ORNL/TM-12386

**OAK RIDGE
NATIONAL
LABORATORY**

MARTIN MARIETTA

**Temperature and Void Reactivity
Coefficient Calculations for the
High Flux Isotope Reactor
Safety Analysis Report**

W. W. Engle, Jr.
L. R. Williams

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Engineering Physics and Mathematics Division

**Temperature and Void Reactivity Coefficient
Calculations for the High Flux Isotope Reactor
Safety Analysis Report**

**W. W. Engle, Jr.
L. R. Williams**

Date Published—July 1994

NOTICE This document contains information of a preliminary nature.
It is subject to revision or correction and therefore does not represent
a final report

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
managed by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

for

TABLE OF CONTENTS

LIST OF TABLES	v
LIST OF FIGURES	vii
ACKNOWLEDGEMENTS	ix
1. INTRODUCTION	1
2. METHODS VERIFICATION	3
2.1. Cross-Section Processing	3
2.2. Method of Analysis	3
2.3. Results of Calculation	4
3. TEMPERATURE AND VOID COEFFICIENT CALCULATIONS	9
3.1. Beginning-of-Life Calculations	9
3.2. Beginning-of-Life Results	11
3.3. End-of-Life and Equilibrium-Xenon Calculations	11
3.4. End-of-Life and Equilibrium-Xenon Results	11
3. CONCLUSIONS	15
4. REFERENCES	17
APPENDIX A	19

LIST OF TABLES

Table 2.1.	Calculated Relative Power Distribution	7
Table 2.2.	Ratio of Calculated-to-Measured Relative Power Distributions	8
Table 3.1.	Control Rod Positions	14
Table 3.2.	Reactivity Coefficients	14

LIST OF FIGURES

Fig. 2.1.	HFIRCE-4 DORT Geometry Model	5
Fig. 2.2.	HFIRCE-4 DORT Geometry Model - Central Region	6
Fig. 3.1.	HFIR DORT Beginning-of-Life Model - Central Region	10
Fig. 3.2.	HFIR DORT End-of-Life Model - Central Region	12
Fig. 3.3.	HFIR DORT Equilibrium Xenon Model - Central Region	13

ACKNOWLEDGEMENTS

R. T. Primm, III, provided valuable assistance in the course of these calculations by modifying the format of the neutron cross sections used in previous work so that they could be used in the DORT code, by providing material compositions and control rod positions for the end-of-life and xenon equilibrium conditions and by participating in several useful discussions concerning the calculational techniques and computer models. R. B. Rothrock served as technical and administrative liaison with the Research Reactors Division and also provided valuable input via many constructive discussions of the calculational procedures and the HFIR DORT models.

1. INTRODUCTION

This report provides documentation of a series of calculations performed in 1991 in order to provide input for the High Flux Isotope Reactor Safety Analysis Report. In particular, temperature and void reactivity coefficients were calculated for beginning-of-life, end-of-life, and xenon equilibrium (29 h) conditions. Much of the data used to prepare the computer models for these calculations was derived from the original HFIR nuclear design study (Ref. 1).

2. METHODS VERIFICATION

In order to verify both the computer code and the cross-section data used in these analyses, a mockup of the HFIR critical experiment, HFIRCE-4, was calculated. The relative power distribution from that calculation was then compared with the relative power distribution reported in Ref. 1.

2.1. Cross-Section Processing

The processing of the cross sections used in the calculations described in the remainder of this report was reported in detail in Ref. 2. To summarize, the ANSL-V General Purpose Neutron library (Ref. 3) was processed using the AJAX, BONAMI, NITAWL, and XSDRNPM modules of the AMPX system (Ref. 4) in order to produce the 39 group cross-section library used in these analyses.

2.2. Method of Analysis

The discrete ordinates code, DORT (Ref. 5) was used to analyze the HFIRCE-4 experiment and determine the k-effective, neutron fluxes and the power distribution. The discrete ordinates method is a numerical technique that yields highly differential results for the entire system being calculated. In the calculation, the system is divided into finite space cells and the calculation maintains a balance between particle gains and losses for each space cell. With the origin (source) of the particles specified and the boundary conditions set, the calculation begins with the highest energy group and sweeps through all lower energy groups and all space cells in the system for all particle directions. Several sweeps (iterations) are required before the results converge to give the number of particles from the source's high-energy group that have entered each space cell, together with their resulting energies and directions. The procedure is repeated for each energy group in decreasing order. In a multiplying system, the fission source is then recalculated using the most recently computed fluxes and the sweep through the energy groups is repeated. This process is repeated until the fission source calculation converges. The results of interest are usually the average particle fluxes in each energy group for each space cell, the fission source in each space cell, and the k-effective value.

The major shortcoming of the DORT discrete ordinates code is that it is limited to two-dimensional geometries. Thus, if a reactor system is to be analyzed by the DORT code, it must be describable in two dimensions. In the case of the HFIR, this is not a significant limitation. DORT also has numerous advantages, not the least of which is its ability to produce large volumes of detailed flux data for essentially all points within a system in a relatively short time and at a relatively economical cost.

The DORT calculation used an R-Z model which was derived from data presented in Figs. A.8 through A.10 and Table A.6 of Ref. 1. The model explicitly included 18 radial fuel regions, 9 each in the inner and outer fuel elements, the central target region, the control rods, the beryllium reflector and the surrounding water. The boundaries of the radial fuel regions and the axial spatial mesh in the fuel region were chosen so that the calculated power density could be compared directly with the relative power distribution shown in Fig. 7.8. in Ref. 1. The HFIRCE-4 core and the DORT computer model contain approximately 0.7×10^{-3} kg less boron as a burnable poison than is contained in the HFIR production cores. Figure 2.1 shows a computer generated plot of the HFIR DORT geometry and Figure 2.2 shows an enlarged view of the target, fuel, and control rod region which more clearly depicts the region descriptions in the DORT geometry. A complete listing of the DORT input data is presented in Appendix A.

2.3. Results of Calculation

The calculated relative power distribution is shown in Table 2.1. and the ratio of the calculated relative power distribution to the measured relative power distribution from Fig 7.8. in Ref. 1 is shown in Table 2.2.

Note in Table 2.2. that only 20 out of 378 values of the calculated to measured ratios show more than a twenty percent discrepancy and 335 out of the 378 values agree to within ten percent or better. The worst disagreement is at the axial ends of the inner edge of the inner fuel element and at the axial ends of the outer edge of the outer fuel element. The method of extrapolation/interpolation of the original measurements made with fission foils is not well understood and the agreement between the calculation and the measurement is considered to be a sufficient verification of the DORT code and cross-section library for their use in the reactivity coefficient calculations described in the following sections of this report.

