200. 50 405 6 27 27 14 6 14 11 1 1 1 1 -14 1 0 2000 0 1 82

4 -1 0 0 3R-1

7 1 -92235 2.616-4 1 92238 6.723-3

6 1 40000 3.673-3 1 551001 4.016-2 1 558016 3.404-2

7 2 8016 3.347-2 2 1001 6.694-2

7 3 24000 1.839-2 3 25000 1.815-3 3 26000 5.994-2

7 4 13027 6.026-2

7 5 32000 3.299-2

7 6 592238 4.773-2 6 -592235 1.052-4

4 BOX TYPE 1

4 CUBOID 1 21.450 0.000 10.725 0.000 1000. -1000. 27\*0.5

7 CUBOID 2 21.996 -0.546 11.271 0.000 1000. -1000. 27\*0.5

3 CORE BDY 0 11.271 -11.271 11.271 0.00 1000. -1000. 27\*0.5

7 ZHEMICYL+Y 2 19.509 1000. -1000. 27\*0.5

7 ZHEMICYL+Y 3 19.600 1000. -1000. 27\*0.5

7 ZHEMICYL+Y 6 25.309 1000. -1000. 27\*0.5

7 ZHEMICYL+Y 5 30.706 1000. -1000. 27\*0.5

7 ZHEMICYL+Y 3 32.93 1000. -1000. 27\*0.5

7 ZHEMICYL+Y 2 45.629 1000. -1000. 27\*0.5

7 ZHEMICYL+Y 3 46.264 1000. -1000. 27\*0.5

7 CUBOID 2 63. -63. 63. 0.00 1000. -1000. 27\*0.5

5 1 1 1 1 1 1 1 1 1

4 END KENO.

NONE. TIME: 0.989 SEC. IMAGE COUNT: 24

CONTROL MODE

IRKENO.SUPERKENO

# KENO OUTPUT - ZIRC NORMAL OPERATION

ONE PWR ASSEMBLY, 3.7 W/O U-235, NORMAL OP.

NUMBER OF GENERATIONS	50	START TYPE
NUMBER PER GENERATION	405	GENERATIONS B
NUMBER OF GENERATIONS TO BE SKIPPED	6	LIST INPUT X-
NUMBER OF ENERGY GROUPS	27	LIST 1-D MIXT
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2-D MIXT
NUMBER OF INPUT NUCLIDES	14	LIST FISS. AN
NUMBER OF MIXTURES	6	USE X-SECTION
NUMBER OF MIXING TABLE ENTRIES	14	USE GEOMETRY
NUMBER OF GEOMETRY CARDS	11	USE VELOCITIE
NUMBER OF BOX TYPES	1	COMPUTE MATRI
NUMBER OF UNITS IN X DIRECTION	1	COMPUTE MATRI
NUMBER OF UNITS IN Y DIRECTION	1	LIST FISS. C
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALC
NUMBER OF NUCLIDES READ FROM TAPE	-14	USE EXPONENT
ALBEDO TYPE	1	CALCULATE FL
SEARCH TYPE	0	CALCULATE FIS

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE +X = 1.00000+000 -X = .00000 +Y = .00000 -Y = 1.00000

MAXIMUM TIME = 270.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 19197  
REMAINING AVAILABLE LOCATIONS= 780303

# KENO OUTPUT - ZIRC NORMAL OPERATION (Continued)

ONE PWR ASSEMBLY, 3.7 W/O U-235, NORMAL OP.

MIXTURE	NUCLIDE	DENSITY
1	-92235	2.61600-004
1	92238	6.72300-003
1	40000	3.67300-003
1	551001	4.01600-002
1	558016	3.40400-002
2	3016	3.34700-002
2	1001	6.69400-002
3	24000	1.83900-002
3	23000	1.81500-003
3	26000	5.99400-002
4	13027	6.02600-002
5	82000	3.22900-002
6	592238	4.77300-002
6	-592235	1.05200-004

## CROSS SECTIONS READ FROM TAPE

NUCLIDE =	1001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	551001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	3016	O-16 1276 218 GP 030476(7)
NUCLIDE =	553016	O-16 1276 218 GP 030476(7)
NUCLIDE =	13027	AL-27 1193 218 GP 040375(5)
NUCLIDE =	24000	CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	26000	FE 218GP RE 5-17-78(1)
NUCLIDE =	23000	NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	40000	ZR(NAT) 7141 21 NGP WT FIS(0.1T020)-1/E-MAX P-3
NUCLIDE =	82000	PS 1288 218NGP 042375 P-3 293K
NUCLIDE =	92235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	592235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	92238	U-238 218GP RE 5-17-78(1)
NUCLIDE =	592238	U-238 218GP RE 5-17-78(1)

# KENO OUTPUT - ZIRC NORMAL OPERATION (Continued)

ONE PWR ASSEMBLY, 3.7 W/O U-235, NORMAL OP.

LIFETIME = 1.50201-004 + OR - 1.35872-006

GENERATION TIME = 6.3648

NO. OF INITIAL  
GENERATIONS  
SKIPPED

AVERAGE  
K-EFFECTIVE      DEVIATION

67 PER CENT  
CONFIDENCE INTERVAL

95 PER  
CONFIDENCE

6	.92666 + OR - .00523	.92142 TO .93189	.91619 TO
7	.92628 + OR - .00534	.92093 TO .93162	.91559 TO
8	.92690 + OR - .00544	.92146 TO .93233	.91603 TO
9	.92665 + OR - .00556	.92109 TO .93222	.91553 TO
10	.92583 + OR - .00564	.92019 TO .93147	.91454 TO
11	.92731 + OR - .00559	.92173 TO .93290	.91614 TO
12	.92787 + OR - .00571	.92216 TO .93357	.91646 TO
13	.92805 + OR - .00586	.92219 TO .93391	.91633 TO
14	.92916 + OR - .00592	.92324 TO .93507	.91733 TO
15	.92894 + OR - .00608	.92286 TO .93503	.91678 TO
20	.92658 + OR - .00616	.92041 TO .93274	.91425 TO
25	.92358 + OR - .00607	.91751 TO .92965	.91144 TO
30	.92419 + OR - .00730	.91689 TO .93150	.90759 TO
35	.92123 + OR - .00891	.91237 TO .93020	.90346 TO
40	.93001 + OR - .01134	.91867 TO .94135	.90733 TO
45	.93051 + OR - .01656	.91395 TO .94708	.89732 TO

NITAWL INPUT - ZIRC HYPOTHETICAL ACCIDENT

LESS.NW1SHA

06/19/87 11:40:39 (21)

13 1SS 0 14 5Z 2 2Z -1 0 T

13 2SS 92238 -592238 92235 -592235 8016 -558016 1001 -551001

13 40000 13027 24000 26000 29000 82000

21 3\*\* 92238 294. 2 .4647 .1462 59.84 2.235-2 1 16 7.67 1 3Z 1.0

18 592238 294. 0 0.0 0.0 20. 4.773-2 1 3Z 3Z 1.0 T

S: NONE. TIME: 0.222 SEC. IMAGE COUNT: 5

IN CONTROL MODE

AWL.NITAWL

# NITAWL OUTPUT - ZIRC HYPOTHETICAL ACCIDENT

THIS XSDRM WORKING TAPE WAS CREATED  
THE TITLE OF THE PARENT CASE IS AS FOLLOWS  
2<sup>nd</sup> NEUTRON GROUP LIBRARY

BASED ON ENDF/B VERSION 4 DATA  
COMPILED FOR NRC

TAPE ID

4321

NUMBER OF NUCLIDES

NUMBER OF NEUTRON GROUPS

27

NUMBER OF GAMMA GROUPS

FIRST THERMAL GROUP

15

## TABLE OF CONTENTS

H 1269 F, 1002 T 213 GP 032475(2)  
H 1269 F, 1002 T 218 GP 032475(2)  
O-15 12<sup>th</sup> 6 213 GP 0304<sup>th</sup> 6(7)  
O-16 12<sup>th</sup> 6 218 GP 0304<sup>th</sup> 6(7)  
AL-27 1193 213 GP 040375(5)  
CR 1191 213NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
FE 213GP RE 5-17-73(1)  
NI 1170 213NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
ZR(NAT) 7141 21 NGP WT FIS(0.1T020)-1/E-MAX P-3  
PB 1233 213NGP 042375 P-3 293K  
U-235 1261 SIGP=5+4 NEWXLACS 213NGP P-3 293K(3)  
U-235 1261 SIGP=5+4 NEWXLACS 213NGP P-3 293K(3)  
U-233 213GP RE 5-17-73(1)  
U-233 213GP RE 5-17-73(1)

PKPT PRINTS



XSDRNPM INPUT - ZIRC HYPOTHETICAL ACCIDENT

XW15HA

- 11:59:05 (33)

WEST 15X15 ASBL, 3.7 W/O U-235, 95XT.D., H.A.

1SS 2 3 20 1 3 3 33 8 3 1 2R20 F0

2SS -2 F0

3SS 1 3Z 1000 2Z 1 F0

4SS -1 27 0 -2 E T

13SS 3R1 2 2R3 9R1 9R2 9R3

14SS 92235 92238 552016 40000 552016 551001

2016 1001 13027 92000 24000 26000 28000

592235 592238 209

15\*\* 3.697-4 2.235-2 4.642-2 4.227-2 3.347-2 6.694-2 F1.-15 T

33\*\* F1.0 T

35\*\* 910.0 .4647 .4742 71.5360 0.891

36SS 10R1 2R2 8R3

38\*\* 10R1.0 0.0 F1.0

39SS 1 2 3

40SS F3

51SS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

21 22 23 24 25 26 27 T

. TIME: 0.242 SEC. IMAGE COUNT: 13

DRNPM

# XSDRNPM OUTPUT - ZIRC HYPOTHETICAL ACCIDENT

GADD,DEP STE\*STAINLESS.XW15HA

WEST 15X15 ASBL, 3.7 W/O U-235, 95XT.D., H.A.

1S ARRAY 15 ENTRIES READ

2S ARRAY 10 ENTRIES READ

3S ARRAY 12 ENTRIES READ

4S ARRAY 9 ENTRIES READ

BT

## DIRECT ACCESS FILES ASSIGNED

3000 WORDS PER RECORD ON UNIT 3

300 WORDS PER RECORD ON UNIT 9

3000 WORDS PER RECORD ON UNIT 10

1 PHYSICAL RECORDS PER LOGICAL

10 PHYSICAL RECORDS PER LOGICAL

1 PHYSICAL RECORDS PER LOGICAL

## GENERAL PROBLEM DESCRIPTION DATA BLOCK

### GENERAL PROBLEM DATA

IGE	1/2/3 = PLANE/CYLINDER/SPHERE	2	ISM	QUADRATURE ORDER
IZM	NUMBER OF ZONES	3	ISCT	ORDER OF SCATTERING
IM	NUMBER OF SPACIAL INTERVALS	20	IEVT	0/1/2/3/4/5/6=Q/K/ALPHA
IBL	0/1/2/3 = VACUUM/REFL/PER/WHITE	1	IIM	INNER ITERATION MAXIMUM
IBR	RIGHT BOUNDARY CONDITION	3	ICM	OUTER ITERATION MAXIMUM
MX	NUMBER OF MIXTURES	3	ICLC	-1/0/N=FLAT RES/SH/...
MS	MIXING TABLE LENGTH	23	ITH	0/1 = FORWARD/ADJOINT
IG	NUMBER OF ENERGY GROUPS	27	IPLU	0/1/2/3/4=L-S/L/S/W/L-W
NNG	NUMBER OF NEUTRON GROUPS	27	IPRT	-2/-1/0/N=MIXTURE XSEC
VGG	NUMBER OF GAMMA GROUPS	0	IDT	0/1/2/3=NO/PRT NO/PCN N
IFTG	NUMBER OF FIRST THERMAL GROUP	15	IPBT	-1/0/1=NONE/FINE/ALL JA

### SPECIAL OPTIONS

IFG	0/1 = NONE/WEIGHTING CALCULATION	1	IPN	DUMMY PARAMETER
IQM	VOLUMETRIC SOURCES (0/N=NO/YES)	0	IDFM	0/1 = NONE/DENSITY FACT
IPM	BOUNDARY SOURCES (0/N=NO/YES)	0	IAZ	0/N = NONE/N ACTIVITIES
IFN	0/1/2 = INPUT 33*/34*/USE LAST	0	IAI	0/1=NONE/ACTIVITIES BY
ITMX	MAXIMUM TIME (MINUTES)	1000	IFCT	0/1=NO/YES UPSCATTER SC
IDT1	0/1/2/3=NO/XSECT/SRCE/FLUX--OUT	0	IPVT	0/1/2=NO/K/ALPHA PARAME

### WEIGHTING DATA (IFG=1)

ICON	-1/0/1=CELL/ZONE/REGION WEIGHT	-1	INTF	TOTAL XSECT PSN IN BRD
IGMF	NUMBER OF BROAD GROUPS	27	VDSF	PSN G-G OR FILE NUMBER
ITP	0/10/20/30/40 C/C/E/AC/A	0	VUSF	TABLE LENGTH OR MAX ORD
IPD	-1/-1/0/N=WGTEO XSECT PRINT	-2	VSCM	EXTRA 1-D X-SECT POSITI
IAP	-1/N ANISN XSECT PRINT	-1		

# XSDRNPM OUTPUT - ZIRC HYPOTHETICAL ACCIDENT (Continued)

115 ASBL, 7.7 W/O U-235, 95XT.D., H.A.

## DATA BLOCK 2 (MIXING TABLE, ETC.)

MIXTURE	MIXING TABLE COMPONENT	ATOM DENSITY	EXTRA XSECT ID'S
1	92235	.86970-003	
1	92238	.22350-001	
1	558016	.46420-001	
2	40000	.42270-001	
3	558016	.33470-001	
3	551001	.66940-001	
1	3016	.10000-014	
1	1001	.10000-014	
1	13027	.10000-014	
1	32000	.10000-014	
1	24000	.10000-014	
1	26000	.10000-014	
1	28000	.10000-014	
1	592235	.10000-014	
1	592238	.10000-014	
2	3016	.10000-014	
2	1001	.10000-014	
2	13027	.10000-014	
2	32000	.10000-014	
2	24000	.10000-014	
2	26000	.10000-014	
2	28000	.10000-014	
2	592235	.10000-014	
2	592238	.10000-014	
3	3016	.10000-014	
3	1001	.10000-014	
3	13027	.10000-014	
3	32000	.10000-014	
3	24000	.10000-014	
3	26000	.10000-014	
3	28000	.10000-014	
3	592235	.10000-014	
3	592238	.10000-014	