Fig. 2.1. HFIRCE-4 DORT Geometry Model

Fig. 2.2. HFIRCE-4 DORT Geometry Model - Central Region

Table 2.1. Calculated Relative Power Distribution

$Z^*(\text{cm})$	25.4	1.286	1.540	1.679	1.750	1.721	1.600	1.464	1.442	1.690	1.621	1.368	1.023	0.641	0.365
	24.0	1.039	0.989	0.894	0.879	0.872	0.960	1.026	1.021	0.940	0.758	0.646	0.529	0.393	0.273
	22.0	0.987	0.929	0.812	0.785	0.789	0.873	0.927	0.927	0.876	0.713	0.606	0.497	0.372	0.258
	20.0	1.039	0.993	0.879	0.854	0.857	0.936	0.979	0.980	0.949	0.788	0.674	0.553	0.410	0.281
	18.0	1.127	1.085	0.968	0.944	0.949	1.030	1.074	1.077	1.051	0.880	0.756	0.622	0.463	0.316
	16.0	1.224	1.181	1.058	1.035	1.041	1.130	1.178	1.183	1.158	0.974	0.841	0.699	0.527	0.367
	14.0	1.318	1.273	1.143	1.120	1.128	1.226	1.278	1.287	1.264	1.071	0.935	0.791	0.612	0.444
	12.0	1.404	1.357	1.221	1.198	1.208	1.315	1.371	1.384	1.364	1.166	1.036	0.908	0.755	0.608
	10.0	1.479	1.431	1.288	1.265	1.278	1.392	1.452	1.471	1.453	1.253	1.132	1.030	0.916	0.816
	8.0	1.541	1.492	1.344	1.322	1.336	1.457	1.520	1.545	1.529	1.328	1.215	1.132	1.043	0.964
	6.0	1.590	1.540	1.388	1.366	1.381	1.508	1.573	1.603	1.588	1.383	1.272	1.195	1.115	1.046
	4.0	1.623	1.573	1.418	1.396	1.412	1.543	1.610	1.642	1.627	1.418	1.306	1.230	1.149	1.081
	2.0	1.640	1.589	1.433	1.411	1.428	1.560	1.629	1.659	1.645	1.433	1.319	1.234	1.139	1.047
	0.0	1.642	1.591	1.435	1.413	1.430	1.562	1.631	1.660	1.646	1.433	1.317	1.227	1.119	1.003
	-2.0	1.629	1.578	1.423	1.400	1.417	1.547	1.616	1.644	1.630	1.418	1.302	1.212	1.105	0.992
	-4.0	1.602	1.551	1.398	1.375	1.391	1.518	1.585	1.610	1.597	1.389	1.275	1.190	1.099	1.003
	-6.0	1.558	1.508	1.358	1.335	1.349	1.472	1.536	1.559	1.545	1.342	1.230	1.149	1.059	0.972
	-8.0	1.500	1.452	1.306	1.283	1.295	1.411	1.472	1.490	1.475	1.275	1.164	1.078	0.982	0.889
	-10.0	1.430	1.383	1.243	1.219	1.229	1.336	1.393	1.407	1.386	1.189	1.065	0.960	0.846	0.741
	-12.0	1.349	1.303	1.170	1.145	1.153	1.252	1.303	1.313	1.287	1.089	0.953	0.811	0.636	0.458
	-14.0	1.259	1.215	1.088	1.064	1.069	1.158	1.204	1.210	1.180	0.985	0.842	0.674	0.473	0.273
	-16.0	1.162	1.120	1.001	0.976	0.979	1.059	1.099	1.106	1.070	0.887	0.745	0.590	0.397	0.220
	-18.0	1.065	1.023	0.910	0.885	0.886	0.959	0.994	0.999	0.963	0.794	0.663	0.519	0.347	0.191
	-20.0	0.977	0.932	0.822	0.796	0.796	0.865	0.902	0.900	0.864	0.707	0.587	0.457	0.306	0.168
	-22.0	0.924	0.868	0.756	0.728	0.728	0.802	0.849	0.844	0.792	0.635	0.524	0.407	0.274	0.153
	-24.0	0.967	0.918	0.827	0.809	0.800	0.876	0.934	0.921	0.842	0.668	0.553	0.430	0.288	0.162
	-25.4	1.186	1.422	1.546	1.605	1.572	1.453	1.336	1.280	1.496	1.406	1.157	0.823	0.473	0.222
		7.14	8.00	9.00	10.00	11.00	12.00	12.60	15.15	16.00	17.00	18.00	19.00	20.00	21.00

Radial Distance from Reactor Centerline (cm)

* Z is measured relative to the reactor midplane

Table 2.2. Ratio of Calculated-to-Measured Relative Power Distributions

$Z^*(\text{cm})$															
25.4	1.51	1.19	1.10	1.09	1.10	1.10	1.09	0.88	1.08	1.13	1.07	0.91	0.90	1.52	
24.0	1.17	1.11	1.00	0.99	0.98	1.07	1.08	0.97	1.01	0.95	0.94	0.95	0.76	0.94	
22.0	1.12	1.08	0.96	0.93	0.92	0.97	1.00	0.91	0.96	0.93	0.96	0.98	0.93	0.96	
20.0	1.02	1.07	0.99	0.97	0.96	1.00	1.00	0.94	1.03	1.00	1.01	1.02	0.98	0.94	
18.0	0.98	1.03	0.99	0.99	0.98	0.99	0.98	0.96	1.04	1.01	1.01	1.00	0.95	0.93	
16.0	0.96	1.03	0.99	0.99	0.98	1.00	0.98	0.97	1.05	1.01	1.00	0.98	0.94	0.92	
14.0	0.96	1.03	0.99	0.99	0.99	1.01	0.99	0.98	1.06	1.03	1.02	1.00	0.96	0.93	
12.0	0.96	1.03	0.98	0.99	0.99	1.02	0.99	1.00	1.08	1.04	1.04	1.04	1.02	1.05	
10.0	0.97	1.03	0.98	0.98	0.98	1.02	1.00	1.01	1.09	1.05	1.06	1.07	1.10	1.17	
8.0	0.97	1.02	0.97	0.97	0.97	1.03	1.01	1.03	1.10	1.06	1.07	1.10	1.12	1.19	
6.0	0.98	1.02	0.96	0.96	0.97	1.02	1.01	1.03	1.11	1.06	1.06	1.10	1.10	1.12	
4.0	0.98	1.02	0.97	0.97	0.97	1.02	1.01	1.03	1.11	1.05	1.07	1.12	1.14	1.17	
2.0	0.98	1.03	0.97	0.97	0.98	1.03	1.01	1.02	1.09	1.05	1.07	1.12	1.14	1.15	
0.0	0.98	1.03	0.98	0.98	0.99	1.03	1.01	1.00	1.08	1.05	1.07	1.12	1.12	1.10	
-2.0	0.97	1.02	0.98	0.99	0.98	1.03	1.00	1.01	1.09	1.04	1.06	1.10	1.12	1.10	
-4.0	0.96	1.02	0.98	0.99	0.99	1.03	1.00	1.02	1.09	1.04	1.05	1.09	1.12	1.10	
-6.0	0.96	1.01	0.98	1.00	0.99	1.03	1.00	1.02	1.09	1.03	1.03	1.06	1.10	1.20	
-8.0	0.96	1.02	0.98	0.99	1.00	1.03	1.01	1.01	1.08	1.04	1.05	1.09	1.15	1.35	
-10.0	0.97	1.02	0.99	1.00	0.99	1.03	1.02	0.99	1.07	1.04	1.05	1.10	1.19	1.43	
-12.0	0.96	1.02	0.98	1.00	0.99	1.02	1.01	0.98	1.06	1.04	1.06	1.10	1.10	1.18	
-14.0	0.97	1.02	0.98	0.98	0.98	1.01	1.00	0.97	1.05	1.03	1.05	1.04	0.98	0.94	
-16.0	0.98	1.03	0.98	0.99	0.97	1.00	0.99	0.97	1.05	1.02	1.03	1.04	0.97	0.96	
-18.0	0.99	1.03	0.99	0.98	0.96	0.99	0.97	0.98	1.06	1.01	1.02	1.02	0.96	1.06	
-20.0	1.03	1.07	1.02	0.98	0.97	0.99	0.98	0.97	1.04	1.00	0.99	1.02	0.99	1.05	
-22.0	1.13	1.13	0.98	1.03	0.93	0.98	0.99	0.92	0.99	0.95	0.97	0.97	0.94	0.90	
-24.0	1.34	1.21	1.09	1.05	1.00	1.07	1.07	0.99	1.04	0.98	1.00	1.02	0.90	0.90	
-25.4	1.88	1.34	1.19	1.15	1.12	1.10	1.10	0.91	1.13	1.16	1.10	0.92	0.99	3.69	
	7.14	8.00	9.00	10.0	11.0	12.0	12.6	15.15	16.0	17.0	18.0	19.0	20.0	21.0	

Radial Distance from Reactor Centerline (cm)

* Z is measured relative to the reactor midplane

3. TEMPERATURE AND VOID COEFFICIENT CALCULATIONS

Using the DORT model described in the previous section with appropriate modifications for each condition, calculations of temperature and void coefficients were completed for three HFIR configurations, at beginning-of-life, at end-of-life, and at the time of xenon equilibrium or twenty-nine hours after the beginning of life. The beginning-of-life calculations are compared with measurements reported in Ref. 1.

3.1. Beginning-of-Life Calculations

Temperature coefficient measurements were made in the HFIRCE-2 experiment and from the description in Appendix A of Ref. 1, the experiments were setup so that the water moderator between the outer side plate of the outer element and the inner side plate of the inner element could be circulated separately from the water in the island, control region, and the external reflector regions. The water in this region could be heated and reactivity differences determined from critical control rod positions. Therefore, in the DORT calculations of temperature coefficients, only the regions within the bounds described above were modified when calculating the temperature coefficients. The geometry model used for the HFIRCE-4 calculations was also modified to change the control rod positions to the critical position calculated in Ref. 2 for the beginning-of-life condition. A listing of the DORT input appears in Appendix A. Fig. 3.1 shows the enlarged view of the central region of the DORT geometry for the beginning-of-life core. A DORT case with 296°K water cross sections was completed and then the 296°K water cross sections in that case were replaced with 350°K water cross sections and the density of the water was adjusted to account for the increased water temperature and for the thermal expansion of the aluminum plates which effectively decreased the width of the water gaps. That DORT case was completed and the difference in the k-effectives was used to determine the temperature coefficient.

Void coefficient measurements are reported in Ref. 1 from HFIRCE-4 measurements. The experiments consisted of replacing a few of the fuel plates with aluminum plates and then replacing those plates with water. Measurements were made separately for the inner and outer fuel elements. In the DORT calculations, the density of the water was arbitrarily changed by one percent in the inner and outer fuel elements in separate calculations to approximate the experiments. The differences in the k-effectives between these two cases and the unperturbed beginning-of-life case were used to calculate the void reactivity coefficients.