# XSDRNPM OUTPUT - ZIRC HYPOTHETICAL ACCIDENT (Continued)

OUTER	INNER	BALANCE	UPSCATTER RATIO	EIGENVALUE	LAMBDA1
1	271	1.0000011+000	1.1342761+000	1.3338323+000	1.4428639+000
2	412	1.0000010+000	1.0066973+000	1.4451531+000	1.0035129+000
3	474	1.0000010+000	9.9592105-001	1.4500193+000	1.0002437+000
4	564	1.0000010+000	9.9389382-001	1.4487024+000	9.9995454-001
5	620	1.0000010+000	9.9997373-001	1.4483556+000	1.0000479+000
6	661	1.0000010+000	9.9999933-001	1.4483560+000	1.0000304+000
GRP. 1	REQUIRED	1 ITERATIONS.	MFD OF 2.26501-005	OCCURRED IN INT.	20 C
GRP. 2	REQUIRED	1 ITERATIONS.	MFD OF 9.51393-006	OCCURRED IN INT.	20 C
GRP. 3	REQUIRED	1 ITERATIONS.	MFD OF 1.61515-005	OCCURRED IN INT.	20 C
GRP. 4	REQUIRED	1 ITERATIONS.	MFD OF 1.73247-005	OCCURRED IN INT.	20 C
GRP. 5	REQUIRED	1 ITERATIONS.	MFD OF 1.32375-005	OCCURRED IN INT.	20 C
GRP. 6	REQUIRED	1 ITERATIONS.	MFD OF 1.26005-005	OCCURRED IN INT.	20 C
GRP. 7	REQUIRED	1 ITERATIONS.	MFD OF 1.34379-005	OCCURRED IN INT.	20 C
GRP. 8	REQUIRED	1 ITERATIONS.	MFD OF 1.59365-005	OCCURRED IN INT.	2 C
GRP. 9	REQUIRED	1 ITERATIONS.	MFD OF 2.02351-005	OCCURRED IN INT.	1 C
GRP. 10	REQUIRED	1 ITERATIONS.	MFD OF 2.29557-005	OCCURRED IN INT.	1 C
GRP. 11	REQUIRED	1 ITERATIONS.	MFD OF 2.47899-005	OCCURRED IN INT.	2 C
GRP. 12	REQUIRED	1 ITERATIONS.	MFD OF 3.18932-005	OCCURRED IN INT.	2 C
GRP. 13	REQUIRED	1 ITERATIONS.	MFD OF 3.32134-005	OCCURRED IN INT.	2 C
GRP. 14	REQUIRED	1 ITERATIONS.	MFD OF 3.23696-005	OCCURRED IN INT.	20 C
GRP. 15	REQUIRED	1 ITERATIONS.	MFD OF 4.52963-005	OCCURRED IN INT.	1 C
GRP. 16	REQUIRED	1 ITERATIONS.	MFD OF 3.06513-005	OCCURRED IN INT.	14 C
GRP. 17	REQUIRED	1 ITERATIONS.	MFD OF 3.17733-005	OCCURRED IN INT.	14 C
GRP. 18	REQUIRED	1 ITERATIONS.	MFD OF 3.09409-005	OCCURRED IN INT.	14 C
GRP. 19	REQUIRED	1 ITERATIONS.	MFD OF 2.63542-005	OCCURRED IN INT.	14 C
GRP. 20	REQUIRED	1 ITERATIONS.	MFD OF 3.34931-005	OCCURRED IN INT.	1 C
GRP. 21	REQUIRED	1 ITERATIONS.	MFD OF 4.20826-005	OCCURRED IN INT.	2 C
GRP. 22	REQUIRED	1 ITERATIONS.	MFD OF 2.20568-005	OCCURRED IN INT.	13 C
GRP. 23	REQUIRED	1 ITERATIONS.	MFD OF 8.64732-006	OCCURRED IN INT.	20 C
GRP. 24	REQUIRED	1 ITERATIONS.	MFD OF 1.05341-005	OCCURRED IN INT.	20 C
GRP. 25	REQUIRED	1 ITERATIONS.	MFD OF 2.17327-006	OCCURRED IN INT.	1 C
GRP. 26	REQUIRED	1 ITERATIONS.	MFD OF 1.72435-006	OCCURRED IN INT.	16 C
GRP. 27	REQUIRED	1 ITERATIONS.	MFD OF 2.21379-006	OCCURRED IN INT.	1 C
623	1.0000010+000	1.0000016+000	1.4483741+000	1.0000123+000	
FINAL MINITOR		LAMBDA	1.4433517+000	ANGULAR FLUX ON	
ELAPSED TIME		3.3393332 MIN.			

# KENO INPUT - ZIRC HYPOTHETICAL ACCIDENT

ESS.KW1SHA

/19/87 12:06:14 (61)

```

60 ONE PWR ASSEMBLY, 3.7 W/O U-235, H.A.
60 200. 50 405 6 27 27 14 6 14 10 1 1 1 1 -14 1 0 2000 0 1 82
60 0 0 0 3R-1
60 1 -92235 2.146-4 1 92238 5.514-3
60 1 40000 3.012-3 1 551001 4.497-2 1 558016 3.394-2
60 2 8016 3.347-2 2 1001 6.694-2
60 3 24000 1.839-2 3 28000 1.815-3 3 26000 5.994-2
60 4 13027 6.026-2
60 5 32000 3.299-2
60 6 592238 4.773-2 6 -592235 1.052-4
60 BOX TYPE 1
61 CUBOID 1 11.271 -11.271 11.271 0.000 1000. -1000. 27*0.5
60 CORE BDY 0 11.271 -11.271 11.271 0.00 1000. -1000. 27*0.5
60 ZHEMICYL+Y 2 19.509 1000. -1000. 27*0.5
60 ZHEMICYL+Y 3 19.600 1000. -1000. 27*0.5
60 ZHEMICYL+Y 6 25.309 1000. -1000. 27*0.5
60 ZHEMICYL+Y 5 30.706 1000. -1000. 27*0.5
60 ZHEMICYL+Y 3 32.93 1000. -1000. 27*0.5
60 ZHEMICYL+Y 2 45.629 1000. -1000. 27*0.5
60 ZHEMICYL+Y 3 46.264 1000. -1000. 27*0.5
60 CUBOID 2 63. -63. 63. 0.00 1000. -1000. 27*0.5
60 1 1 1 1 1 1 1 1 1 1 1 1
60 END KENO.

```

NONE. TIME: 0.331 SEC. IMAGE COUNT: 23

CONTROL MODE

ERKENO.SUPERKENO

# KENO OUTPUT - ZIRC HYPOTHETICAL ACCIDENT

ONE PWR ASSEMBLY, 3.7 W/O U-235, H.A.

NUMBER OF GENERATIONS	50	START TYPE
NUMBER PER GENERATION	405	GENERATIONS
NUMBER OF GENERATIONS TO BE SKIPPED	6	LIST INPUT X
NUMBER OF ENERGY GROUPS	27	LIST 1-D MIX
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2-D MIX
NUMBER OF INPUT NUCLIDES	14	LIST FISS. A
NUMBER OF MIXTURES	6	USE X-SECTIO
NUMBER OF MIXING TABLE ENTRIES	14	USE GEOMETRY
NUMBER OF GEOMETRY CARDS	10	USE VELOCITI
NUMBER OF BOX TYPES	1	COMPUTE MATR
NUMBER OF UNITS IN X DIRECTION	1	COMPUTE FLUX
NUMBER OF UNITS IN Y DIRECTION	1	LIST FISS PR
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALC
NUMBER OF NUCLIDES READ FROM TAPE	-14	USE EXPONENT
ALBEDO TYPE	1	CALCULATE FL
SEARCH TYPE	0	CALCULATE FI

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE +X = .00000 -X = .00000 +Y = .00000 -Y = 1.0000

MAXIMUM TIME = 200.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 13213

REMAINING AVAILABLE LOCATIONS= 331007

# KENO OUTPUT - ZIRC HYPOTHETICAL ACCIDENT (Continued)

ONE PWR ASSEMBLY, 3.7 W/O U-235, H.A.

MIXTURE	NUCLIDE	DENSITY
1	-92235	2.14600-004
1	92238	5.51400-003
1	40000	3.01200-003
1	351001	4.49700-002
1	553016	3.39400-002
2	3016	3.34700-002
2	1001	6.69400-002
2	24000	1.83900-002
3	23000	1.81500-003
3	26000	5.99400-002
4	13027	6.02600-002
5	32000	3.20900-002
6	592238	4.77300-002
6	-592235	1.05200-004

## CROSS SECTIONS READ FROM TAPE

NUCLIDE =	1001	H 1260 F, 1002 T 218 GP 032475(2)
NUCLIDE =	351001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	8016	0-16 1276 218 GP 030476(7)
NUCLIDE =	553016	0-16 1276 218 GP 030476(7)
NUCLIDE =	13027	AL-27 1193 213 GP 040375(5)
NUCLIDE =	24000	CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	26000	FE 218GP RE 5-17-78(1)
NUCLIDE =	23000	NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	40000	ZR(NAT) 7141 21 NGP WT FIS(0.1T020)-1/E-MAX P-3
NUCLIDE =	32000	PB 1288 218NGP 042375 P-3 293K
NUCLIDE =	92235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	592235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	72233	U-238 218GP RE 5-17-78(1)
NUCLIDE =	592238	U-238 218GP RE 5-17-73(1)

# KENO OUTPUT - ZIRC HYPOTHETICAL ACCIDENT (Continued)

ONE PWR ASSEMBLY, 3.7 W/O U-235, H.A.

LIFETIME = 1.25773-004 + OR - 1.23140-006

GENERATION TIME = 6.44498

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE		DEVIATION	67 PER CENT CONFIDENCE INTERVAL		95 PER CONFIDENCE
6	.95411	+ OR -	.00497	.94914 TO	.95907	.94417 TO
7	.95202	+ OR -	.00461	.94740 TO	.95663	.94279 TO
8	.95196	+ OR -	.00473	.94724 TO	.95669	.94251 TO
9	.95134	+ OR -	.00484	.94700 TO	.95663	.94216 TO
10	.95194	+ OR -	.00496	.94698 TO	.95690	.94201 TO
11	.95201	+ OR -	.00509	.94692 TO	.95710	.94183 TO
12	.95235	+ OR -	.00521	.94714 TO	.95756	.94192 TO
13	.95194	+ OR -	.00534	.94660 TO	.95728	.9412 TO
14	.95274	+ OR -	.00543	.94732 TO	.95817	.94189 TO
15	.95375	+ OR -	.00549	.94326 TO	.95924	.94277 TO
20	.95959	+ OR -	.00543	.95416 TO	.96502	.94873 TO
25	.96104	+ OR -	.00589	.95515 TO	.96693	.94927 TO
30	.95676	+ OR -	.00667	.95309 TO	.96343	.94742 TO
35	.95355	+ OR -	.00773	.94582 TO	.96123	.94308 TO
40	.94324	+ OR -	.00871	.93453 TO	.95195	.92582 TO
45	.94279	+ OR -	.00683	.93594 TO	.94961	.92911 TO



# NITAWL INPUT - STAINLESS NORMAL OPERATION

```

- . . . . .
12 75R2G5 06/19/87 14:40:27 (24)
1. 24 155 0 15 5Z 2 22 -1 0 T
2. 20 255 92238 -592238 92235 -592235 8016 -558016 1001 -551001
3. 24 40000 13027 24000 26000 -526000 23000 82000
4. 21 3** 92238 294. 2 .4647 .2217 54.66 2.228-2 1 16 7.67 1 3Z 1.0
5. 20 592238 294. 0 0.0 0.0 20. 4.773-2 1 3Z 3Z 1.0 T

```

-T. ERRORS: NONE. TIME: 0.305 SEC. IMAGE COUNT: 5

IGNORED - IN CONTROL MODE

421000\*NITAWL.NITAWL

# NITAWL OUTPUT - STAINLESS NORMAL OPERATION

THIS XSDRM WORKING TAPE WAS CREATED  
THE TITLE OF THE PARENT CASE IS AS FOLLOWS  
2<sup>ND</sup> NEUTRON GROUP LIBRARY

BASED ON ENDF/B VERSION 4 DATA

COMPILED FOR NRC

TAPE ID

4321

NUMBER OF NUCLIDES

NUMBER OF NEUTRON GROUPS

27

NUMBER OF GAMMA GROUPS

FIRST THERMAL GROUP

15

## TABLE OF CONTENTS

H 1260 F, 1002 T 213 GP 032475(2)  
H 1260 F, 1002 T 218 GP 032475(2)  
O-16 1276 213 GP 030476(7)  
O-16 1276 218 GP 030476(7)  
AL-27 1193 218 GP 040375(5)  
CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
FE 213GP RE 5-17-78(1)  
FE 213GP RE 5-17-78(1)  
NI 1170 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
ZR(NAT) 7141 21 NGP WT FIS(0.1T020)-1/E-MAX P-3  
PB 1293 218NGP 042375 P-3 293K  
U-235 1261 SIGP=5+4 NEWLACS 218NGP P-3 293K(3)  
U-235 1261 SIGP=5+4 NEWLACS 218NGP P-3 293K(3)  
U-233 213GP RE 5-17-78(1)  
U-233 213GP RE 5-17-78(1)

3BRKPT PRINTS

# XSDRNP INPUT - STAINLESS NORMAL OPERATION

ESS.XW15S

19/87 15:04:46 (35)

```

WEST 15X15 ASBL, 4.0 W/O U-235, STAINLESS CLAD, NORMAL OP.
1SS 2 3 20 1 3 3 3 8 3 1 2R20 FO
2SS -2 FO
3SS 1 3Z 1000 2Z 1 FO
4SS -1 27 0 -2 E T
13SS 3R1 2 2R3 9R1 9R2 9R3
14SS 92235 92233 553016 526000 553016 551001
      8016 1001 13027 82000 24000 26000 28000
      592235 592238 289
15** 9.403-4 2.223-2 4.642-2 8.01-2 3.347-2 6.694-2 F1.-15 T
33** F1.0 T
35** 910.0 .4647 .4742 71.5360 0.8068
36SS 10R1 2R2 8R3
38** 10R1.0 0.0 F1.0
39SS 1 2 3
40SS F3
51SS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
      21 22 23 24 25 26 27 T

```

ONE. TIME: 0.242 SEC. IMAGE COUNT: 18

\*.XSDRNP

# XSDRNPM - STAINLESS NORMAL OPERATION

QADD,DEP STE\*STAINLESS.XW15S

WEST 15X15 ASBL, 4.0 W/O U-235, STAINLESS CLAD, NORM

1S ARRAY 15 ENTRIES READ

2S ARRAY 10 ENTRIES READ

3S ARRAY 12 ENTRIES READ

4S ARRAY 9 ENTRIES READ

JT

## DIRECT ACCESS FILES ASSIGNED

3000 WORDS PER RECORD ON UNIT 8

330 WORDS PER RECORD ON UNIT 9

3000 WORDS PER RECORD ON UNIT 10

1 PHYSICAL RECORDS PER LOGICAL

10 PHYSICAL RECORDS PER LOGICAL

1 PHYSICAL RECORDS PER LOGICAL

## GENERAL PROBLEM DESCRIPTION DATA BLOCK

### GENERAL PROBLEM DATA

IGE 1/2/3 = PLANE/CYLINDER/SPHERE 2  
 IZN NUMBER OF ZONES 3  
 IM NUMBER OF SPACIAL INTERVALS 20  
 IBL 0/1/2/3 = VACUUM/REFL/PER/WHITE 1  
 IBR RIGHT BOUNDARY CONDITION 3  
 MXX NUMBER OF MIXTURES 3  
 MS MIXING TABLE LENGTH 33  
 IGM NUMBER OF ENERGY GROUPS 27  
 NNG NUMBER OF NEUTRON GROUPS 27  
 NGG NUMBER OF GAMMA GROUPS 0  
 IFTG NUMBER OF FIRST THERMAL GROUP 15

ISN QUADRATURE ORDER  
 ISCT ORDER OF SCATTERING  
 IEVT 0/1/2/3/4/5/6=Q/K/ALPHA/  
 IIN INNER ITERATION MAXIMUM  
 ICM OUTER ITERATION MAXI  
 ICLC -1/0/N--FLAT RES/SN/  
 ITH 0/1 = FORWARD/ADJOINT  
 IFLU 0/1/2/3/4=L-S/L/S/W/L-W  
 IPRT -2/-1/0/N=MIXTURE XSEC P  
 IDI 0/1/2/3=NO/PRT ND/PCN N/  
 IPBT -1/0/1=NONE/FINE/ALL BAL

### SPECIAL OPTIONS

IFG 0/1 = NONE/WEIGHTING CALCULATION 1  
 IQM VOLUMETRIC SOURCES (0/N=NO/YES) 0  
 IPM BOUNDARY SOURCES (0/N=NO/YES) 0  
 IFN 0/1/2 = INPUT 33\*/34\*/USE LAST 0  
 ITMX MAXIMUM TIME (MINUTES) 1000  
 IDT1 0/1/2/3=NO/XSECT/SRCE/FLUX--OUT 0

IPN DUMMY PARAMETER  
 IDFM 0/1 = NONE/DENSITY FACTO  
 IAZ 0/N = NONE/N ACTIVITIES  
 IAI 0/1=NONE/ACTIVITIES BY I  
 IFCT 0/1=NO/YES UPSCATTER SCA  
 IPVT 0/1/2=NO/K/ALPHA PARAMET

### WEIGHTING DATA (IFG=1)

ICON -1/0/1=CELL/ZONE/REGION WEIGHT -1  
 IGMF NUMBER OF BROAD GROUPS 27  
 ITP 0/10/20/30/40 0/C/E/AC/A 0  
 IPP -2/-1/0/1=VGTEO XSECT PRINT -2  
 IAP -1/0 ANISH XSECT PRINT -1

IHTF TOTAL XSECT PSN IN BRD G  
 NDSF PSN G-G OR FILE NUMBER  
 NUSF TABLE LENGTH OR MAX ORDE  
 MSCM EXTRA 1-D X-SECT POSITIO

### FLOATING POINT PARAMETERS

Page Added  
 Oct. 1990

X-G30

# XSDRNPH OUTPUT - STAINLESS NORMAL OPERATION (Continued)

3 ASBL, 4.0 W/O U-235, STAINLESS CLAD, NORMAL OP.

## DATA BLOCK 2 (MIXING TABLE, ETC.)

MIXTURE	MIXING TABLE COMPONENT	ATOM DENSITY	EXTRA XSECT ID'S
1	92235	.94030-003	
1	92238	.22280-001	
1	558016	.46420-001	
2	526000	.80100-001	
3	558016	.33470-001	
3	551001	.66940-001	
1	8016	.10000-014	
1	1001	.10000-014	
1	13027	.10000-014	
1	82000	.10000-014	
1	24000	.10000-014	
1	26000	.10000-014	
1	28000	.10000-014	
1	592235	.10000-014	
1	592238	.10000-014	
2	8016	.10000-014	
2	1001	.10000-014	
2	13027	.10000-014	
2	82000	.10000-014	
2	24000	.10000-014	
2	26000	.10000-014	
2	28000	.10000-014	
2	592235	.10000-014	
2	592238	.10000-014	
3	8016	.10000-014	
3	1001	.10000-014	
3	13027	.10000-014	
3	82000	.10000-014	
3	24000	.10000-014	
3	26000	.10000-014	
3	28000	.10000-014	
3	592235	.10000-014	
3	592238	.10000-014	

# XSDRNPM OUTPUT - STAINLESS NORMAL OPERATION (Continued)

OUTER	INNER	BALANCE	UPSCATTER	RATIO	EIGENVALUE	LAMBDA1
1	279	1.0000014+000	1.1426466+000	1.2934294+000	1.3251336+000	
2	424	1.0000014+000	1.0011651+000	1.3294693+000	1.0034903+000	
3	500	1.0000014+000	9.9362516-001	1.3316592+000	1.0001303+000	
4	571	1.0000014+000	9.9835870-001	1.3302430+000	9.9989019-001	
5	623	1.0000014+000	9.9982852-001	1.3299635+000	1.0000816+000	
6	669	1.0000014+000	9.9993499-001	1.3299539+000	1.0000241+000	
GRP.	1	REQUIRED	1	ITERATIONS. MFD OF	2.16023-005	OCCURRED IN INT. 20 CC
GRP.	2	REQUIRED	1	ITERATIONS. MFD OF	1.08659-005	OCCURRED IN INT. 20 CO
GRP.	3	REQUIRED	1	ITERATIONS. MFD OF	1.76437-005	OCCURRED IN INT. 20 CC
GRP.	4	REQUIRED	1	ITERATIONS. MFD OF	2.03545-005	OCCURRED IN INT. 20 CO
GRP.	5	REQUIRED	1	ITERATIONS. MFD OF	1.48687-005	OCCURRED IN INT. 20 CO
GRP.	6	REQUIRED	1	ITERATIONS. MFD OF	1.50689-005	OCCURRED IN INT. 20 CO
GRP.	7	REQUIRED	1	ITERATIONS. MFD OF	1.67806-005	OCCURRED IN INT. 20 CO
GRP.	8	REQUIRED	1	ITERATIONS. MFD OF	1.98332-005	OCCURRED IN INT. 1 CC
GRP.	9	REQUIRED	1	ITERATIONS. MFD OF	2.59465-005	OCCURRED IN INT. 1 CO
GRP.	10	REQUIRED	1	ITERATIONS. MFD OF	2.94334-005	OCCURRED IN INT. 1 CO
GRP.	11	REQUIRED	1	ITERATIONS. MFD OF	3.11602-005	OCCURRED IN INT. 2 CC
GRP.	12	REQUIRED	1	ITERATIONS. MFD OF	3.98160-005	OCCURRED IN INT. 20 CO
GRP.	13	REQUIRED	1	ITERATIONS. MFD OF	4.22388-005	OCCURRED IN INT. 20 CO
GRP.	14	REQUIRED	1	ITERATIONS. MFD OF	4.12007-005	OCCURRED IN INT. 20 CO
GRP.	15	REQUIRED	1	ITERATIONS. MFD OF	5.53696-005	OCCURRED IN INT. 2 CC
GRP.	16	REQUIRED	1	ITERATIONS. MFD OF	4.12413-005	OCCURRED IN INT. 14 CO
GRP.	17	REQUIRED	1	ITERATIONS. MFD OF	4.26836-005	OCCURRED IN INT. 14 CO
GRP.	18	REQUIRED	1	ITERATIONS. MFD OF	4.15576-005	OCCURRED IN INT. 14 CO
GRP.	19	REQUIRED	1	ITERATIONS. MFD OF	3.49234-005	OCCURRED IN INT. 14 CO
GRP.	20	REQUIRED	1	ITERATIONS. MFD OF	4.37999-005	OCCURRED IN INT. 1 CO
GRP.	21	REQUIRED	1	ITERATIONS. MFD OF	4.57831-005	OCCURRED IN INT. 13 CC
GRP.	22	REQUIRED	1	ITERATIONS. MFD OF	2.73770-005	OCCURRED IN INT. 14 CO
GRP.	23	REQUIRED	1	ITERATIONS. MFD OF	2.30833-005	OCCURRED IN INT. 20 CO
GRP.	24	REQUIRED	1	ITERATIONS. MFD OF	1.07240-005	OCCURRED IN INT. 20 CO
GRP.	25	REQUIRED	1	ITERATIONS. MFD OF	7.91199-006	OCCURRED IN INT. 20 CO
GRP.	26	REQUIRED	1	ITERATIONS. MFD OF	3.32037-006	OCCURRED IN INT. 1 CO
GRP.	27	REQUIRED	1	ITERATIONS. MFD OF	2.55561-006	OCCURRED IN INT. 20 CO
7	696	1.0000014+000	9.9999621-001	1.3299680+000	1.0000127+000	
		FINAL MINITOR	LAMBDA	1.3299434+000	ANGULAR FLUX ON	
ELAPSED TIME		2.61433330 MIN.				

# KENO INPUT - STAINLESS NORMAL OPERATION

ESS.KW15S

/01/87 09:04:51 (61)

```

60 ONE PWR ASSEMBLY, 4.0 W/O U-235, NORMAL OP., STAINLESS CLAD
61 200. 50 501 6 27 27 14 6 14 11 1 1 1 1 -14 1 0 2000 0 1 8Z
60 -1 0 0 3R-1
60 1 -92235 3.107-4 1 92238 7.361-3
60 1 526000 4.880-3 1 551001 3.946-2 1 558016 3.506-2
60 2 3016 3.347-2 2 1001 6.694-2
60 3 24000 1.339-2 3 29000 1.315-3 3 26000 5.994-2
60 4 13027 6.026-2
60 5 82000 3.299-2
60 6 592238 4.773-2 6 -592235 1.052-4
60 BOX TYPE 1
60 CUBOID 1 21.450 0.000 10.725 0.000 1000. -1000. 27*0.5
60 CUBOID 2 21.996 -0.546 11.271 0.000 1000. -1000. 27*0.5
60 CORE BDY 0 11.271 -11.271 11.271 0.00 1000. -1000. 27*0.5
60 ZHEMICYL+Y 2 19.509 1000. -1000. 27*0.5
60 ZHEMICYL+Y 3 19.600 1000. -1000. 27*0.5
60 ZHEMICYL+Y 6 25.309 1000. -1000. 27*0.5
60 ZHEMICYL+Y 5 30.706 1000. -1000. 27*0.5
60 ZHEMICYL+Y 3 32.03 1000. -1000. 27*0.5
60 ZHEMICYL+Y 2 45.629 1000. -1000. 27*0.5
60 ZHEMICYL+Y 3 46.264 1000. -1000. 27*0.5
60 CUBOID 2 63. -63. 63. 0.00 1000. -1000. 27*0.5
60 1 1 1 1 1 1 1 1 1 1
60 END KENO.

```

NONE. TIME: 0.417 SEC. IMAGE COUNT: 24

! CONTROL MODE

PERKENO.SUPERKENO

# KENO OUTPUT - STAINLESS NORMAL OPERATION

ONE PWR ASSEMBLY, 4.0 W/O U-235, NORMAL OP., STAINLESS CLAD

NUMBER OF GENERATIONS	50	START TYPE
NUMBER PER GENERATION	501	GENERATIONS
NUMBER OF GENERATIONS TO BE SKIPPED	6	LIST INPUT X
NUMBER OF ENERGY GROUPS	27	LIST 1-D MIX
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2-D MIX
NUMBER OF INPUT NUCLIDES	14	LIST FISS. A
NUMBER OF MIXTURES	6	USE X-SECTION
NUMBER OF MIXING TABLE ENTRIES	14	USE GEOMETRY
NUMBER OF GEOMETRY CARDS	11	USE VELOCITY
NUMBER OF BOX TYPES	1	COMPUTE MATR
NUMBER OF UNITS IN X DIRECTION	1	COMPUTE M
NUMBER OF UNITS IN Y DIRECTION	1	LIST FISS PRO
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALC
NUMBER OF NUCLIDES READ FROM TAPE	-14	USE EXPONENT
ALBEDO TYPE	1	CALCULATE FLI
SEARCH TYPE	0	CALCULATE FI

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE +X = 1.00000+000 -X = .00000 +Y = .00000 -Y = 1.00000

MAXIMUM TIME = 200.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 20637  
 REMAINING AVAILABLE LOCATIONS= 372367



ONE PWR ASSEMBLY, 4.0 W/O U-235, NORMAL OP., STAINLESS CLAD

MIXTURE	NUCLIDE	DENSITY
1	-92235	3.10700-004
1	92238	7.36100-003
1	526000	4.58000-003
1	551001	3.94600-002
1	553016	3.50600-002
2	3016	3.34700-002
2	1001	6.69400-002
3	24000	1.83900-002
3	23000	1.81500-003
3	26000	5.99400-002
4	13027	6.02600-002
5	32000	3.27900-002
6	592238	4.77300-002
6	-592235	1.05200-004

CROSS SECTIONS READ FROM TAPE

NUCLIDE =	1001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	551001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	3016	0-16 1276 218 GP 030476(7)
NUCLIDE =	553016	0-16 1276 218 GP 030476(7)
NUCLIDE =	13027	AL-27 1193 218 GP 040375(5)
NUCLIDE =	24000	CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	26000	FE 213GP RE 5-17-78(1)
NUCLIDE =	526000	FE 213GP RE 5-17-78(1)
NUCLIDE =	23000	NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	22000	PB 1293 218NGP 042375 P-3 293K
NUCLIDE =	92235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	592235	U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =	92233	U-238 218GP RE 5-17-78(1)
NUCLIDE =	592238	U-238 218GP RE 5-17-78(1)