Fig. 3.1. HFIR DORT Beginning-of-Life Model - Central Region

3.2. Beginning-of-Life Results

The measured value for the temperature coefficient, " $(\Delta k/k)/^{\circ}\text{F}$ "¹, was taken from Fig. 9.2. of Ref. 1 using the curve labeled "FUEL REGION (WITH 300-g PU TARGET)." The value at approximately 130°F corresponds to the average of the two cross-section temperatures used in the calculation and is approximately -1.1×10^{-4} . The calculated value is -1.15×10^{-4} . The agreement between measured and calculated values is good.

The measured values reported in Ref. 1 for $(\Delta k/k)/(\Delta V/V)$ for the inner and outer elements respectively were -0.080 and -0.170. The values calculated by the DORT code were -0.135 and -0.256 resulting in C/Es of 1.7 and 1.5 respectively. Ref. 1 mentions making a "small correction" for the absorption in aluminum in order to convert the aluminum coefficients to void coefficients. The details of this correction are not known so it is not possible to duplicate the experiment more accurately.

3.3. End-of-Life and Equilibrium-Xenon Calculations

As a result of calculation previously performed and reported in Ref. 2, data was available which defined the revised fuel compositions due to burnup and the critical control rod positions for the end-of-life and equilibrium-xenon conditions. After making changes in the DORT model to specify the control rod positions as determined in Ref. 2, calculations were completed as before for the temperature coefficients and the inner and outer fuel element void coefficients for the end-of-life and equilibrium-xenon conditions. Table 3.1 provides a summary of the control positions for the four configurations described in this report. A listing of the DORT model for each of these conditions is included in Appendix A. Geometry plots of the central region which includes the control rods are shown in Figs. 3.2 and 3.3. The additional two axial zones in each end of each radial fuel zone (relative to Fig. 3.1) are a result of the axial variation of the fuel burnup.

3.4 End-of-Life and Equilibrium-Xenon Results

Table 3.2 presents a summary of the DORT calculations and the measurements of temperature and void coefficients including the previously described beginning-of-life condition results. Because all of the experiments were performed with beginning-of-life conditions, no experimental data are available for comparison at the other conditions.

¹Units used in Ref. 1.

Fig. 3.2. HFIR DORT End-of-Life Model - Central Region

Fig. 3.3. HFIR DORT Equilibrium Xenon Model - Central Region

Table 3.1. Control Rod Positions

HFIR Configuration	Gray(Ta-Al) - White(Al) Interface
	Inner Rod/Outer Rod (cm) Measured Relative to Midplane
HFIRCE-4	1.016/-1.016
Beginning-of-Life	-1.027/1.027
Xenon Equilibrium (29 h)	-10.05/10.05
End-of-Life	-24.85/24.85

Table 3.2. Reactivity Coefficients

Condition	$(\Delta k/k)/^{\circ}\text{C}$	$(\Delta k/k)/^{\circ}\text{F}^2$	inner element	outer element
			$(\Delta k/k)/(\Delta V/V)$	$(\Delta k/k)/(\Delta V/V)$
Measured b-o-l	-1.98×10^{-4}	-1.10×10^{-4}	-0.080	-0.170
DORT b-o-l	-2.07×10^{-4}	-1.15×10^{-4}	-0.135	-0.256
DORT e-o-l	-2.32×10^{-4}	-1.29×10^{-4}	-0.058	-0.102
DORT (29 h)	-2.23×10^{-4}	-1.24×10^{-4}	-0.097	-0.249

²This column included for consistency in comparing with Ref. 1.

3. CONCLUSIONS

Using a 39 group neutron cross-section library prepared for the HFIR and based on the ANSL-V General Purpose Neutron library, the DORT two dimensional discrete ordinates code was used to calculate the power distribution in a model of the HFIRCE-4 experiment. The calculated power distribution was compared with the distribution measured in the HFIRCE-4 and the agreement was considered good, and therefore, a verification of the cross sections, the DORT code, and the HFIR geometry model developed for the DORT code.

By changing control rod positions, cross-section temperatures and water densities in subsequent DORT calculations, temperature coefficients of reactivity and void coefficients of reactivity were calculated for HFIR beginning-of-life conditions. These coefficients were compared with measured values at similar conditions. The temperature coefficient comparison was excellent, but the void coefficient comparison was not as good. A calculated correction in the measured void coefficients, thought to be small, could not be duplicated in the DORT calculations.

Control rod positions were then changed to approximate end-of-life conditions and xenon equilibrium (29 h) conditions. The sequence of DORT calculations was then repeated in order to calculate the reactivity coefficients at end-of-life and at xenon equilibrium. No measurements were available for comparison at these conditions.

4. REFERENCES

1. R. D. Cheverton and T. M. Sims, "HFIR Core Nuclear Design," ORNL-4621 (July 1971).
2. R. T. Primm, III, "Reactor Physics Input to the Safety Analysis Report for the High Flux Isotope Reactor," ORNL/TM-11956 (March 1992).
3. W. E. Ford, III, et al., "ANSL-V:ENDF/B-V Based Multigroup Cross-Section Libraries for Advanced Neutron Source (ANS) Reactor Studies," ORNL-6618 (September 1990).
4. N. M. Greene, et al., "AMPX: A Modular Code System for Generating Coupled Multigroup Neutron-Gamma Libraries from ENDF/B," ORNL-TM-3706 (March 1976).
5. W. A. Rhoades and R. L. Childs, "The DORT Two-Dimensional Discrete Ordinates Transport Code," Nucl. Sci. & Engr. 99, 1, 88-89 (May 1988).

APPENDIX A

Following is a listing of the cross-section ID numbers used in the HFIRCE-4 DORT calculation and a brief description of the materials corresponding to these ID numbers:

ID	DESCRIPTION
1010	p0 boc z 1 control areas - eu
1011	p1 boc z 1 control areas - eu
1012	p2 boc z 1 control areas - eu
1013	p3 boc z 1 control areas - eu
1020	p0 boc z 2 control areas - ta
1021	p1 boc z 2 control areas - ta
1022	p2 boc z 2 control areas - ta
1023	p3 boc z 2 control areas - ta
1180	p0 boc z 18 h2o
1181	p1 boc z 18 h2o
1182	p2 boc z 18 h2o
1183	p3 boc z 18 h2o
1190	p0 boc z 19 al - h2o
1191	p1 boc z 19 al - h2o
1192	p2 boc z 19 al - h2o
1193	p3 boc z 19 al - h2o
1200	p0 boc z 20 side plates & h2o - fuel
1201	p1 boc z 20 side plates & h2o - fuel
1202	p2 boc z 20 side plates & h2o - fuel
1203	p3 boc z 20 side plates & h2o - fuel
1210	p0 boc z 21 side plates & h2o - target
1211	p1 boc z 21 side plates & h2o - target
1212	p2 boc z 21 side plates & h2o - target
1213	p3 boc z 21 side plates & h2o - target
1230	p0 boc z 23 removable beryllium
1231	p1 boc z 23 removable beryllium
1232	p2 boc z 23 removable beryllium
1233	p3 boc z 23 removable beryllium
1240	p0 boc z 24 target extension
1241	p1 boc z 24 target extension
1242	p2 boc z 24 target extension
1243	p3 boc z 24 target extension
1300	p0 boc z 30 side plates & h2o - control
1301	p1 boc z 30 side plates & h2o - control
1302	p2 boc z 30 side plates & h2o - control
1303	p3 boc z 30 side plates & h2o - control
1410	p0 boc z 41 side plates & h2o - fuel*
1411	p1 boc z 41 side plates & h2o - fuel*
1412	p2 boc z 41 side plates & h2o - fuel*
1413	p3 boc z 41 side plates & h2o - fuel*
1420	p0 boc z 42 target
1421	p1 boc z 42 target
1422	p2 boc z 42 target
1423	p3 boc z 42 target
1430	p0 boc z 43 side plates & h2o - target*
1431	p1 boc z 43 side plates & h2o - target*
1432	p2 boc z 43 side plates & h2o - target*
1433	p3 boc z 43 side plates & h2o - target*
1440	p0 boc z 44 permanent beryllium
1441	p1 boc z 44 permanent beryllium
1442	p2 boc z 44 permanent beryllium
1443	p3 boc z 44 permanent beryllium
1450	p0 boc z 45 h2o pool
1451	p1 boc z 45 h2o pool
1452	p2 boc z 45 h2o pool
1453	p3 boc z 45 h2o pool
1510	p0 boc z 51 inner fuel - midplane
1511	p1 boc z 51 inner fuel - midplane
1512	p2 boc z 51 inner fuel - midplane
1513	p3 boc z 51 inner fuel - midplane
1520	p0 boc z 52 inner fuel - midplane
1521	p1 boc z 52 inner fuel - midplane
1522	p2 boc z 52 inner fuel - midplane