# KENO OUTPUT - STAINLESS NORMAL OPERATION (Continued)

ONE PWR ASSEMBLY, 4.0 W/O U-235, NORMAL OP., STAINLESS CLAD

LIFETIME = 1.23723-004 + OR - 1.32370-006

GENERATION TIME = 5.36435

NO. OF INITIAL  
GENERATIONS  
SKIPPED

AVERAGE  
K-EFFECTIVE

DEVIATION

67 PER CENT  
CONFIDENCE INTERVAL

95 PER  
CONFIDENCE

5	.90339	+ OR - .00416	.89973 TO .90805	.89557 TO
7	.90360	+ OR - .00425	.89935 TO .90734	.89510 TO
9	.90362	+ OR - .00435	.89927 TO .90797	.89492 TO
10	.90378	+ OR - .00445	.89932 TO .90823	.89487 TO
10	.90413	+ OR - .00455	.89958 TO .90368	.89503 TO
11	.90433	+ OR - .00466	.89967 TO .90900	.89500 TO
12	.90387	+ OR - .00477	.89911 TO .90364	.89434 TO
13	.90332	+ OR - .00486	.89846 TO .90819	.89360 TO
14	.90354	+ OR - .00500	.89854 TO .90853	.89354 TO
15	.90521	+ OR - .00484	.90037 TO .91005	.89552 TO
20	.90633	+ OR - .00540	.90093 TO .91173	.89557 TO
25	.90932	+ OR - .00585	.90348 TO .91517	.89763 TO
30	.90572	+ OR - .00663	.89909 TO .91235	.89246 TO
35	.90520	+ OR - .00697	.89833 TO .91226	.89176 TO
40	.90133	+ OR - .00684	.89449 TO .90817	.88764 TO
45	.90431	+ OR - .00589	.89842 TO .91020	.89257 TO

NITAWL INPUT - STAINLESS HYPOTHETICAL ACCIDENT

INLESS.NW15SHA

07/01/87 12:02:14 (21)

21 1\$\$ 0 15 5Z 2 2Z -1 0 T

21 2\$\$ 92238 -592238 92235 -592235 8016 -558016 1001 -551001

21 40000 13027 24000 26000 -526000 28000 82000

21 3\*\* 92238 294. 2 .4647 .1521 57.87 2.228-2 1 16 7.67 1 3Z 1.0

21 592238 294. 0 0.0 0.0 20. 4.773-2 1 3Z 3Z 1.0 T

IS: NONE. TIME: 0.223 SEC. IMAGE COUNT: 5

IN CONTROL MODE

AWL.NITAWL

# NITAWL OUTPUT - STAINLESS HYPOTHETICAL ACCIDENT

THIS XSDRN WORKING TAPE WAS CREATED  
THE TITLE OF THE PARENT CASE IS AS FOLLOWS  
2<sup>nd</sup> NEUTRON GROUP LIBRARY  
BASED ON ENDF/B VERSION 4 DATA

COMPILED FOR NRC

TAPE ID

4321

NUMBER OF NUCLIDES

NUMBER OF NEUTRON GROUPS

27

NUMBER OF GAMMA GROUPS

FIRST THERMAL GROUP

15

## TABLE OF CONTENTS

H 1269 F, 1002 T 213 GP 032475(2)  
H 1269 F, 1002 T 213 GP 032475(2)  
O-16 12<sup>6</sup> 213 GP 030476(7)  
O-16 12<sup>6</sup> 213 GP 030476(7)  
AL-27 1193 213 GP 040375(5)  
CR 1171 213NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
FE 213GP RE 5-17-73(1)  
FE 213GP RE 5-17-73(1)  
NI 1190 213NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)  
ZR(NAT) 7141 21 NGP WT FIS(0.1T020)-1/E-MAX P-3  
P9 1238 213NGP 042375 P-3 293K  
U-233 1261 SIGP=5+4 NEWXLACS 213NGP P-3 293K(3)  
U-235 1261 SIGP=5+4 NEWXLACS 213NGP P-3 293K(3)  
U-233 218GP RE 5-17-73(1)  
U-235 218GP RE 5-17-73(1)

CBRKPT PRINT3

# XSDRNPM INPUT - STAINLESS HYPOTHETICAL ACCIDENT

.ESS.XW15SHA

/01/87 12:21:05 (33)

```

13 WEST 15X15 ASBL, 4.0 W/O U-235, STAINLESS CLAD, H.A.
13 1SS 2 3 20 1 3 3 33 8 3 1 2R20 FO
13 2SS -2 FO
13 3SS 1 3Z 1000 2Z 1 FO
13 4SS -1 27 3 -2 E T
13 13SS 3R1 2 2R3 9R1 9R2 9R3
13 14SS 92235 92233 558016 526000 558016 551001
13 9016 1001 13027 82000 24000 26000 28000
13 592235 592238 209
13 15** 9.403-4 2.228-2 4.642-2 9.01-2 3.347-2 6.694-2 F1.-15 T
13 33** F1.0 T
13 35** 910.0 .4647 .4742 71.5360 0.891
13 36SS 10R1 2R2 8R3
13 38** 10R1.0 0.0 F1.0
13 39SS 1 2 3
13 40SS F3
13 51SS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
13 21 22 23 24 25 26 27 T.

```

NONE. TIME: 0.243 SEC. IMAGE COUNT: 19

PM.XSDRNPM

# XSDRNPM OUTPUT - STAINLESS HYPOTHETICAL ACCIDENT

3ADD,DEP STE\*STAINLESS.XW15SHA

WEST 15X15 ASBL, 4.0 W/O U-235, STAINLESS CLAD, H.A.

1S ARRAY 15 ENTRIES READ

2S ARRAY 10 ENTRIES READ

3S ARRAY 12 ENTRIES READ

4S ARRAY 9 ENTRIES READ

BT

## DIRECT ACCESS FILES ASSIGNED

7000 WORDS PER RECORD ON UNIT 3

330 WORDS PER RECORD ON UNIT 9

7000 WORDS PER RECORD ON UNIT 10

1 PHYSICAL RECORDS PER LOGICAL

10 PHYSICAL RECORDS PER LOGICAL

1 PHYSICAL RECORDS PER LOGICAL

## GENERAL PROBLEM DESCRIPTION DATA BLOCK

### GENERAL PROBLEM DATA

IGE 1/2/3 = PLANE/CYLINDER/SPHERE	2	ISN QUADRATURE ORDER
IZM NUMBER OF ZONES	3	ISCT ORDER OF SCATTERING
IM NUMBER OF SPACIAL INTERVALS	20	IEVT 0/1/2/3/4/5/6=Q/K/ALPHA
IBL 0/1/2/3 = VACUUM/REFL/PER/WHITE	1	IIM INNER ITERATION MAXIMUM
ISR RIGHT BOUNDARY CONDITION	3	ICM OUTER ITERATION MAX
MXM NUMBER OF MIXTURES	3	ICLC -1/0/N--FLAT RES/SH
MS MIXING TABLE LENGTH	33	ITH 0/1 = FORWARD/ADJOINT
IGM NUMBER OF ENERGY GROUPS	27	IFLU 0/1/2/3/4=L-S/L/S/W/L-W
VNG NUMBER OF NEUTRON GROUPS	27	IPRT -2/-1/0/N=MIXTURE XSEC
NGG NUMBER OF GAMMA GROUPS	3	ID1 0/1/2/3=NO/PRT NO/PCH N
IFTG NUMBER OF FIRST THERMAL GROUP	15	IPBT -1/0/1=NONE/FINE/ALL BAL

### SPECIAL OPTIONS

IFG 0/1 = NONE/WEIGHTING CALCULATION	1	IPN DUMMY PARAMETER
IQM VOLUMETRIC SOURCES (0/N=NO/YES)	3	IDFM 0/1 = NONE/DENSITY FACT
IPM BOUNDARY SOURCES (0/N=NO/YES)	0	IAZ 0/N = NONE/N ACTIVITIES
IFN 0/1/2 = INPUT 33*/34*/USE LAST	0	IAI 0/1=NONE/ACTIVITIES BY
ITMX MAXIMUM TIME (MINUTES)	1000	IFCT 0/1=NO/YES UPSCATTER SC
IDT1 0/1/2/3=NO/XSECT/SRCE/FLUX--OUT	3	IPVT 0/1/2=NO/K/ALPHA PARAMET

### WEIGHTING DATA (IFG=1)

ICON -1/0/1=CELL/ZONE/REGION WEIGHT	-1	IHTF TOTAL XSECT PSN IN BRD
IGMF NUMBER OF BROAD GROUPS	27	NDSF PSN G-G OR FILE NUMBER
ITP 0/1/2/3/4/5/6/7/8/9/10/11/12/13/14/15/16/17/18/19/20/21/22/23/24/25/26/27/28/29/30/31/32/33/34/35/36/37/38/39/40/41/42/43/44/45/46/47/48/49/50/51/52/53/54/55/56/57/58/59/60/61/62/63/64/65/66/67/68/69/70/71/72/73/74/75/76/77/78/79/80/81/82/83/84/85/86/87/88/89/90/91/92/93/94/95/96/97/98/99/100	0	NUSF TABLE LENGTH OR MAX ORDE
IPP -2/-1/0/N=WTGTD XSECT PRINT	-2	MSCH EXTRA 1-9 X-SECT POSITIO
IAP -1/N ANISH XSECT PRINT	-1	

### FLOATING POINT PARAMETERS

Page Added

Oct. 1990

X-G40

# XSDRNPM OUTPUT - STAINLESS HYPOTHETICAL ACCIDENT (Continued)

IF ASBL, 4.0 W/O U-235, STAINLESS CLAD, H.A.

## DATA BLOCK 2 (MIXING TABLE, ETC.)

MIXTURE	MIXING TABLE COMPONENT	ATOM DENSITY	EXTRA XSECT ID'S
1	92235	.94030-003	
1	92238	.22280-001	
1	553016	.46420-001	
2	526000	.80100-001	
3	558016	.33470-001	
3	551001	.66940-001	
1	3016	.10000-014	
1	1001	.10000-014	
1	13027	.10000-014	
1	32000	.10000-014	
1	24000	.10000-014	
1	26000	.10000-014	
1	29000	.10000-014	
1	592235	.10000-014	
1	592238	.10000-014	
2	3016	.10000-014	
2	1001	.10000-014	
2	13027	.10000-014	
2	32000	.10000-014	
2	24000	.10000-014	
2	26000	.10000-014	
2	29000	.10000-014	
2	592235	.10000-014	
2	592238	.10000-014	
3	3016	.10000-014	
3	1001	.10000-014	
3	13027	.10000-014	
3	32000	.10000-014	
3	24000	.10000-014	
3	26000	.10000-014	
3	29000	.10000-014	
3	592235	.10000-014	
3	592238	.10000-014	

# XSDRNPM OUTPUT - STAINLESS HYPOTHETICAL ACCIDENT (Continued)

OUTER	INNER	BALANCE	UPSCATTER	RATIO	EIGENVALUE	LAMBDA1
1	276	1.0000011+000	1.1732834+000		1.3066863+000	1.3500972+000
2	415	1.0000010+000	1.0060307+000		1.3530315+000	1.0035961+000
3	496	1.0000010+000	9.9542741-001		1.3567732+000	1.0002523+000
4	564	1.0000010+000	9.9875232-001		1.3556230+000	9.9994114-001
5	620	1.0000010+000	9.9987601-001		1.3553561+000	1.0000669+000
6	661	1.0000010+000	9.9998923-001		1.3553326+000	1.0000091+000
GRP.	1 REQUIRED	1 ITERATIONS.	MFD OF	1.92031-005	OCCURRED	IN INT. 20 C
GRP.	2 REQUIRED	1 ITERATIONS.	MFD OF	9.83198-006	OCCURRED	IN INT. 20 C
GRP.	3 REQUIRED	1 ITERATIONS.	MFD OF	1.40509-005	OCCURRED	IN INT. 20 C
GRP.	4 REQUIRED	1 ITERATIONS.	MFD OF	1.53691-005	OCCURRED	IN INT. 20 C
GRP.	5 REQUIRED	1 ITERATIONS.	MFD OF	1.52750-005	OCCURRED	IN INT. 20 C
GRP.	6 REQUIRED	1 ITERATIONS.	MFD OF	1.44143-005	OCCURRED	IN INT. 20 C
GRP.	7 REQUIRED	1 ITERATIONS.	MFD OF	1.52138-005	OCCURRED	IN INT. 20 C
GRP.	8 REQUIRED	1 ITERATIONS.	MFD OF	1.70943-005	OCCURRED	IN INT. 2 C
GRP.	9 REQUIRED	1 ITERATIONS.	MFD OF	2.16135-005	OCCURRED	IN INT. 1 C
GRP.	10 REQUIRED	1 ITERATIONS.	MFD OF	2.39839-005	OCCURRED	IN INT. 2 C
GRP.	11 REQUIRED	1 ITERATIONS.	MFD OF	2.51603-005	OCCURRED	IN INT. 1 C
GRP.	12 REQUIRED	1 ITERATIONS.	MFD OF	3.21919-005	OCCURRED	IN INT. 20 C
GRP.	13 REQUIRED	1 ITERATIONS.	MFD OF	3.33969-005	OCCURRED	IN INT. 20 C
GRP.	14 REQUIRED	1 ITERATIONS.	MFD OF	3.28163-005	OCCURRED	IN INT. 19 C
GRP.	15 REQUIRED	1 ITERATIONS.	MFD OF	5.17172-005	OCCURRED	IN INT. 2 C
GRP.	16 REQUIRED	1 ITERATIONS.	MFD OF	3.86018-005	OCCURRED	IN INT. 14 C
GRP.	17 REQUIRED	1 ITERATIONS.	MFD OF	3.99649-005	OCCURRED	IN INT. 14 C
GRP.	18 REQUIRED	1 ITERATIONS.	MFD OF	3.88444-005	OCCURRED	IN INT. 14 C
GRP.	19 REQUIRED	1 ITERATIONS.	MFD OF	3.28551-005	OCCURRED	IN INT. 14 C
GRP.	20 REQUIRED	1 ITERATIONS.	MFD OF	4.18073-005	OCCURRED	IN INT. 1 C
GRP.	21 REQUIRED	1 ITERATIONS.	MFD OF	4.70205-005	OCCURRED	IN INT. 13 C
GRP.	22 REQUIRED	1 ITERATIONS.	MFD OF	2.57851-005	OCCURRED	IN INT. 14 C
GRP.	23 REQUIRED	1 ITERATIONS.	MFD OF	1.37101-005	OCCURRED	IN INT. 20 C
GRP.	24 REQUIRED	1 ITERATIONS.	MFD OF	1.23396-005	OCCURRED	IN INT. 20 C
GRP.	25 REQUIRED	1 ITERATIONS.	MFD OF	5.54742-006	OCCURRED	IN INT. 2 C
GRP.	26 REQUIRED	1 ITERATIONS.	MFD OF	1.64554-006	OCCURRED	IN INT. 1 C
GRP.	27 REQUIRED	1 ITERATIONS.	MFD OF	1.40885-006	OCCURRED	IN INT. 13 C
	623	1.0000010+000	9.9999553-001		1.3553297+000	9.9999910-001
	FINAL MINITOR		LAMBDA	1.3553076+000		ANGULAR FLUX ON
	ELAPSED TIME	2.6722332 MIN.				



# KENO INPUT - STAINLESS HYPOTHETICAL ACCIDENT

ESS.KW15SHA

01/87 12:27:00 (60)

```

50 ONE PWR ASSEMBLY, 4.0 W/O U-235, H.A., STAINLESS CLAD
50 200. 50 405 6 27 27 14 6 14 10 1 1 1 1 -14 1 0 2000 0 1 82
50 0 0 0 3R-1
50 1 -92235 2.548-4 1 92238 6.037-3
50 1 526000 4.003-3 1 551001 4.440-2 1 558016 3.478-2
50 2 3016 3.347-2 2 1001 6.694-2
50 3 24000 1.839-2 3 28000 1.815-3 3 26000 5.994-2
50 4 13027 6.026-2
50 5 32000 3.299-2
50 6 592238 4.773-2 6 -592235 1.052-4
50 BOX TYPE 1
50 CUBOID 1 11.271 -11.271 11.271 0.000 1000. -1000. 27*0.5
50 CORE BDY 0 11.271 -11.271 11.271 0.00 1000. -1000. 27*0.5
50 ZHEMICYL+Y 2 19.509 1000. -1000. 27*0.5
50 ZHEMICYL+Y 3 19.600 1000. -1000. 27*0.5
50 ZHEMICYL+Y 6 25.309 1000. -1000. 27*0.5
50 ZHEMICYL+Y 5 30.706 1000. -1000. 27*0.5
50 ZHEMICYL+Y 3 32.93 1000. -1000. 27*0.5
50 ZHEMICYL+Y 2 45.629 1000. -1000. 27*0.5
50 ZHEMICYL+Y 3 46.264 1000. -1000. 27*0.5
50 CUBOID 2 63. -63. 63. 0.00 1000. -1000. 27*0.5
50 1 1 1 1 1 1 1 1 1 1
50 END KENO.

```

NONE. TIME: 0.293 SEC. IMAGE COUNT: 23

CONTROL MODE

ERKENO.SUPERKENO

# KENO OUTPUT - STAINLESS HYPOTHETICAL ACCIDENT

ONE PWR ASSEMBLY, 4.0 W/O U-235, H.A., STAINLESS CLAD

NUMBER OF GENERATIONS	50	START TYPE
NUMBER PER GENERATION	405	GENERATIONS
NUMBER OF GENERATIONS TO BE SKIPPED	6	LIST INPUT
NUMBER OF ENERGY GROUPS	27	LIST 1-D MI
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2-D MI
NUMBER OF INPUT NUCLIDES	14	LIST FISS.
NUMBER OF MIXTURES	6	USE X-SECTION
NUMBER OF MIXING TABLE ENTRIES	14	USE GEOMETRY
NUMBER OF GEOMETRY CARDS	10	USE VELOCITY
NUMBER OF BOX TYPES	1	COMPUTE MATH
NUMBER OF UNITS IN X DIRECTION	1	COMPUTE MATH
NUMBER OF UNITS IN Y DIRECTION	1	LIST FISS.
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALC
NUMBER OF NUCLIDES READ FROM TAPE	-14	USE EXPONENTIAL
ALBEDO TYPE	1	CALCULATE FLUX
SEARCH TYPE	3	CALCULATE FI

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE +X = .00000 -X = .00000 +Y = .00000 -Y = 1.00000

MAXIMUM TIME = 200.0000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 13712  
REMAINING AVAILABLE LOCATIONS = 381037

# KENO OUTPUT - STAINLESS HYPOTHETICAL ACCIDENT (Continued)

ONE PWR ASSEMBLY, 4.0 W/O U-235, H.A., STAINLESS CLAD

MIXTURE	NUCLIDE	DENSITY
1	-92235	2.54800-004
1	92238	6.03700-003
1	226000	4.00300-003
1	551001	4.44000-002
1	558016	3.47800-002
2	3016	3.34700-002
2	1001	6.69400-002
2	24000	1.83900-002
3	23000	1.81500-003
3	26000	5.99400-002
4	13027	6.02600-002
5	82000	3.29900-002
6	592238	4.77300-002
6	-592235	1.05200-004

## CROSS SECTIONS READ FROM TAPE

NUCLIDE =	1001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	551001	H 1269 F, 1002 T 218 GP 032475(2)
NUCLIDE =	3016	O-16 1276 218 GP 030476(7)
NUCLIDE =	558016	O-16 1276 218 GP 030476(7)
NUCLIDE =	13027	AL-27 1193 218 GP 040375(5)
NUCLIDE =	24000	CR 1191 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	26000	FE 213GP RE 5-17-73(1)
NUCLIDE =	226000	FE 213GP RE 5-17-73(1)
NUCLIDE =	22000	NI 1190 218NGP WT 1/E P-3 293K SIGP=5+4 RE(042375)
NUCLIDE =	32000	PB 1239 218NGP 042375 P-3 293K
NUCLIDE =	92235	U-235 1261 SIGP=5+4 NEWLACS 218NGP P-3 293K(3)
NUCLIDE =	592235	U-235 1261 SIGP=5+4 NEWLACS 218NGP P-3 293K(3)
NUCLIDE =	92238	U-238 213GP RE 5-17-73(1)
NUCLIDE =	592238	U-238 213GP RE 5-17-73(1)

# KENO OUTPUT - STAINLESS HYPOTHETICAL ACCIDENT (Continued)

ONE PWR ASSEMBLY, 4.0 W/O U-235, H.A., STAINLESS CLAD

LIFETIME = 1.13940-004 + OR - 1.26732-006

GENERATION TIME = 5.2623

NO. OF INITIAL  
GENERATIONS  
SKIPPED

AVERAGE  
K-EFFECTIVE

DEVIATION

57 PER CENT  
CONFIDENCE INTERVAL

75 PER  
CONFIDENCE

5	.93540 + OR - .00477	.93364 TO .94017	.92587 TO
7	.93461 + OR - .00481	.92980 TO .93942	.92499 TO
9	.93512 + OR - .00490	.93022 TO .94001	.92532 TO
11	.93505 + OR - .00502	.93003 TO .94007	.92501 TO
13	.93462 + OR - .00513	.92950 TO .93975	.92437 TO
15	.93586 + OR - .00510	.93076 TO .94097	.92565 TO
17	.93682 + OR - .00515	.93167 TO .94196	.92652 TO
19	.93625 + OR - .00526	.93099 TO .94151	.92573 TO
21	.93439 + OR - .00522	.92967 TO .94011	.92444 TO
23	.93255 + OR - .00431	.92775 TO .93736	.92294 TO
25	.93275 + OR - .00541	.92734 TO .93815	.92193 TO
27	.93006 + OR - .00603	.92403 TO .93609	.91801 TO
29	.92469 + OR - .00666	.91803 TO .93135	.91137 TO
31	.92123 + OR - .00716	.91412 TO .92845	.90696 TO
33	.92082 + OR - .01015	.91067 TO .92007	.90052 TO
35	.93476 + OR - .01254	.92221 TO .94730	.90067 TO

*Section XI*

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**SECTION XI**  
**STRUCTURAL ANALYSIS**

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STRUCTURAL  
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Revised  
Oct. 1990



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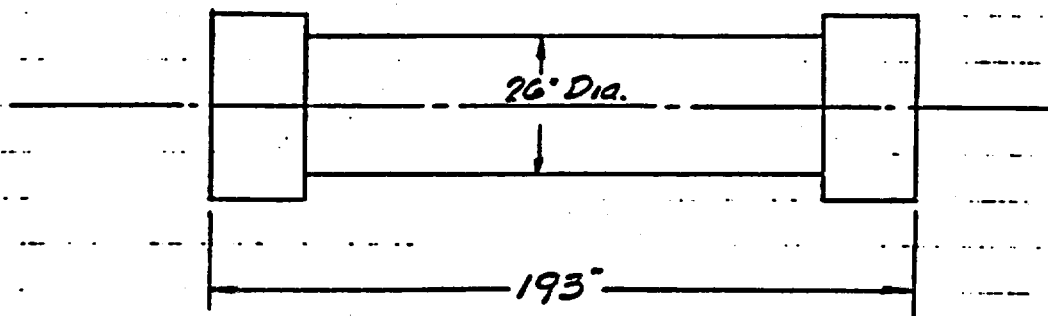
## SECTION XI

### STRUCTURAL ANALYSIS.

The structural analysis for the NLI 1/2 shipping cask is presented in two parts. Part 1.0 analyzes the structural integrity of the shipping cask under normal conditions of shipment as delineated by 10 CFR 71. Part 2.0 of this section analyzes the structural integrity of the shipping cask under the hypothetical accident conditions as delineated by 10 CFR 71, Appendix "B".

#### 1.0 NORMAL CONDITIONS of TRANSPORT

##### 1.1 CASK AS A SIMPLE BEAM 10 CFR 71.32(a)



Design weight	48000 #
Thickness of outer shell	0.875"
Loading requirement	5g
Outer shell material	Stainless Steel Type 316
Yield strength	55000 psi

$$\text{Outer shell section modulus} = \frac{\pi}{32} \frac{26^4 - 24.25^4}{26} =$$
$$Z = \underline{419.71 \text{ in}^3}$$

For a uniformly distributed load, the maximum bending moment occurs at the center and equals:

$$M_{max} = \frac{48000 \times 5 \times 193}{8} = 5,790,000 \text{ in-lb.}$$

Maximum bending stress in outer shell equals

$$\sigma = \frac{M_{max}}{Z} = \frac{5,790,000}{419.71} = 13,795 \text{ psi}$$

$$M.S. = \frac{55000}{13795} - 1 = 2.987$$

The requirement of 10 CFR 71.32(a), that the yield strength of the cask shall not be exceeded under a distributed load equal to 5 times its fully loaded weight is satisfied.

## 1.2 EXTERNAL PRESSURE 10 CFR 71.32(b)

Requirement: The containment vessel will suffer no loss of contents if subjected to an external pressure of 25 psig.

The removable inner container is the containment vessel. No credit is taken for the support of the containment shell provided by the fuel basket. Since there is a significant external pressure on the outer shell due to the operating pressure of the water jacket, the outer shell is also checked for adequacy under external pressure.

## Containment vessel (Inner Container)

Formulas taken from Ref. 1 Table XIII, Case 1 Shell material - SA-351, CF8M or SA-240, Type 304, or A-358, Class 1

Minimum yield point is 30000 psi for both materials.

$$p' = \frac{t}{R} \left( \frac{S_y}{1 + 4 \frac{S_y}{E} \left( \frac{R}{t} \right)^2} \right)$$

$$t = 0.25''$$

$$R = 6.44''$$

$$S_y = 30000 \text{ psi}$$

$$E = 29 \times 10^6 \text{ psi}$$

$$p' = \frac{0.25}{6.44} \left( \frac{30000}{1 + 4 \frac{30000}{29 \times 10^6} \left( \frac{6.44}{0.25} \right)^2} \right)$$

$$p' = \underline{311.73 \text{ psi}}$$

Containment shell is more than adequate to withstand 25 psig external pressure.

### Outer Shell

Shell material - Allegheny Ludlum Steel Corp.  
Type 216 Stainless Steel.

$$t = 0.875''$$

$$R = 12.563''$$

$$S_y = 55000 \text{ psi}$$

$$E = 29 \times 10^6 \text{ psi}$$

$$p' = \frac{0.875}{12.563} \left( \frac{55000}{1 + 4 \frac{55000}{29 \times 10^6} \left( \frac{12.563}{0.875} \right)^2} \right)$$

$P' = 1493.6 \text{ psi}$

Outer shell is more than adequate to withstand the water jacket design pressure of 185 psig

### 1.3 PRESSURE VESSEL DESIGN - CASE Cavity

See page X1-B2 & B3

$$P = \frac{0.50 \times 16500}{6.94} = 1188.8 \text{ psi} > 22.5 \text{ psi}$$

$$P = \frac{R}{t + G_y}$$

$t = 0.50$   
 $G_y = 16500 \text{ psi Ref. 4}$   
 $R = 6.94$

Ref. 1, Table XIII, Case 1

This compares to an allowable shell pressure based on the yield strength of the material at 850°F as follows:

or 22.5 psig Design Pressure

$$P_2 = \frac{P_1 t_2}{t_1} = \frac{15 \times 1310^\circ R}{528^\circ R} = 37.216 \text{ psia.}$$

Design Pressure - Maximum inner container temperature, which occurs during the post fire accident condition, is calculated to be 799°F. To provide an additional margin of safety the design temperature is set at 850°F. The design pressure for the cask cavity is based on the gas pressure developed as a result of the temperature rise from 68°F to the design temperature of 850°F, assuming the gas temperature to be the same as the hot metal temperature. Maximum internal pressure under the fire accident condition would be:

### 1.3.1 EXTERNAL PRESSURE - INNER CONTAINER @ 850°F

Ref. 1, Table XIII, Case 1

$$P' = \frac{t}{R} \left( 1 + 4 \frac{S_y}{R} \left( \frac{t}{R} \right)^2 \right)$$