1523	p3	boc	z	52	inner	fuel	-	midplane
1530	p0	boc	z	53	inner	fuel	-	midplane
1531	p1	boc	z	53	inner	fuel	-	midplane
1532	p2	boc	z	53	inner	fuel	-	midplane
1533	p3	boc	z	53	inner	fuel	-	midplane
1540	p0	boc	z	54	inner	fuel	-	midplane
1541	p1	boc	z	54	inner	fuel	-	midplane
1542	p2	boc	z	54	inner	fuel	-	midplane
1543	p3	boc	z	54	inner	fuel	-	midplane
1550	p0	boc	z	55	inner	fuel	-	midplane
1551	p1	boc	z	55	inner	fuel	-	midplane
1552	p2	boc	z	55	inner	fuel	-	midplane
1553	p3	boc	z	55	inner	fuel	-	midplane
1560	p0	boc	z	56	inner	fuel	-	midplane
1561	p1	boc	z	56	inner	fuel	-	midplane
1562	p2	boc	z	56	inner	fuel	-	midplane
1563	p3	boc	z	56	inner	fuel	-	midplane
1570	p0	boc	z	57	inner	fuel	-	midplane
1571	p1	boc	z	57	inner	fuel	-	midplane
1572	p2	boc	z	57	inner	fuel	-	midplane
1573	p3	boc	z	57	inner	fuel	-	midplane
1580	p0	boc	z	58	inner	fuel	-	midplane
1581	p1	boc	z	58	inner	fuel	-	midplane
1582	p2	boc	z	58	inner	fuel	-	midplane
1583	p3	boc	z	58	inner	fuel	-	midplane
1590	p0	boc	z	59	inner	fuel	-	midplane
1591	p1	boc	z	59	inner	fuel	-	midplane
1592	p2	boc	z	59	inner	fuel	-	midplane
1593	p3	boc	z	59	inner	fuel	-	midplane
1600	p0	boc	z	60	outer	fuel	-	midplane
1601	p1	boc	z	60	outer	fuel	-	midplane
1602	p2	boc	z	60	outer	fuel	-	midplane
1603	p3	boc	z	60	outer	fuel	-	midplane
1610	p0	boc	z	61	outer	fuel	-	midplane
1611	p1	boc	z	61	outer	fuel	-	midplane
1612	p2	boc	z	61	outer	fuel	-	midplane
1613	p3	boc	z	61	outer	fuel	-	midplane
1620	p0	boc	z	62	outer	fuel	-	midplane
1621	p1	boc	z	62	outer	fuel	-	midplane
1622	p2	boc	z	62	outer	fuel	-	midplane
1623	p3	boc	z	62	outer	fuel	-	midplane
1630	p0	boc	z	63	outer	fuel	-	midplane
1631	p1	boc	z	63	outer	fuel	-	midplane
1632	p2	boc	z	63	outer	fuel	-	midplane
1633	p3	boc	z	63	outer	fuel	-	midplane
1640	p0	boc	z	64	outer	fuel	-	midplane
1641	p1	boc	z	64	outer	fuel	-	midplane
1642	p2	boc	z	64	outer	fuel	-	midplane
1643	p3	boc	z	64	outer	fuel	-	midplane
1650	p0	boc	z	65	outer	fuel	-	midplane
1651	p1	boc	z	65	outer	fuel	-	midplane
1652	p2	boc	z	65	outer	fuel	-	midplane
1653	p3	boc	z	65	outer	fuel	-	midplane
1660	p0	boc	z	66	outer	fuel	-	midplane
1661	p1	boc	z	66	outer	fuel	-	midplane
1662	p2	boc	z	66	outer	fuel	-	midplane
1663	p3	boc	z	66	outer	fuel	-	midplane
1670	p0	boc	z	67	outer	fuel	-	midplane
1671	p1	boc	z	67	outer	fuel	-	midplane
1672	p2	boc	z	67	outer	fuel	-	midplane
1673	p3	boc	z	67	outer	fuel	-	midplane
1680	p0	boc	z	68	outer	fuel	-	midplane
1681	p1	boc	z	68	outer	fuel	-	midplane
1682	p2	boc	z	68	outer	fuel	-	midplane
1683	p3	boc	z	68	outer	fuel	-	midplane

Following is the input listing for the discrete ordinates system required to run the DORT case for the HFIRCE-4 configuration described in this report:

```
=gip
hfirce-4  r-z model - boc gip xs 10/03/91
1$ 7 3 8 14 0 0 128 128 0 3 1 0 2 e t
13$ 2i 1010 1013 2i 1020 1023 2i 1180 1183 2i 1190 1193
    2i 1200 1203 2i 1210 1213 2i 1230 1233 2i 1240 1243
    2i 1300 1303 2i 1410 1413 2i 1420 1423 2i 1430 1433
    2i 1440 1443 2i 1450 1453 2i 1510 1513 2i 1520 1523
    2i 1530 1533 2i 1540 1543 2i 1550 1553 2i 1560 1563
    2i 1570 1573 2i 1580 1583 2i 1590 1593 2i 1600 1603
    2i 1610 1613 2i 1620 1623 2i 1630 1633 2i 1640 1643
    2i 1650 1653 2i 1660 1663 2i 1670 1673 2i 1680 1683

t
=dort
hfirce-4  r-z model - boc k-calc - rev run 1 s4-p1 10/03/91
61$ 0 44 8 0 e
62$ 0 1 68 76 91 7 3 8 14 0 45 0 128 0 16
    1 1 0 0 0 1 -1 0 4 1 1 0 2z 0
    4z 0 -1 0 2r 1 0 5z e
62$ a21 60 4s 2 2z 3 e
62$ a62 -1 400 400 1 e
63** 18.0 1.0 1.0-4 1.0-4 1.0-4 e
63** a17 5.0-3 e

t
81** 0.0 2r 8.3333-2 q3 q2 q8
82** -.47140 -.33333 .33333
    -.94281 -.88192 -.33333 .33333 .88192 q8
83** 3r -.88192 5r -.33333 3r .88192 5r .33333

t
1** 0.98648 0.01352 f 0.0
2** 7i -60.82 2i -39.82 -36.00 1i -35.55 1i -33.20 -30.40
    1i -29.39 -26.59 -25.40 -25.39 10i -24.50 -13.50
    -12.316 -11.684 6i -10.50 -3.50 -2.984 -1.016
    1.016 2.984 6i 3.50 10.50 11.684 12.316
    10i 13.50 24.50 25.39 25.40 1i 26.59 29.39 1i 30.40
    1i 33.20 35.55 2i 36.00 7i 39.82 60.82
4** 0.0 3i 0.887 3i 3.547 1i 6.40 7.14 7.15 4i 7.50 12.50
    12.59 12.60 13.34 14.41 15.15 15.16 4i 15.50 20.50
    20.99 21.00 21.7678 3i 22.0238 1i 22.6588 3i 22.9868
    23.6218 23.9668 9i 24.1268 9i 32.9764 9i 53.9764 78.9764
31$ 1 2 6 16 12 11
    17 18 2i 7 10 19 20 22 21 43 42 24 25 26
    27 28 29 45 23 44 7i 51 59 7i 60 68
32** 3r 22.0238 3r 22.9868
    2r 0.0 2r 7.14 2r 15.15 12.60 6.40 21.00 3.547 0.0
    0.887 2r 0.0 21.7678 22.6588
    23.6218 23.9668 2r 24.1268 32.9764
    7.14 7.15 4i 7.50 12.50 12.59
    15.15 15.16 4i 15.50 20.50 20.99
33** 3r 22.6588 3r 23.6218
    2r 21.7678 2r 12.60 2r 21.00 15.15 7.14 21.7678 6.40
    0.887 3r 3.547 22.0238 22.9868 23.9668
    24.1268 78.9764 32.9764 53.9764
    7.15 4i 7.50 12.50 12.59 12.60
    15.16 4i 15.50 20.50 20.99 21.00
34** -60.82 -11.684 1.016 -60.82 -1.016 11.684 -60.82 25.40
    -30.40 25.40 q2 3r -30.40 3r -25.40 -39.82 25.40 -60.82
    3r -60.82 -60.82 2r -30.40 18r -25.40
35** -11.684 1.016 60.82 -1.016 11.684 60.82 -25.40 60.82
    -25.40 30.40 q2 3r 30.40 3r 25.40 -25.40 39.82
    2r 60.82 2r 60.82 60.82 2r 30.40 18r 25.40
9$ 1 4r 5 33 4r 13 1 4r 5 33 2r 9 37 17 21 17
    25 2r 29 3r 9 17 12r 33 41 45 49 53
    5r 33 7i 57 89 7i 93 125
28$ f 4
29$ 49
30$ 4

t
93** 11z 9r 1.0 3z 9r 1.0 f 0.0 t
94** 20z 51r 1.0 20z t
```

95** 0.98648 0.01352 f 0.0 t
=end

Following is a listing of the cross-section ID numbers used in the HFIR beginning-of-life DORT calculation and a brief description of the material corresponding to these ID numbers:

ID	DESCRIPTION
2010	p0 h296k z 1 control areas - eu
2011	p1 h296k z 1 control areas - eu
2012	p2 h296k z 1 control areas - eu
2013	p3 h296k z 1 control areas - eu
2020	p0 h296k z 2 control areas - ta
2021	p1 h296k z 2 control areas - ta
2022	p2 h296k z 2 control areas - ta
2023	p3 h296k z 2 control areas - ta
2180	p0 h296k z18 h2o
2181	p1 h296k z18 h2o
2182	p2 h296k z18 h2o
2183	p3 h296k z18 h2o
2190	p0 h296k z19 al - h2o
2191	p1 h296k z19 al - h2o
2192	p2 h296k z19 al - h2o
2193	p3 h296k z19 al - h2o
2200	p0 h296k z20 side plates & h2o - fuel
2201	p1 h296k z20 side plates & h2o - fuel
2202	p2 h296k z20 side plates & h2o - fuel
2203	p3 h296k z20 side plates & h2o - fuel
2210	p0 h296k z21 side plates & h2o - target
2211	p1 h296k z21 side plates & h2o - target
2212	p2 h296k z21 side plates & h2o - target
2213	p3 h296k z21 side plates & h2o - target
2230	p0 h296k z23 removable beryllium
2231	p1 h296k z23 removable beryllium
2232	p2 h296k z23 removable beryllium
2233	p3 h296k z23 removable beryllium
2240	p0 h296k z24 target extension
2241	p1 h296k z24 target extension
2242	p2 h296k z24 target extension
2243	p3 h296k z24 target extension
2300	p0 h296k z30 side plates & h2o - control
2301	p1 h296k z30 side plates & h2o - control
2302	p2 h296k z30 side plates & h2o - control
2303	p3 h296k z30 side plates & h2o - control
2410	p0 h296k z41 side plates & h2o - fuel*
2411	p1 h296k z41 side plates & h2o - fuel*
2412	p2 h296k z41 side plates & h2o - fuel*
2413	p3 h296k z41 side plates & h2o - fuel*
2420	p0 h296k z42 target
2421	p1 h296k z42 target
2422	p2 h296k z42 target
2423	p3 h296k z42 target
2430	p0 h296k z43 side plates & h2o - target*
2431	p1 h296k z43 side plates & h2o - target*
2432	p2 h296k z43 side plates & h2o - target*
2433	p3 h296k z43 side plates & h2o - target*
2440	p0 h296k z44 permanent beryllium
2441	p1 h296k z44 permanent beryllium
2442	p2 h296k z44 permanent beryllium
2443	p3 h296k z44 permanent beryllium
2450	p0 h296k z45 h2o pool
2451	p1 h296k z45 h2o pool
2452	p2 h296k z45 h2o pool
2453	p3 h296k z45 h2o pool
2510	p0 h296k z51 inner fuel - midplane
2511	p1 h296k z51 inner fuel - midplane
2512	p2 h296k z51 inner fuel - midplane
2513	p3 h296k z51 inner fuel - midplane
2520	p0 h296k z52 inner fuel - midplane
2521	p1 h296k z52 inner fuel - midplane
2522	p2 h296k z52 inner fuel - midplane
2523	p3 h296k z52 inner fuel - midplane
2530	p0 h296k z53 inner fuel - midplane
2531	p1 h296k z53 inner fuel - midplane

2532	p2	h296k	z53	inner	fuel	-	midplane
2533	p3	h296k	z53	inner	fuel	-	midplane
2540	p0	h296k	z54	inner	fuel	-	midplane
2541	p1	h296k	z54	inner	fuel	-	midplane
2542	p2	h296k	z54	inner	fuel	-	midplane
2543	p3	h296k	z54	inner	fuel	-	midplane
2550	p0	h296k	z55	inner	fuel	-	midplane
2551	p1	h296k	z55	inner	fuel	-	midplane
2552	p2	h296k	z55	inner	fuel	-	midplane
2553	p3	h296k	z55	inner	fuel	-	midplane
2560	p0	h296k	z56	inner	fuel	-	midplane
2561	p1	h296k	z56	inner	fuel	-	midplane
2562	p2	h296k	z56	inner	fuel	-	midplane
2563	p3	h296k	z56	inner	fuel	-	midplane
2570	p0	h296k	z57	inner	fuel	-	midplane
2571	p1	h296k	z57	inner	fuel	-	midplane
2572	p2	h296k	z57	inner	fuel	-	midplane
2573	p3	h296k	z57	inner	fuel	-	midplane
2580	p0	h296k	z58	inner	fuel	-	midplane
2581	p1	h296k	z58	inner	fuel	-	midplane
2582	p2	h296k	z58	inner	fuel	-	midplane
2583	p3	h296k	z58	inner	fuel	-	midplane
2590	p0	h296k	z59	inner	fuel	-	midplane
2591	p1	h296k	z59	inner	fuel	-	midplane
2592	p2	h296k	z59	inner	fuel	-	midplane
2593	p3	h296k	z59	inner	fuel	-	midplane
2600	p0	h296k	z60	outer	fuel	-	midplane
2601	p1	h296k	z60	outer	fuel	-	midplane
2602	p2	h296k	z60	outer	fuel	-	midplane
2603	p3	h296k	z60	outer	fuel	-	midplane
2610	p0	h296k	z61	outer	fuel	-	midplane
2611	p1	h296k	z61	outer	fuel	-	midplane
2612	p2	h296k	z61	outer	fuel	-	midplane
2613	p3	h296k	z61	outer	fuel	-	midplane
2620	p0	h296k	z62	outer	fuel	-	midplane
2621	p1	h296k	z62	outer	fuel	-	midplane
2622	p2	h296k	z62	outer	fuel	-	midplane
2623	p3	h296k	z62	outer	fuel	-	midplane
2630	p0	h296k	z63	outer	fuel	-	midplane
2631	p1	h296k	z63	outer	fuel	-	midplane
2632	p2	h296k	z63	outer	fuel	-	midplane
2633	p3	h296k	z63	outer	fuel	-	midplane
2640	p0	h296k	z64	outer	fuel	-	midplane
2641	p1	h296k	z64	outer	fuel	-	midplane
2642	p2	h296k	z64	outer	fuel	-	midplane
2643	p3	h296k	z64	outer	fuel	-	midplane
2650	p0	h296k	z65	outer	fuel	-	midplane
2651	p1	h296k	z65	outer	fuel	-	midplane
2652	p2	h296k	z65	outer	fuel	-	midplane
2653	p3	h296k	z65	outer	fuel	-	midplane
2660	p0	h296k	z66	outer	fuel	-	midplane
2661	p1	h296k	z66	outer	fuel	-	midplane
2662	p2	h296k	z66	outer	fuel	-	midplane
2663	p3	h296k	z66	outer	fuel	-	midplane
2670	p0	h296k	z67	outer	fuel	-	midplane
2671	p1	h296k	z67	outer	fuel	-	midplane
2672	p2	h296k	z67	outer	fuel	-	midplane
2673	p3	h296k	z67	outer	fuel	-	midplane
2680	p0	h296k	z68	outer	fuel	-	midplane
2681	p1	h296k	z68	outer	fuel	-	midplane
2682	p2	h296k	z68	outer	fuel	-	midplane
2683	p3	h296k	z68	outer	fuel	-	midplane

Following is the input listing for the discrete ordinates system required to run the DORT case for the HFIR beginning-of-life configuration described in this report:

```
=gip
  hfir 85 mwe r-z model - boc gip xs - 296k h in all areas 12/18/91
1$ 57 3 28 84 0 0 128 128 0 3 1 0 2 e t
13$ 2i 2010 2013 2i 2020 2023 2i 2180 2183 2i 2190 2193
    2i 2200 2203 2i 2210 2213 2i 2230 2233 2i 2240 2243
    2i 2300 2303 2i 2410 2413 2i 2420 2423 2i 2430 2433
    2i 2440 2443 2i 2450 2453 2i 2510 2513 2i 2520 2523
    2i 2530 2533 2i 2540 2543 2i 2550 2553 2i 2560 2563
    2i 2570 2573 2i 2580 2583 2i 2590 2593 2i 2600 2603
    2i 2610 2613 2i 2620 2623 2i 2630 2633 2i 2640 2643
    2i 2650 2653 2i 2660 2663 2i 2670 2673 2i 2680 2683

t
=dort
  hfir 85 mwe r-z model - boc k-calc - run 92 - h-296k-all 12/18/91
61$ 0 44 8 0 e
62$ 0 1 68 76 97 57 3 28 84 0 49 0 128 0 16
    1 1 0 0 0 1 -1 0 4 1 1 0 2z 0
    4z 0 -1 0 2r 1 0 5z e
62$ a21 66 4s 2 2z 3 e
62$ a62 -1 400 400 1 e
63** 145.0 1.0 1.0-4 1.0-6 1.0-6 e
63** a17 5.0-3 e

t
t
81** 0.0 2r 8.3333-2 q3 q2 q8
82** -.47140 -.33333 .33333
    -.94281 -.88192 -.33333 .33333 .88192 q8
83** 3r -.88192 5r -.33333 3r .88192 5r .33333

t
1** 0.01910 0.19646 0.22405 0.12658 0.16461 0.17281
    0.08288 0.01254 0.00090 0.00007 f 0.0
2** 7i -60.82 2i -39.82 -36.00 1i -35.55 1i -33.20 -30.40
    1i -29.39 -26.59 -25.40 -25.0825 8i -24.50 1i -15.50
    -14.03 1i -13.97 8i -12.50 -3.50 -2.73 -1.27 -0.40
    0.40 1.27 2.73 8i 3.50 1i 12.50 13.97 1i 14.03
    8i 15.50 24.50 25.0825 25.40 1i 26.59 29.39 1i 30.40
    1i 33.20 35.55 2i 36.00 7i 39.82 60.82
4** 0.0 3i 0.887 3i 3.547 1i 6.40 7.14 7.15 4i 7.50 12.50
    12.59 12.60 13.34 14.41 15.15 15.16 4i 15.50 20.50
    20.99 21.00 21.7678 3i 22.0238 1i 22.6588 3i 22.9868
    23.6218 23.9668 9i 24.1268 9i 32.9764 9i 53.9764 78.9764
31$ 1 2 6 16 12 11
    17 18 2i 7 10 19 20 22 21 43 42 24 25 26
    2r 27 2r 28 29 30 31 45 23 44 7i 51 59 7i 60 68
32** 3r 22.0238 3r 22.9868
    2r 0.0 2r 7.14 2r 15.15 12.60 6.40 21.00 3.547 0.0
    0.887 2r 0.0 21.7678 22.0238 22.6588 22.9868
    23.6218 23.9668 22.0238 22.9868 2r 24.1268 32.9764
    7.14 7.15 4i 7.50 12.50 12.59
    15.15 15.16 4i 15.50 20.50 20.99
33** 3r 22.6588 3r 23.6218
    2r 21.7678 2r 12.60 2r 21.00 15.15 7.14 21.7678 6.40
    0.887 3r 3.547 22.0238 22.6588 22.9868 23.6218 23.9668
    24.1268 22.6588 23.6218 78.9764 32.9764 53.9764
    7.15 4i 7.50 12.50 12.59 12.60
    15.16 4i 15.50 20.50 20.99 21.00
34** -60.82 -13.97 -1.27 -60.82 1.27 13.97 -60.82 25.40
    -30.40 25.40 q2 3r -30.40 3r -25.40 -39.82 25.40 -60.82
    39.82 4r -60.82 -1.27 2r -60.82 2r -30.40 18r -25.40
35** -13.97 -1.27 60.82 1.27 13.97 60.82 -25.40 60.82
    -25.40 30.40 q2 3r 30.40 3r 25.40 -25.40 39.82
    3r 60.82 -39.82 3r 60.82 1.27 60.82 2r 30.40 18r 25.40
9$ 1 4r 5 33 4r 13 1 4r 5 33 2r 9 37 17 21 17
    25 2r 29 3r 9 17 12r 33 9 45 49 53
    5r 33 7i 57 89 7i 93 125
28$ 39r 3 18z
29$ 49
30$ 4
t
```

```
93** 11z 9r 1.0 3z 9r 1.0 f 0.0 t
94** 20z 57r 1.0 20z t
95** 0.01910 0.19646 0.22405 0.12658 0.16461 0.17281
      0.08288 0.01254 0.00090 0.00007 f 0.0 t
=end
```

Following is a listing of the cross-section ID numbers used in the HFIR end-of-life DORT calculation and a brief description of the material corresponding to these ID numbers:

<u>ID</u>	<u>DESCRIPTION</u>
1010	p0 eoc z 1 control areas - eu
1011	p1 eoc z 1 control areas - eu
1020	p0 eoc z 2 control areas - ta
1021	p1 eoc z 2 control areas - ta
1030	p0 eoc z 9 control areas - al-h2o
1031	p1 eoc z 9 control areas - al-h2o
1040	p0 eoc z 19 al - h2o
1041	p1 eoc z 19 al - h2o
1050	p0 eoc z 20 side plates & h2o - fuel
1051	p1 eoc z 20 side plates & h2o - fuel
1060	p0 eoc z 21 side plates & h2o - target
1061	p1 eoc z 21 side plates & h2o - target
1070	p0 eoc z 23 removable beryllium
1071	p1 eoc z 23 removable beryllium
1080	p0 eoc z 24 target extension
1081	p1 eoc z 24 target extension
1090	p0 eoc z 30 side plates & h2o - control
1091	p1 eoc z 30 side plates & h2o - control
1100	p0 eoc z 41 side plates & h2o - fuel*
1101	p1 eoc z 41 side plates & h2o - fuel*
1110	p0 eoc z 42 target
1111	p1 eoc z 42 target
1120	p0 eoc z 43 side plates & h2o - target*
1121	p1 eoc z 43 side plates & h2o - target*
1130	p0 eoc z 44 permanent beryllium
1131	p1 eoc z 44 permanent beryllium
1140	p0 eoc z 45 h2o pool
1141	p1 eoc z 45 h2o pool
1150	p0 eoc z 18 h2o - core area
1151	p1 eoc z 18 h2o - core area
1210	p0 eoc z 51 inner fuel - midplane
1211	p1 eoc z 51 inner fuel - midplane
1220	p0 eoc z 52 inner fuel - midplane
1221	p1 eoc z 52 inner fuel - midplane
1230	p0 eoc z 53 inner fuel - midplane
1231	p1 eoc z 53 inner fuel - midplane
1240	p0 eoc z 54 inner fuel - midplane
1241	p1 eoc z 54 inner fuel - midplane
1250	p0 eoc z 55 inner fuel - midplane
1251	p1 eoc z 55 inner fuel - midplane
1260	p0 eoc z 56 inner fuel - midplane
1261	p1 eoc z 56 inner fuel - midplane
1270	p0 eoc z 57 inner fuel - midplane
1271	p1 eoc z 57 inner fuel - midplane
1280	p0 eoc z 58 inner fuel - midplane
1281	p1 eoc z 58 inner fuel - midplane
1290	p0 eoc z 59 inner fuel - midplane
1291	p1 eoc z 59 inner fuel - midplane
1310	p0 eoc z 60 outer fuel - midplane
1311	p1 eoc z 60 outer fuel - midplane
1320	p0 eoc z 61 outer fuel - midplane
1321	p1 eoc z 61 outer fuel - midplane
1330	p0 eoc z 62 outer fuel - midplane
1331	p1 eoc z 62 outer fuel - midplane
1340	p0 eoc z 63 outer fuel - midplane
1341	p1 eoc z 63 outer fuel - midplane
1350	p0 eoc z 64 outer fuel - midplane
1351	p1 eoc z 64 outer fuel - midplane
1360	p0 eoc z 65 outer fuel - midplane
1361	p1 eoc z 65 outer fuel - midplane
1370	p0 eoc z 66 outer fuel - midplane
1371	p1 eoc z 66 outer fuel - midplane
1380	p0 eoc z 67 outer fuel - midplane
1381	p1 eoc z 67 outer fuel - midplane
1390	p0 eoc z 68 outer fuel - midplane
1391	p1 eoc z 68 outer fuel - midplane
1410	p0 eoc z 71 inner fuel - inner axial