$t = 0.25$   
 $R = 6.44$   
 $S_y = 16,500$  Ref. 2  
 $E = 23.7 \times 10^6$  Ref. 2

$$P' = \frac{0.25}{16,500} \left( 1 + 4 \frac{16,500}{23.7 \times 10^6} \left( \frac{0.25}{6.44} \right)^2 \right)$$

$$P' = 224.8 \text{ PSI} > 22.5 \text{ PSI}$$

### 1.3.2 BOTTOM HEAD - CASK CAVITY

Formula from Ref. 2

$$T = d \sqrt{\frac{S}{CP}} ; \quad P = \frac{T^2 S}{d^2 C}$$

$T = 1.225$   
 $d = 13.375$   
 $S = 16,500 \text{ PSI}$   
 $C = 0.3$

$$P = \frac{(1.225)^2 16,500}{(13.375)^2 0.3}$$

$$= 461 \text{ PSI} > 22.5 \text{ PSI}$$

### 1.3.3 OUTER CLOSURE HEAD

See page XI-B4

### 1.3.4 OUTER CLOSURE HEAD BOLTS

See page XI-B4



XI-1-8

### 1.3.5 WATER JACKET

The bulk water temperature is calculated to be 331°F. For design purposes use 335°F. The saturation pressure at this temperature is 110 psia. The expansion tank is designed for an operating pressure of 200 psia (185 psig) to accommodate the decrease in volume of the air trapped in the tanks. The design conditions for the neutron water shield system are:

Design metal temperature 400°F  
 Design pressure 250 psig  
 Operating pressure 185 psig  
 Relief valve setting 200 psig

Hoop stress in jacket shell, Ref. I, Table XII, Case 1  
 Shell material - Allegheny Ludlum Steel Corp  
 Type 216 stainless steel. Yield strength at temperature is 45900 psi. Allowable stress value based Ref. 2  
 $1545900 \times 0.666 = 30570 \text{ psi}$

$$\sigma_r = \frac{pr}{t}$$

$$p = 250 \text{ psi}$$

$$R = 18.125$$

$$t = 0.25$$

$$\sigma_r = \frac{(250)(18.125)}{0.25} = 18125 \text{ psi} < \sigma_{all} = 30570 \text{ psi}$$

## 1.4 WATER JACKET EXPANSION TANK.

The water jacket expansion Tank is arranged as a separate Tank, surrounding the upper part of the water Jacket. This arrangement allows a solid water shield to be present around the cask body at all times as the jacket always stays filled, transferring water through a submerged siphon tube as needed. The expansion Tank capacity is sufficient to allow complete refill of the jacket at  $-40^{\circ}\text{F}$  and still maintain the siphon submergence level in any attitude of handling and transport.

The solution used is Ethylene Glycol, 54% by weight.

<u>SGR</u>	<u>LBS/FT<sup>3</sup></u>	<u>AT</u>
.953	59.467	$335^{\circ}\text{F}$
1.070	66.768	$68^{\circ}\text{F}$
1.097	68.453	$-40^{\circ}\text{F}$

As stated in section 1.3.5, the bulk water design temperature is  $335^{\circ}\text{F}$  and for purposes of structural design the design pressure is 250 psig at  $900^{\circ}\text{F}$

### 1.4.1 WATER EXPANSION

#### JACKET VOLUME.

$$\begin{aligned} V_J &= \pi(18^2 - 13^2)145.75'' + \pi(17.875^2 - 13.437^2)10.5'' \\ &\quad + \pi(18^2 - 13.437^2)2.5'' + \pi(18^2 - 13.218^2)4'' \\ &= \underline{77558 \text{ IN}^3} \\ &= \underline{45.46 \text{ FT}^3} \end{aligned}$$

# EXPANSION TANK VOLUME

$$\begin{aligned} \text{SECTION AREA AT TOP} &= \frac{1}{4}(46.375^2 - 36.75^2) = 628.38 \text{ in}^2 \\ \text{SECTION AREA AT BOTTOM} &= \frac{1}{4}(46.375^2 - 36.5^2) = 642.76 \text{ in}^2 \\ \text{TOTAL VOLUME} &= (628.38)(1.5) + (642.76)(20.0) \\ V_T &= 943.0 + 12855 = 13798 \text{ in}^3 \end{aligned}$$

The expansion tank contains a minimum to cover the siphon tube, plus the overflow from the jacket, and cushioning fill air, all varying in temperature and pressure.

Reserve volume to cover siphon tube end -  $\frac{3}{4}$ " min. height vertical.

$$\begin{aligned} \text{WEIGHT OF SOLUTION IN JACKET AT } -40^\circ\text{F} \\ W_1 &= 45.46 \text{ ft}^3 (68.453) = 3112 \text{ lbs} \end{aligned}$$

$$\begin{aligned} \text{WEIGHT OF SOLUTION PASSED FROM JACKET TO TANK AT } 68^\circ\text{F} \\ W_2 &= 3112 - 45.46 (66.768) = 3112 - 3035.27 \\ &= 76.73 \text{ lbs} \\ V_{02} &= 76.73 / 66.768 = 1.149 \text{ ft}^3 = 1986 \text{ in}^3 \end{aligned}$$

$$\begin{aligned} \text{WEIGHT OF SOLUTION PASSED AT } 335^\circ\text{F} \\ W_3 &= 3112 - 45.46 (59.467) = 3112 - 2703.3 \\ &= 408.7 \text{ lbs} \\ V_{03} &= 408.7 / 59.467 = 6.873 \text{ ft}^3 = 11,877 \text{ in}^3 \end{aligned}$$

$$\begin{aligned} \text{AT } 68^\circ \text{ THE TOTAL VOLUME OF TANK FILLED WITH SOLUTION IS} \\ V_{04} &= V_{02} + V_R = 1986 + 482 = 2468 \text{ in}^3 \end{aligned}$$

$$\begin{aligned} \text{THE NET VOLUME FILLED WITH AIR (AT } 14.7 \text{ PSIA) IS} \\ V_{05} &= V_T - V_{04} = 13798 - 2468 = 11,330 \text{ in}^3 \end{aligned}$$

$$\begin{aligned} \text{AT } 335^\circ \text{ THE NET VOLUME FILLED WITH AIR IS} \\ V_{06} &= V_T - V_{03} - V_R = 13798 - 11877 - 482 \\ &= 1439 \text{ in}^3 \end{aligned}$$

## 1.4.2 TANK WATER FILL AND AIR PRESSURE.

The height of the standpipe to limit the filling of the tank at 68°F is

$$h = \frac{\text{Vol}_4}{\text{Vol}_5} = \frac{2468}{642.76} = 3.84" \quad \text{USE } 3\frac{7}{8}"$$

After filling the jacket completely and the tank to  $h = 3\frac{7}{8}"$  at 68°F, the remaining volume (vs) in the tank is occupied by air at 14.7 psia and 68°F (528°R)

Upon a temperature rise to 335°F (795°R), the air is compressed to a pressure of

$$P_{335} = (14.7) \left( \frac{\text{Vol}_5}{\text{Vol}_6} \right) \left( \frac{795^\circ\text{R}}{528^\circ\text{R}} \right) = 14.7 \left( \frac{11330}{1439} \right) \left( \frac{795}{528} \right)$$

$$= 174.3 \text{ psia} = 159.6 \text{ psig}$$

## 1.4.3 PRESSURE VESSEL CALCULATIONS

EXPANSION TANK SHELL. A-240, Type 304 S.S.

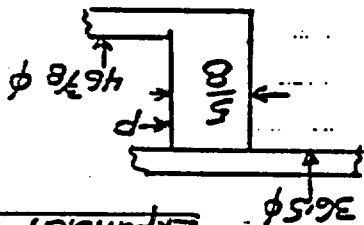
From Ref 2, allowable stress at 400°F is 18,700 psi

Required shell thickness

$$t = \frac{P \cdot R}{S - 0.5P} = \frac{250(23.188)}{18700 - 0.5(250)} = .312" \quad \text{OK } \frac{3}{8}" \text{ actual thickness}$$

EXPANSION TANK END PLATE A-240, Type 304 S.S.

MARK II - CASE 16 - SUPPORTED EDGES.



$$\max. S_n = \frac{3W a^2}{\pi^2} = \frac{0.034(250)(23.188)^2}{\pi^2} = 18700$$

$$W = 250 \text{ psi}$$

$$a = 23.188$$

$$\frac{W}{a} = 1.27$$

$$\frac{W}{a} = 0.034$$

$$t^2 = .24438 \quad t = .494" \quad \text{OK } \frac{5}{8}" \text{ used.}$$

# 1.4.4 PENETRATION - JACKET AND TANK -

(10 CFR 71 - APPENDIX A)

Impact is from a 1 1/4" dia. steel bar, weighing 13 lbs, and dropped from a height of 40 inches upon the exposed surface of the jacket or tank at the most vulnerable point.

$$K.E. \text{ of impact} = (13 \text{ lbs}) (40 \text{ in}) = 520 \text{ in. lbs}$$

Any deformation before shearing would absorb part of this energy. Therefore, the energy required to shear out a 1 1/4 dia. plug under pure shear would be the minimum required to penetrate

JACKET - 1/4" x - 21655 - 55000 psi y.p

$$U_{REQD.} = K T (\pi D) x^2$$

$$= 5263 \text{ in. lbs}$$

$$OK. > 520 \text{ in. lbs}$$

$$T = .6 (55000) = 33000 \text{ psi}$$

Ref 7 - pg 13-15

To fracture, SS

$$K = .39 = \text{penetration}$$

$$x = .25 \text{ "}$$

TANK - 5/16" x - 30455 - 30000 psi y.p

$$U_{REQD.} = K T (\pi D) x^2$$

$$= .39 (18000) \pi (1 1/4) (.3175)^2$$

$$= 2692 \text{ in. lbs}$$

$$OK > 520 \text{ in. lbs}$$

Since the energy required to shear out a 1 1/4 in. dia. plug is considerably greater than that produced by the impacting bar, penetration is prevented in both shells.

XI-1-11a

#### 1.4.5. PENETRATION - RELIEF VALVE GUARD

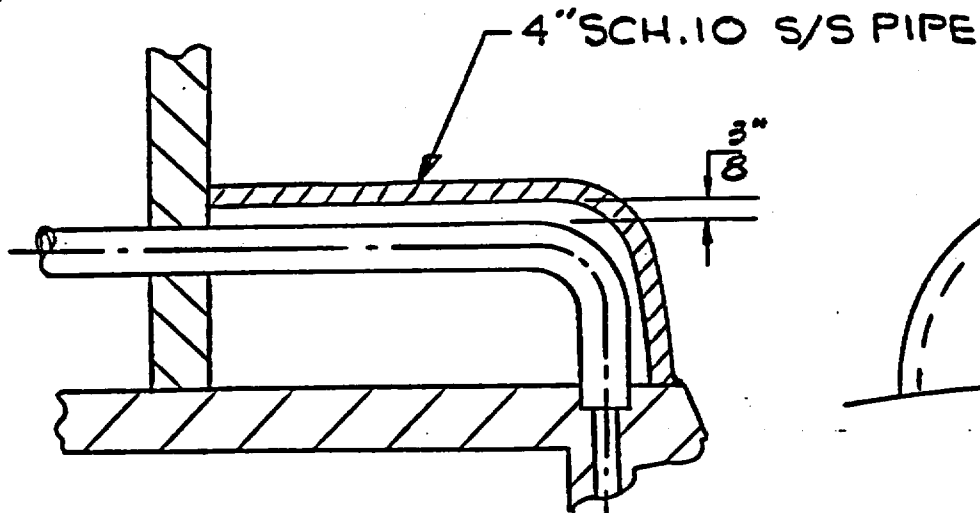
FIGURE WITHHELD UNDER 10 CFR 2.390

#### 1.4.6. PENETRATION - EXPANSION TANK DRAIN VALVE GUARD

Assume entire energy is absorbed in deforming a 1" w strip along the free edge on one side. It is conservative to assume the length between points of inflection of this strip, which is fixed at one end to the cask and continuous over a support at the end away from the cask, is  $4.5 - .25 - .25 = 4$  in.

FIGURE WITHHELD UNDER 10 CFR 2.390

### 1.4.7 PENETRATION - VENT LINE GUARD



This construction allows calculation as a cylinder with closed ends and end supports, with a center load  $P$  concentrated over a very short length.

Roark Table XIII - case 9

$$\text{For } S_2, \quad P = \frac{S_{yp} b^{3/2} t^{5/4}}{.130 A^{1/8} R^{3/4}} \quad \text{where}$$

$b = .625$  rad. pin,  $t = .120$  wall thickness of 4" SCH. 10  
 $A = 10.92$  constant,  $R = 2.19$  rad. pipe

$$S_{yp} = 30000 \text{ psi}$$

$$P = \frac{30000 (1.39) (.120) (.589)}{.130 (1.348) (1.8)}$$

$$P = 9444 \text{ lbs going plastic}$$

$$\text{K.E. of drop} = 13 \text{ lbs.} \times 40 \text{ in.} = 520 \text{ in lbs}$$

$$\text{Penetration} = \frac{KE}{P} = \frac{520}{9440} = .055 \text{ in. plastic deformation only, beyond elastic deflection.}$$

A plastic deformation of .25 inches could be tolerated without damage to the vent line.



## 1.5 DIFFERENTIAL THERMAL EXPANSIONS

Check of thermal strain of the various elements in the cask structure to assure objectionable stresses are not generated in the structure.

FIGURE WITHHELD UNDER 10 CFR 2.390

# TEMPERATURE DISTRIBUTION FOR VARIOUS CONDITIONS (°F)

LOCATION	Initial Steady State	0.5 hour hypothetical fire accident & post fire accident conditions						
		0.5 hr.	0.75 hr.	1 hr.	1.5 hr.	2 hr.	3 hr.	4 hr.
Aluminum Basket	661	670	691	716	757	783	807	813*
Inner Container	645	658	682	707	746	772	793	798*
Inner Shell	440	538	610	638	660	664*	656	648
Uranium Shell	373	582	617	623	627*	617	594	580
Lead	356	641*	621	621	621	605	581	---
Outer Shell	352	702*	621	617	611	596	572	558
Water Jacket Shell	340							

61-1-13

## COEFFICIENTS OF THERMAL EXPANSION

$$\alpha_{\text{Uranium}} = 17.39 \times 10^{-6} \text{ in/in/}^{\circ}\text{C}, \quad 0^{\circ} - 400^{\circ}\text{C}$$

$$\alpha_{\text{Uranium}} = 9.661 \times 10^{-6} \text{ in/in/}^{\circ}\text{F}$$

$$\alpha_{\text{304 S/S}} = 9.9 \times 10^{-6} \text{ in/in/}^{\circ}\text{F}, \quad 68^{\circ} - 1000^{\circ}\text{F}$$

### 1.5.1 AXIAL EXPANSION - INNER CONTAINER / INNER SHELL

Largest temperature gradient occurs at initial steady state conditions.

$$\text{Inner Container } 645^{\circ}\text{F} \quad \Delta T = 645^{\circ} - 68^{\circ} = 577^{\circ}\text{F}$$

$$\epsilon_T = 9.9 \times 10^{-6} \times 577 \times 174.75 = \underline{.998}$$

$$\text{Length of inner container at temperature } 174.75 + .998 = \underline{175.748''}$$

$$\text{Inner Shell } 440^{\circ}\text{F} \quad \Delta T = 440^{\circ} - 68^{\circ} = 372^{\circ}\text{F}$$

$$\epsilon_T = 9.9 \times 10^{-6} \times 372 \times 176.25 = \underline{0.649''}$$

$$\text{Length of inner shell at temperature } 176.25 + 0.649 = \underline{176.899''}$$

No axial interference between inner container and inner shell

### 1.5.2 AXIAL EXPANSION - INNER SHELL / URANIUM SHIELD

Largest temperature gradient occurs at initial steady state conditions.

Inner Shell  $440^{\circ}\text{F}$   $\Delta T = 440 - 68 = 372^{\circ}\text{F}$

$$\epsilon_T = 9.9 \times 10^{-6} \times 372 \times 169.375 = \underline{0.624}$$

Length of inner shell at temperature  
 $169.375 + 0.624 = \underline{169.999}$

Uranium Shield  $373^{\circ}\text{F}$   $\Delta T = 373 - 68 = 305^{\circ}\text{F}$

$$\epsilon_T = 9.661 \times 10^{-6} \times 305 \times 169.625 = \underline{0.4998}$$

Length of uranium shield at temperature  
 $169.625 + 0.4998 = \underline{170.1248}$

No axial interference between inner shell  
and uranium shield.

### 1.5.3 AXIAL EXPANSION - URANIUM SHIELD / OUTER SHELL

Largest temperature gradient occurs 3.5 hours  
after the 0.5 hour fire terminates.

Uranium Shield  $580^{\circ}\text{F}$   $\Delta T = 580 - 68 = 512^{\circ}\text{F}$

$$\epsilon_T = 9.661 \times 10^{-6} \times 512 \times 172.750 = \underline{0.856}$$

Length of uranium shield at temperature  
 $172.75 + 0.856 = \underline{173.606}$

Outer Shell  $558^{\circ}\text{F}$   $\Delta T = 558 - 68 = 490^{\circ}\text{F}$

$$\epsilon_T = 9.9 \times 10^{-6} \times 490 \times 172.781 = \underline{0.838}$$

Length of outer shell at temperature  
 $172.781 + 0.838 = \underline{173.619}$

No axial interference between uranium shield  
and outer shell.

### 1.5.3.1. AXIAL EXPANSION URANIUM SHIELD / WATER JACKET

The condition which results in the largest temperature gradient, the uranium being the higher of the two, occurs at initial steady state conditions.

$$\text{Uranium Shield } 373^{\circ}\text{F} \quad \Delta T = 373 - 68 = 305^{\circ}\text{F}$$
$$\epsilon_T = 9.661 \times 10^{-6} \times 305 \times 172.75 = \underline{0.509}$$

$$\text{Length of uranium shield at temperature}$$
$$172.75 + 0.509 = \underline{173.259}$$

$$\text{Jacket Shell } 340^{\circ}\text{F} \quad \Delta T = 340 - 68 = 272^{\circ}\text{F}$$
$$\epsilon_T = 9.9 \times 10^{-6} \times 272 \times 172.781 = \underline{0.4653}$$

$$\text{Length of jacket shell at temperature}$$
$$172.781 + 0.4653 = \underline{173.2463}$$

No axial interference between uranium shield and the stainless steel walls.

### 1.5.3.2 AXIAL EXPANSION OUTER SHELL / JACKET SHELL

The temperature gradient of concern is that which occurs at initial steady state condition.

$$\text{Outer shell } 352^{\circ}\text{F} \quad \Delta T = 352 - 68 = 284^{\circ}\text{F}$$
$$\epsilon_T = 9.9 \times 10^{-6} \times 284 \times 164.25 = \underline{0.462}$$

$$\text{Jacket shell } 340^{\circ}\text{F} \quad \Delta T = 340 - 68 = 272^{\circ}\text{F}$$
$$\epsilon_T = 9.9 \times 10^{-6} \times 272 \times 164.25 = \underline{0.442}$$

## SHELL LOADINGS

Outer shell - Area =  $69 \text{ in}^2$ ,  $E = 26.8 \times 10^6$

$$P_o = \frac{(.462 - d) 69 (26.8 \times 10^6)}{164.25}$$

Jacket shell - Area =  $28.47 \text{ in}^2$   $E = 26.8 \times 10^6$

$$P_j = \frac{(d - .442) 28.47 (26.8 \times 10^6)}{164.25}$$

Now  $P_o = P_j$  solving for  $d$ ,

$$31.878 - 69d = 28.47d - 12.584$$

$$97.47d = 44.462$$

$$d = .45616$$

$$P_o = \frac{(.462 - .45616) 69 (26.8 \times 10^6)}{164.25} = \underline{65,749 \text{ lbs}}$$

$$S_c = \frac{65749}{69} = \underline{953 \text{ psi}}$$

$$P_j = \frac{(.45616 - .442) 28.47 (26.8 \times 10^6)}{164.25} = \underline{65,777 \text{ lbs}}$$

$$S_t = \frac{65777}{28.47} = \underline{2310 \text{ psi}} < S_y = 45900 \text{ psi}$$

Outer shell in compression and jacket shell in tension. Shell stresses are well below the material yield point stress

### 1.5.3.3. Axial Expansion Outer Shell/Jacket Shell

The condition which results in the largest temperature gradient during the hypothetical fire accident case occurs 0.5 hrs. after the start of the fire.

$$\text{Outer Shell } 702^{\circ}\text{F} \quad \Delta T = 702 - 68 = 634^{\circ}\text{F} \\ \epsilon_T = 10.3 \times 10^{-6} \times 634^{\circ}\text{F} \times 164.25 = 1.0726$$

$$\text{Outer Shell area} = 69 \text{ in}^2 \quad \epsilon = 24.9 \times 10^{-6} \\ \delta_o = \frac{(d - 1.0726) 69 (24.9 \times 10^{-6})}{164.25}$$

$$= (10.46027 d - 11.21969) 10^{-6}$$

$$\text{Jacket Shell } 1280^{\circ}\text{F} \quad \Delta T = 1280 - 68 = 1212^{\circ}\text{F} \\ \epsilon_T = 10.3 \times 10^{-6} \times 1212^{\circ}\text{F} \times 164.25 = 2.05043$$

$$\text{Jacket Shell area } 28.47 \quad \epsilon = 22.4 \times 10^{-6} \\ \delta_j = \frac{(2.05043 - d) 28.47 (22.4 \times 10^{-6})}{164.25}$$

$$= (7.9610 - 3.8826 d) 10^{-6}$$

Now  $\delta_o = \delta_j$  solving for d

$$10.46027 d - 11.21969 = 7.9610 - 3.8826 d \\ 14.34287 d = 19.18069 \\ d = 1.3373$$

$$\delta_o = [10.46027 (1.3373) - 11.21969] 10^{-6} = 2.768,820 \text{ lbs.}$$

### Outer Shell Stress

$$S_t = \frac{2,768,820}{69} = \underline{40128 \text{ psi Tension}} < S_y = 40900 \text{ psi}$$

### Jacket Shell Stress

$$S_c = \frac{2,768,820}{28.47} = \underline{97,254 \text{ psi Compression}}$$

Plastic yielding of the jacket shell under accident conditions is acceptable. There is no breach of the outer shell and containment of the lead shield is assured. A breach of the water jacket would be of no consequence since containment of water is not a requirement for shielding adequacy. The water jacket, however, would only suffer some permanent compression and possible slight buckling.



#### 1.5.4 RADIAL EXPANSION ALUMINUM BASKET / INNER CONTAINER

Largest temperature gradient occurs at initial steady state conditions.

Aluminum Basket  $661^{\circ}\text{F}$   $\Delta T = 661 - 68 = 593^{\circ}\text{F}$

$$* L_1 = L_0 [1 + \alpha (12.19 + 0.003115 t^2) 10^{-6}]$$

\* Reference Alcoa Aluminum Handbook

$L_1$  = length at temperature

$L_0$  = length at  $68^{\circ}\text{F}$

$\alpha$  = Alloy constant (from table)  
 $t = 593^{\circ}\text{F}$

$$L_1 = 12.550 [1 + 0.990 (12.19 \times 593 + 0.003115 \times 593^2) 10^{-6}]$$

$$L_1 = \underline{12.653}$$

Inner Container  $645^{\circ}\text{F}$   $\Delta T = 645 - 68 = 577^{\circ}\text{F}$

$$\epsilon_f = 9.9 \times 10^{-6} \times 577 \times 12.625 = 0.0721$$

I.D. of inner container at temperature  
 $12.625 + 0.0721 = \underline{12.697}$

No radial interference between aluminum basket and inner container

### 1.5.5 Radial Expansion - INNER CONTAINER/INNER SHELL

Largest temperature gradient occurs at initial steady state conditions

Inner Container 645°F  $\Delta T = 645 - 68 = 577^\circ\text{F}$

$$\epsilon_T = 9.9 \times 10^{-6} \times 577 \times 13.145 = 0.0751$$

O.D. of inner container at temperature  $13.145 + 0.0751 = 13.220$

Inner Shell 440°F  $\Delta T = 440 - 68 = 372^\circ\text{F}$

$$\epsilon_T = 9.9 \times 10^{-6} \times 372 \times 13.375 = 0.049$$

I.D. of inner shell at temperature  $13.375 + 0.049 = 13.424$

No radial interference between inner container and inner shell.

### 1.5.6 Radial Expansion - INNER SHELL/DEMIUM SHIELD

Largest temperature gradient occurs at initial steady state conditions

Inner Shell 440°F  $\Delta T = 440 - 68 = 372^\circ\text{F}$

$$\epsilon_T = 9.9 \times 10^{-6} \times 372 \times 14.400 = 0.053$$

O.D. of inner shell at temperature  $14.400 + 0.053 = 14.453$

Uranium Shield  $373^{\circ}\text{F}$   $\Delta T = 373 - 68 = 305^{\circ}\text{F}$

$$E_f = 9.661 \times 10^{-6} \times 305 \times 14.453 = 0.0426$$

I.D. of uranium shield at temperature  
 $14.453 + 0.0426 = 14.4956$

No radial interference between inner shell  
and uranium shield.

# 1.5.7 Radial Expansion Uranium Shield/Lead/Outer Shell

<u>Data</u>	<u>Uranium</u>	<u>Lead</u>	<u>Outer S-S</u>	<u>Neutron Shield</u>	<u>Water Jacket Shell</u>
Inner Radius , in.	7.25	10.00	12.125	13.00	18.00
Outer Radius , in.	10.00	12.125	13.00	18.00	18.25
Common Effective length, in.	161.38	161.38	161.38	161.38	161.38
Steady State Operating Temp. °F	373	356	352	346	340
Pressure On:					
Inner Radius, psi	0	$P_a$	$P_c$	80.96	80.96
Outer Radius, psi	$P_a$	$P_c$	80.96	80.96	0
Material Properties at Temperature					
Coeff. of Linear					
Expansion, in./in./°F	$9.661 \times 10^{-6}$	$16.3 \times 10^{-6}$	$9.9 \times 10^{-6}$	-	$9.9 \times 10^{-6}$
Elastic Modulus, psi	$24.0 \times 10^6$	$1.95 \times 10^6$	$26.8 \times 10^6$	-	$26.8 \times 10^6$
Yield Stress, psi	27,000	711	45,900	-	45,900
Poissons Ratio	0.2	0.45	0.3	-	0.3

### Procedure of Analysis

To study the behavior of the Uranium-Lead-Outer Stainless Steel System, a calculation is made which will give a maximum stress by the approximation method. The lead annulus is simplified to a full simple cylinder of inner radius 10.00 in., outer rad. of 12.125 in. and the length of the annulus is 162.625 in. This simplified volume gives us a greater volume of lead than actual and hence, a greater than actual increase in volume due to the thermal expansion.

The lead is assumed to exert a uniform pressure "P". The expansion of the annular space from pressure "P" and the thermal expansion is calculated. This valve is equated to a free, unrestricted, thermally expanded volume of lead, to give the value of "P". In reality, the lead would be compressed radially and axially and its final volume would be less and hence the actual "P" would be less than the calculated value.

The combines stresses are compared with the yield stresses to demonstrate the safety of the system.

### Thermal Expansions

Initial volume of Lead void space

$$\begin{aligned} &= \pi (12.125^2 - 10^2) \times 161.38 \\ &= 23,836.462 \text{ in.}^3 = V_1 \end{aligned}$$

Increase in Volume of Lead when it is free of all external stresses

$$\begin{aligned} &= V_1 \times \Delta T \times 3\alpha \\ &= 23,836.462 \times (356-68) \times 3 \times 16.3 \times 10^{-6} \\ &= 335.694 \text{ in.}^3 = \Delta V \end{aligned}$$

Increase in internal radius of Outer Stainless Steel

$$\begin{aligned} &= R \times \Delta T \times \alpha \\ &= 12.125 \times (352-68) \times 9.9 \times 10^{-6} \\ &= 0.034 \text{ in.} = U_{OSS,T} \end{aligned}$$

Increase in external radius of Uranium

$$= 10.00 \times (373-68) \times 9.661 \times 10^{-6} = 0.0295 \text{ in.} = U_{U,T}$$

### Axial Stresses Due to Differential Thermal Expansion

The cask construction is such that the axial expansions of Outer S-S and the Water Jacket Shell interact with the Water Pressure and Lead Pressure.

Free Axial Thermal Expansions of:

$$\begin{aligned}\text{Water Jacket Shell} &= L \times \Delta T \times \alpha \\ &= 161.38 \times (340-68) \times 9.9 \times 10^{-6} \\ &= 0.4346 \text{ ins.} = l_{WJ}\end{aligned}$$

$$\begin{aligned}\text{Outer S-S} &= 161.38 \times (352-68) \times 9.9 \times 10^{-6} \\ &= 0.4537 \text{ in.} = l_{OSS}\end{aligned}$$

Axial Pressure in:

$$\text{Water} = 80.96 \text{ psi} \quad \text{Ref. 12}$$

$$\text{Lead} = P \quad (\text{unknown now})$$

Axial Forces due to Pressure:

$$\begin{aligned}\text{Water} &= \pi (R^2 - r^2) \times p = F_W \\ &= \pi (18^2 - 13^2) \times (-80.96) \\ &= -39,423.2179 \text{ lbs.} \quad (- \therefore \text{ compressive})\end{aligned}$$

$$\begin{aligned}\text{Lead} &= \pi (12.125^2 - 10^2) \times (-P) = F_L \\ &= -147.704 \text{ lbs.} (P)\end{aligned}$$

Let "L" ins. be the resultant axial expansion due to these forces

$\therefore$  Axial forces produced are:

$$\text{Water Jacket Shell} = (\text{Area}) \times \left( \frac{\text{Change in Length}}{\text{Original Length}} \right) \times (\text{Elastic Modulus})$$

$$= \pi (R^2 - r^2) \times \frac{(l - l_{WJ})}{161.38} \times E_{WJ} = F_{WJ}$$

$$= \pi (18.25^2 - 18^2) \times \frac{(l - 0.4346)}{161.38} \times 26.8 \times 10^6$$

$$= (4.728 \times l - 2.055) \times 10^6$$

$$\text{Outer S-S} = \pi (13^2 - 12.125^2) \times \frac{(l - 0.4537)}{161.38} \times 26.8 \times 10^6$$

$$= (11.4696 \times l - 5.204) \times 10^6 = F_{OSS}$$

Hence, making a force balance in the axial direction, we have

$$F_W + F_L + F_{WJ} + F_{OSS} = \sum F = 0$$

$$\therefore -39,423.2179 - 147.704 \times P + (4.728 l - 2.055) \times 10^6 +$$

$$(11.4696 l - 5.204) \times 10^6 = 0$$

$$\therefore l = 0.45 + 9.119 \times 10^{-6} \times P$$

$\therefore$  Axial stress (assumed constant over radius) for:

$$\text{Outer S-S} = \frac{F_{OSS}}{\pi (13^2 - 12.125^2)} = \sigma_{z_{OSS}} = 1.514 \times P - 525.166$$

#### Radial Expansion Due to Radial and Axial Stresses

For thick cylinders with internal radius  $R_1$ ,

External radius  $R_2$ , internal pressure  $P_1$ ,

External pressure  $P_0$  & Axial Stress  $\sigma_z$ ,

The radial and hoop stresses at any radius "r" are given by:

$$\sigma_r = \frac{1}{R_2^2 - R_1^2} \left[ R_1^2 p_1 - R_2^2 p_0 - \left( \frac{R_1 R_2}{r} \right)^2 (p_1 - p_0) \right]$$

$$\sigma_h = \frac{1}{R_2^2 - R_1^2} \left[ R_1^2 p_1 - R_2^2 p_0 + \left( \frac{R_1 R_2}{r} \right)^2 (p_1 - p_0) \right]$$

For cylindrical coordinates, hoop strain is given by

$$\epsilon_h = \frac{U}{r} = \frac{1}{E} \left[ \sigma_h - \nu (\sigma_r + \sigma_z) \right]$$

Where  $U$  = Radial displacement at Radius ' $r$ '.

$$\therefore U = \frac{r}{E (R_2^2 - R_1^2)} \left[ (1-\nu) (R_1^2 p_1 - R_2^2 p_0) + (1+\nu) \left( \frac{R_1 R_2}{r} \right)^2 (p_1 - p_0) \right] - \frac{\nu \sigma_z}{E}$$

= Radial displacement due to pressure and axial stress.

∴ Radial displacements due to pressure and axial stresses for:

Outer S-S, at inner radius

$$= \frac{12.125}{26.8 \times 10^6 (132 - 12.125^2)} \left[ (1-0.3) (12.125^2 \times p - 132^2 \times 80.96) + (1+0.3) \times (p-80.96) \right] - \frac{0.3 \times 1.514 \times p - 525.166}{26.8 \times 10^6}$$

$$= 6.622 \times 10^{-6} \times p - 557.266 \times 10^{-6} \text{ in.} = U_{OSS, p}$$



Uranium at outer radius , ( $\sigma_z = 0$  here)

$$= \frac{10.00}{24.0 \times 10^6 (10^2 - 7.252)} \left[ (1-0.2) (-10^2 \times p) + (1+0.2) \times 7.25^2 (-p) \right]$$

$$= 1.257 \times 10^{-6} \times P \text{ in.} = U_{U,P}$$

#### New Dimensions of Lead Annulus

$$\begin{aligned} \text{Length} &= \text{Initial length} + l \\ &= 161.38 + \left[ 0.451 + 9.1188 \times 10^{-6} P \right] \\ &= 9.1188 \times 10^{-6} \times P + 161.831 = L \end{aligned}$$

$$\begin{aligned} \text{Outer Radius} &= \text{Initial Outer Radius} + U_{OSS, T} + U_{OSS, P} \\ &= 12.125 + 0.034 + 6.622 \times 10^{-6} \times P - 557.266 \times 10^{-6} \end{aligned}$$

$$= 6.622 \times 10^{-6} \times P + 12.159 = R_2$$

$$\begin{aligned} \text{Inner Radius} &= \text{Initial Inner Radius} + U_{U, T} + U_{U, P} \\ &= 10.00 + 0.0294 - 1.2566 \times 10^{-6} \times P \\ &= -1.2566 \times 10^{-6} \times P + 10.029 = R_1 \end{aligned}$$

$$\text{Outer Area} = \pi (R_2)^2 = \pi \left[ 161.032 \times 10^{-6} \times P + 147.8299 \right] = A_2$$

$$\text{Inner Area} = \pi (R_1)^2 = \pi \left[ -25.208 \times 10^{-6} \times P + 100.590 \right] = A_1$$

$$\text{Cross-Sectional Area} = A_2 - A_1$$

$$= \pi \left[ 186.240 \times 10^{-6} \times P + 47.2397 \right]$$

$$\text{Volume} = L \times (A_2 - A_1) = V_2$$

$$\therefore V_2 = 96,038.915 \times 10^{-6} \times P + 24,016.957$$

Equating the Volume Increases of Lead and Lead Annulus

$$\Delta V = V_2 - V_1$$

$$335.694 = 24,016.957 + 96,038.915 \times 10^{-6} \times P - 23836.462$$

$$\therefore P = 1,615.995 \text{ psi.}$$

Hence, when the pressure in the Lead Annulus

= 1,616 psi the free expansion of the lead is taken up by the Lead Annulus.

Results

Pressure in Lead Annulus = 1,616 = P

Maximum Hoop Stresses in:

Outer Stainless Steel =  $\sigma_{h, \max.}$  (at inner rad.)

$$\begin{aligned}\sigma_{h, \max.} &= \frac{1}{R_2^2 - R_1^2} \left[ R_1^2 p_1 - R_2^2 p_o + R_2^2 (p_1 - p_o) \right] \\ &= \frac{1}{R_2^2 - R_1^2} \left[ (R_1^2 + R_2^2) p_1 - 2 R_2^2 p_o \right] \\ &= \frac{1}{13^2 - 12.125^2} \left[ (12.125^2 + 13^2) \times 1,616 - 2(13^2) \times 80.9 \right] \\ &= 21,984.558 = \sigma_{1, \text{OSS}} = 21,985 \text{ psi.}\end{aligned}$$

Uranium ( at inner rad. &  $p_1$ ) = 0

$$\begin{aligned}\sigma_{h, \max.} &= \frac{1}{10^2 - 7.25^2} - 2 \times (10^2) \times 1,616 \\ &= 6813.175 = \sigma_{1, U} = 6813 \text{ psi}\end{aligned}$$

Radial Stresses in:

$$\begin{aligned}\text{Outer S-Steel ( at inner rad.)} &= -1,616 \text{ (compressive)} \\ &= \sigma_{2, \text{OSS}}\end{aligned}$$

$$\text{Uranium (at inner rad.)} = 0 = \sigma_{2, U}$$

Axial Stresses in:

$$\begin{aligned}\text{Outer S-Steel} &= 1.514 \times P - 525.166 \\ &= 1,922.013 \text{ psi} = \sigma_{3, \text{OSS}} = 1922 \text{ psi}\end{aligned}$$

$$\text{Uranium} = 0 = \sigma_{3, U}$$

From Distortion Energy Criterion, for Combined Stresses, the equivalent combined stress  $\sigma_o$  is given by:

$$2 \sigma_o^2 = (\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2$$

$\therefore$  For Outer S-Steel Shell,

$$2 \sigma_o^2 = (21,985 + 1,616)^2 + (-1,616 - 1,922)^2 + (1,922 - 21,985)^2$$

$$\begin{aligned}\therefore \sigma_{o, \text{OSS}} &= 22,045.959 \text{ psi} < \sigma_y \text{ for S-Steel} \\ &= 22,046 < \sigma_y = 45,900 \text{ psi.}\end{aligned}$$

For Uranium

$$2 \sigma_o^2 = (6,813)^2 + (6,813)^2$$

$$\therefore \sigma_{o, U} = (6,813) \text{ psi} < \sigma_y \text{ for Uranium} = 27,000 \text{ psi.}$$

### 1.5.8 Radial Expansion Uranium Shield/Lead/Outer Shell

The highest temperatures thru the cask walls occurs 0.5 hrs. after the start of the hypothetical fire accident condition.

Uranium shield 582° F, 20" O.D.  $\Delta T = 582 - 68 = 514^\circ \text{F}$

Lead Shield 641° F  $\Delta T = 641 - 68 = 573^\circ \text{F}$

Volume of lead = 23146 in.<sup>3</sup>

Volume of void = 650 in.<sup>3</sup>

Linear expansion of lead  $16.3 \times 10^{-6}$  in./in./°F.

Outer Shell 702° F, 24.25" I.D.,  $\Delta T = 702 - 68 = 634^\circ \text{F}$

Increase in volume of Uranium Shield over 160" length

$$\epsilon_T = 9.661 \times 10^{-6} \times 514 \times 10 = \underline{.04966}$$

$$\text{Volume increase} = (\pi \times 20 \times .04966) \times .04966 (160) = \underline{500.382 \text{ in.}^3}$$

Increase in volume due to Outer Shell expansion over 160"

$$\epsilon_T = 10.3 \times 10^{-6} \times 634 \times 12.125 = \underline{.079179}$$

$$\text{Volume increase} = (\pi \times 24.204179) \times .079179 (160) = 963.137 \text{ in.}^3$$

Net increase in space available for lead

$$963.137 - 500.382 = 462.755 \text{ in.}^3$$

Total space available, including original void

$$462.755 + 650 = 1112.755 \text{ in.}^3$$

Bulk expansion of lead shield to 641° F

$$\epsilon_T = 3 \times 16.3 \times 10^{-6} \times 573 \times 23146 = \underline{648.5 \text{ in.}^3}$$

Expansion of lead on melting

$$.036 (23146) = \underline{833.3 \text{ in.}^3}$$

$$\text{Total bulk increase of lead} = 648.5 + 833.3 = \underline{1481.8 \text{ in.}^3}$$

$$\text{Deficiency in available space} = 1481.8 - 1112.755 = \underline{369.045}$$

Consider expanding the Outer Shell over 160" length Surface area of I.D. = 160 ( $\pi$  24.4084) = 12266.7 in.<sup>2</sup>

$$\text{Radial expansion required } \frac{369,045}{12266.7} = 0.030 \text{ " radial}$$

$$\text{Hoop Strain} = \frac{.030}{12.2042} = .246\%$$

$$\text{M.S.} = \frac{48.0}{.246} - 1 = 181.9$$

Plastic yielding of the outer shell under accident condition is acceptable since there is no breach incurred and containment of the lead shielding is assured.

The following analysis is for the change in conditions from 0.5 hrs. after start of the hypothetical fire accident condition to 1.5 hrs. after same.

$$\text{Uranium shield } 627^{\circ}\text{F, } 20" \text{ O.D. } \Delta T = 627 - 582 = +45^{\circ}\text{F}$$

$$\text{Lead Shield } 621^{\circ}\text{F } \Delta T = 621 - 641 = -20^{\circ}\text{F}$$

$$\text{Outer Shell } 611^{\circ}\text{F, } 24.25" \text{ I.D. , } \Delta T = 611 - 702 = -90^{\circ}\text{F}$$

Increase in volume of Uranium Shield over 160" length

$$\epsilon_r = 9.661 \times 10^{-6} \times (+45) \times 10.04966 = .004369$$

$$\text{Mean Dia.} = 20. + 2 (.04966) + .004369 = 20.103689$$

$$\text{Vol. Increase} = \pi (20.103689) (.004369) 160 = +44.14969 \text{ in.}^3$$

Decrease in vol. due to Outer Shell contraction over 160"

$$\text{Previous rad.} = 12.125 + .079179 = 12.204179$$

$$\epsilon_r = 10.3 \times 10^{-6} \times (-91) (12.204179) = -.07438976$$

$$\text{Mean Dia.} = 2 (12.204179) - .011438976 = 24.39692$$

$$\text{Vol. decrease} = \pi (24.39692) (-.011438976) = -140.27785 \text{ in.}^3$$

Net decrease in space available for lead

$$-140.27785 - 44.14969 = -184.42754 \text{ in.}^3$$

Bulk contraction of lead from 641° to 621° F

$$\epsilon_r = 3 \times 16.3 \times 10^{-6} (20) (23146 + 1481.8) = -24.08599 \text{ in.}^3$$

Further deficiency in available space

$$-184.42754 + 24.08599 = -160.34155 \text{ in.}^3$$

This is equivalent to expanding the outer shell over 160"

$$\text{Surface area of I.D.} = 160 (24.4034) = 12266.7 \text{ in.}^2$$

Radial expansion required

$$\frac{160.34155}{12266.7} = .013" \text{ radial}$$

$$\text{Hoop strain} = \frac{.013}{12.20} = .00106 = .106\%$$

$$\text{Total strain from start up is } .246 + .106 = .352\%$$

$$\text{M.S.} = \frac{45}{.352} - 1 = 126.8$$

Very slight plastic yielding is indicated.

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