1411	p1	eoc	z	71	inner	fuel	-	inner	axial
1420	p0	eoc	z	72	inner	fuel	-	inner	axial
1421	p1	eoc	z	72	inner	fuel	-	inner	axial
1430	p0	eoc	z	73	inner	fuel	-	inner	axial
1431	p1	eoc	z	73	inner	fuel	-	inner	axial
1440	p0	eoc	z	74	inner	fuel	-	inner	axial
1441	p1	eoc	z	74	inner	fuel	-	inner	axial
1450	p0	eoc	z	75	inner	fuel	-	inner	axial
1451	p1	eoc	z	75	inner	fuel	-	inner	axial
1460	p0	eoc	z	76	inner	fuel	-	inner	axial
1461	p1	eoc	z	76	inner	fuel	-	inner	axial
1470	p0	eoc	z	77	inner	fuel	-	inner	axial
1471	p1	eoc	z	77	inner	fuel	-	inner	axial
1480	p0	eoc	z	78	inner	fuel	-	inner	axial
1481	p1	eoc	z	78	inner	fuel	-	inner	axial
1490	p0	eoc	z	79	inner	fuel	-	inner	axial
1491	p1	eoc	z	79	inner	fuel	-	inner	axial
1510	p0	eoc	z	80	outer	fuel	-	inner	axial
1511	p1	eoc	z	80	outer	fuel	-	inner	axial
1520	p0	eoc	z	81	outer	fuel	-	inner	axial
1521	p1	eoc	z	81	outer	fuel	-	inner	axial
1530	p0	eoc	z	82	outer	fuel	-	inner	axial
1531	p1	eoc	z	82	outer	fuel	-	inner	axial
1540	p0	eoc	z	83	outer	fuel	-	inner	axial
1541	p1	eoc	z	83	outer	fuel	-	inner	axial
1550	p0	eoc	z	84	outer	fuel	-	inner	axial
1551	p1	eoc	z	84	outer	fuel	-	inner	axial
1560	p0	eoc	z	85	outer	fuel	-	inner	axial
1561	p1	eoc	z	85	outer	fuel	-	inner	axial
1570	p0	eoc	z	86	outer	fuel	-	inner	axial
1571	p1	eoc	z	86	outer	fuel	-	inner	axial
1580	p0	eoc	z	87	outer	fuel	-	inner	axial
1581	p1	eoc	z	87	outer	fuel	-	inner	axial
1590	p0	eoc	z	88	outer	fuel	-	inner	axial
1591	p1	eoc	z	88	outer	fuel	-	inner	axial
1610	p0	eoc	z	91	inner	fuel	-	outer	axial
1611	p1	eoc	z	91	inner	fuel	-	outer	axial
1620	p0	eoc	z	92	inner	fuel	-	outer	axial
1621	p1	eoc	z	92	inner	fuel	-	outer	axial
1630	p0	eoc	z	93	inner	fuel	-	outer	axial
1631	p1	eoc	z	93	inner	fuel	-	outer	axial
1640	p0	eoc	z	94	inner	fuel	-	outer	axial
1641	p1	eoc	z	94	inner	fuel	-	outer	axial
1650	p0	eoc	z	95	inner	fuel	-	outer	axial
1651	p1	eoc	z	95	inner	fuel	-	outer	axial
1660	p0	eoc	z	96	inner	fuel	-	outer	axial
1661	p1	eoc	z	96	inner	fuel	-	outer	axial
1670	p0	eoc	z	97	inner	fuel	-	outer	axial
1671	p1	eoc	z	97	inner	fuel	-	outer	axial
1680	p0	eoc	z	98	inner	fuel	-	outer	axial
1681	p1	eoc	z	98	inner	fuel	-	outer	axial
1690	p0	eoc	z	99	inner	fuel	-	outer	axial
1691	p1	eoc	z	99	inner	fuel	-	outer	axial
1710	p0	eoc	z	100	outer	fuel	-	outer	axial
1711	p1	eoc	z	100	outer	fuel	-	outer	axial
1720	p0	eoc	z	101	outer	fuel	-	outer	axial
1721	p1	eoc	z	101	outer	fuel	-	outer	axial
1730	p0	eoc	z	102	outer	fuel	-	outer	axial
1731	p1	eoc	z	102	outer	fuel	-	outer	axial
1740	p0	eoc	z	103	outer	fuel	-	outer	axial
1741	p1	eoc	z	103	outer	fuel	-	outer	axial
1750	p0	eoc	z	104	outer	fuel	-	outer	axial
1751	p1	eoc	z	104	outer	fuel	-	outer	axial
1760	p0	eoc	z	105	outer	fuel	-	outer	axial
1761	p1	eoc	z	105	outer	fuel	-	outer	axial
1770	p0	eoc	z	106	outer	fuel	-	outer	axial
1771	p1	eoc	z	106	outer	fuel	-	outer	axial
1780	p0	eoc	z	107	outer	fuel	-	outer	axial
1781	p1	eoc	z	107	outer	fuel	-	outer	axial
1790	p0	eoc	z	108	outer	fuel	-	outer	axial
1791	p1	eoc	z	108	outer	fuel	-	outer	axial

Following is the input listing for the discrete ordinates system required to run the DORT case for the HFIR end-of-life configuration described in this report:

```
=gip
  hfir 85 mwe r-z model - eoc gip xs 10/04/91
1$ 39 3 28 67 0 0 138 138 0 1 1 0 2 e t
13$ 1010 1011 1020 1021 1030 1031 1040 1041 1050 1051
    1060 1061 1070 1071 1080 1081 1090 1091 1100 1101
    1110 1111 1120 1121 1130 1131 1140 1141 1150 1151
    1210 1211 1220 1221 1230 1231 1240 1241 1250 1251
    1260 1261 1270 1271 1280 1281 1290 1291
    1310 1311 1320 1321 1330 1331 1340 1341 1350 1351
    1360 1361 1370 1371 1380 1381 1390 1391
    1410 1411 1420 1421 1430 1431 1440 1441 1450 1451
    1460 1461 1470 1471 1480 1481 1490 1491
    1510 1511 1520 1521 1530 1531 1540 1541 1550 1551
    1560 1561 1570 1571 1580 1581 1590 1591
    1610 1611 1620 1621 1630 1631 1640 1641 1650 1651
    1660 1661 1670 1671 1680 1681 1690 1691
    1710 1711 1720 1721 1730 1731 1740 1741 1750 1751
    1760 1761 1770 1771 1780 1781 1790 1791

t
=dort
  hfir 85 mwe r-z model - eoc k-calc - run 01 - base case 10/04/91
61$ 0 44 8 0 e
62$ 0 1 108 76 69 39 3 28 67 0 117 0 138 0 16
    1 1 0 0 0 1 -1 0 4 1 1 0 2z 0
    4z 0 -1 0 2r 1 0 5z e
62$ a21 77 4s 2 2z 3 e
62$ a62 -1 400 400 1 e
63** 144.0 1.0 1.0-4 1.0-6 1.0-6 e
63** a17 5.0-3 e

t
81** 0.0 2r 8.3333-2 q3 q2 q8
82** -.47140 -.33333 .33333
    -.94281 -.88192 -.33333 .33333 .88192 q8
83** 3r -.88192 5r -.33333 3r .88192 5r .33333

t
1** 0.01910 0.19646 0.22405 0.12658 0.16461 0.17281
    0.08288 0.01254 0.00090 0.00007 f 0.0
2** 9i -60.82 3i -37.55 3i -30.48 1i -25.40 1i -24.85
    1i -22.75 20i -21.0 1i 21.0 1i 22.75 1i 24.85
    3i 25.40 3i 30.48 9i 37.55 60.82
4** 0.0 3i 0.887 3i 3.547 1i 6.40 7.14 7.15 4i 7.50 12.50
    12.59 12.60 13.34 14.41 15.15 15.16 4i 15.50 20.50
    20.99 21.00 21.7678 3i 22.0238 1i 22.6588 3i 22.9868
    23.6218 23.9668 9i 24.1268 9i 32.9764 9i 53.9764 78.9764
31$ 1 2 6 16 12 11
    17 18 2i 7 10 19 20 22 21 43 42 24 25 26
    27 28 29 45 23 44 7i 51 59 7i 60 68
    7i 71 79 7i 80 88 q18 7i 91 99 7i 100 108 q18
32** 3r 22.0238 3r 22.9868
    2r 0.0 2r 7.14 2r 15.15 12.60 6.40 21.00 3.547 0.0
    0.887 2r 0.0 21.7678 22.6588
    23.6218 23.9668 2r 24.1268 32.9764
    7.14 7.15 4i 7.50 12.50 12.59
    15.15 15.16 4i 15.50 20.50 20.99 4q18
    3r 22.6588 3r 23.6218
33** 2r 21.7678 2r 12.60 2r 21.00 15.15 7.14 21.7678 6.40
    0.887 3r 3.547 22.0238 22.9868 23.9668
    24.1268 78.9764 32.9764 53.9764
    7.15 4i 7.50 12.50 12.59 12.60
    15.16 4i 15.50 20.50 20.99 21.00 4q18
34** -60.82 -37.55 -24.85 -60.82 24.85 37.55 -60.82 25.40
    -30.40 25.40 q2 3r -30.40 3r -25.40 -37.55 25.40 -60.82
    3r -60.82 -60.82 2r -30.40 18r -25.40
    18r -24.85 18r 22.75 18r -25.40 18r 24.85
35** -37.55 -24.85 60.82 24.85 37.55 60.82 -25.40 60.82
    -25.40 30.40 q2 3r 30.40 3r 25.40 -25.40 37.55
    2r 60.82 2r 60.82 60.82 2r 30.40 18r 22.75
    18r -22.75 18r 24.85 18r -24.85 18r 25.40
```

```

9$$ 1 4r 3 5 4r 7 1 4r 3 5 2r 29 19 9 11 9
    13 2r 15 3r 5 9 12r 17 21 23 25 27
    5r 17 7i 31 47 7i 49 65 2r 27
    7i 67 83 7i 85 101 2r 27 7i 103 119 7i 121 137
28$$ f 3
29$$ 49
30$$ 4
    t
93** 11z 9r 1.0 3z 9r 1.0 f 0.0 t
94** 18z 33r 1.0 18z t
95** 0.01910 0.19646 0.22405 0.12658 0.16461 0.17281
    0.08288 0.01254 0.00090 0.00007 f 0.0 t
=end

```


Following is a listing of the cross-section ID numbers used in the HFIR xenon equilibrium DORT calculation and a brief description of the material corresponding to these ID numbers:

<u>ID</u>	<u>DESCRIPTION</u>
1010	p0 29h z 1 control areas - eu
1011	p1 29h z 1 control areas - eu
1020	p0 29h z 2 control areas - ta
1021	p1 29h z 2 control areas - ta
1030	p0 29h z 9 control areas - al-h2o
1031	p1 29h z 9 control areas - al-h2o
1040	p0 29h z 19 al - h2o
1041	p1 29h z 19 al - h2o
1050	p0 29h z 20 side plates & h2o - fuel
1051	p1 29h z 20 side plates & h2o - fuel
1060	p0 29h z 21 side plates & h2o - target
1061	p1 29h z 21 side plates & h2o - target
1070	p0 29h z 23 removable beryllium
1071	p1 29h z 23 removable beryllium
1080	p0 29h z 24 target extension
1081	p1 29h z 24 target extension
1090	p0 29h z 30 side plates & h2o - control
1091	p1 29h z 30 side plates & h2o - control
1100	p0 29h z 41 side plates & h2o - fuel*
1101	p1 29h z 41 side plates & h2o - fuel*
1110	p0 29h z 42 target
1111	p1 29h z 42 target
1120	p0 29h z 43 side plates & h2o - target*
1121	p1 29h z 43 side plates & h2o - target*
1130	p0 29h z 44 permanent beryllium
1131	p1 29h z 44 permanent beryllium
1140	p0 29h z 45 h2o pool
1141	p1 29h z 45 h2o pool
1150	p0 29h z 18 h2o - core area
1151	p1 29h z 18 h2o - core area
1210	p0 29h z 51 inner fuel - midplane
1211	p1 29h z 51 inner fuel - midplane
1220	p0 29h z 52 inner fuel - midplane
1221	p1 29h z 52 inner fuel - midplane
1230	p0 29h z 53 inner fuel - midplane
1231	p1 29h z 53 inner fuel - midplane
1240	p0 29h z 54 inner fuel - midplane
1241	p1 29h z 54 inner fuel - midplane
1250	p0 29h z 55 inner fuel - midplane
1251	p1 29h z 55 inner fuel - midplane
1260	p0 29h z 56 inner fuel - midplane
1261	p1 29h z 56 inner fuel - midplane
1270	p0 29h z 57 inner fuel - midplane
1271	p1 29h z 57 inner fuel - midplane
1280	p0 29h z 58 inner fuel - midplane
1281	p1 29h z 58 inner fuel - midplane
1290	p0 29h z 59 inner fuel - midplane
1291	p1 29h z 59 inner fuel - midplane
1310	p0 29h z 60 outer fuel - midplane
1311	p1 29h z 60 outer fuel - midplane
1320	p0 29h z 61 outer fuel - midplane
1321	p1 29h z 61 outer fuel - midplane
1330	p0 29h z 62 outer fuel - midplane
1331	p1 29h z 62 outer fuel - midplane
1340	p0 29h z 63 outer fuel - midplane
1341	p1 29h z 63 outer fuel - midplane
1350	p0 29h z 64 outer fuel - midplane
1351	p1 29h z 64 outer fuel - midplane
1360	p0 29h z 65 outer fuel - midplane
1361	p1 29h z 65 outer fuel - midplane
1370	p0 29h z 66 outer fuel - midplane
1371	p1 29h z 66 outer fuel - midplane
1380	p0 29h z 67 outer fuel - midplane
1381	p1 29h z 67 outer fuel - midplane
1390	p0 29h z 68 outer fuel - midplane

1391	p1 29h z 68	outer fuel - midplane
1410	p0 29h z 71	inner fuel - inner axial
1411	p1 29h z 71	inner fuel - inner axial
1420	p0 29h z 72	inner fuel - inner axial
1421	p1 29h z 72	inner fuel - inner axial
1430	p0 29h z 73	inner fuel - inner axial
1431	p1 29h z 73	inner fuel - inner axial
1440	p0 29h z 74	inner fuel - inner axial
1441	p1 29h z 74	inner fuel - inner axial
1450	p0 29h z 75	inner fuel - inner axial
1451	p1 29h z 75	inner fuel - inner axial
1460	p0 29h z 76	inner fuel - inner axial
1461	p1 29h z 76	inner fuel - inner axial
1470	p0 29h z 77	inner fuel - inner axial
1471	p1 29h z 77	inner fuel - inner axial
1480	p0 29h z 78	inner fuel - inner axial
1481	p1 29h z 78	inner fuel - inner axial
1490	p0 29h z 79	inner fuel - inner axial
1491	p1 29h z 79	inner fuel - inner axial
1510	p0 29h z 80	outer fuel - inner axial
1511	p1 29h z 80	outer fuel - inner axial
1520	p0 29h z 81	outer fuel - inner axial
1521	p1 29h z 81	outer fuel - inner axial
1530	p0 29h z 82	outer fuel - inner axial
1531	p1 29h z 82	outer fuel - inner axial
1540	p0 29h z 83	outer fuel - inner axial
1541	p1 29h z 83	outer fuel - inner axial
1550	p0 29h z 84	outer fuel - inner axial
1551	p1 29h z 84	outer fuel - inner axial
1560	p0 29h z 85	outer fuel - inner axial
1561	p1 29h z 85	outer fuel - inner axial
1570	p0 29h z 86	outer fuel - inner axial
1571	p1 29h z 86	outer fuel - inner axial
1580	p0 29h z 87	outer fuel - inner axial
1581	p1 29h z 87	outer fuel - inner axial
1590	p0 29h z 88	outer fuel - inner axial
1591	p1 29h z 88	outer fuel - inner axial
1610	p0 29h z 91	inner fuel - outer axial
1611	p1 29h z 91	inner fuel - outer axial
1620	p0 29h z 92	inner fuel - outer axial
1621	p1 29h z 92	inner fuel - outer axial
1630	p0 29h z 93	inner fuel - outer axial
1631	p1 29h z 93	inner fuel - outer axial
1640	p0 29h z 94	inner fuel - outer axial
1641	p1 29h z 94	inner fuel - outer axial
1650	p0 29h z 95	inner fuel - outer axial
1651	p1 29h z 95	inner fuel - outer axial
1660	p0 29h z 96	inner fuel - outer axial
1661	p1 29h z 96	inner fuel - outer axial
1670	p0 29h z 97	inner fuel - outer axial
1671	p1 29h z 97	inner fuel - outer axial
1680	p0 29h z 98	inner fuel - outer axial
1681	p1 29h z 98	inner fuel - outer axial
1690	p0 29h z 99	inner fuel - outer axial
1691	p1 29h z 99	inner fuel - outer axial
1710	p0 29h z 100	outer fuel - outer axial
1711	p1 29h z 100	outer fuel - outer axial
1720	p0 29h z 101	outer fuel - outer axial
1721	p1 29h z 101	outer fuel - outer axial
1730	p0 29h z 102	outer fuel - outer axial
1731	p1 29h z 102	outer fuel - outer axial
1740	p0 29h z 103	outer fuel - outer axial
1741	p1 29h z 103	outer fuel - outer axial
1750	p0 29h z 104	outer fuel - outer axial
1751	p1 29h z 104	outer fuel - outer axial
1760	p0 29h z 105	outer fuel - outer axial
1761	p1 29h z 105	outer fuel - outer axial
1770	p0 29h z 106	outer fuel - outer axial
1771	p1 29h z 106	outer fuel - outer axial
1780	p0 29h z 107	outer fuel - outer axial
1781	p1 29h z 107	outer fuel - outer axial
1790	p0 29h z 108	outer fuel - outer axial
1791	p1 29h z 108	outer fuel - outer axial

Following is the input listing for the discrete ordinates system required to run the DORT case for the HFIR xenon equilibrium configuration described in this report:

```
=gip
hfir 85 mwe r-z model - 29 hrs(1.2 days) gip x-s 11/26/91
1$$ 39 3 28 67 0 0 138 138 0 1 1 0 2 e t
13$$ 1010 1011 1020 1021 1030 1031 1040 1041 1050 1051
1060 1061 1070 1071 1080 1081 1090 1091 1100 1101
1110 1111 1120 1121 1130 1131 1140 1141 1150 1151
1210 1211 1220 1221 1230 1231 1240 1241 1250 1251
1260 1261 1270 1271 1280 1281 1290 1291
1310 1311 1320 1321 1330 1331 1340 1341 1350 1351
1360 1361 1370 1371 1380 1381 1390 1391
1410 1411 1420 1421 1430 1431 1440 1441 1450 1451
1460 1461 1470 1471 1480 1481 1490 1491
1510 1511 1520 1521 1530 1531 1540 1541 1550 1551
1560 1561 1570 1571 1580 1581 1590 1591
1610 1611 1620 1621 1630 1631 1640 1641 1650 1651
1660 1661 1670 1671 1680 1681 1690 1691
1710 1711 1720 1721 1730 1731 1740 1741 1750 1751
1760 1761 1770 1771 1780 1781 1790 1791

t
=dort
hfir 85 mwe r-z model - 29h k-calc - run 01 - 296k h bc 11/26/91
61$$ 0 44 8 0 e
62$$ 0 1 108 76 71 39 3 28 67 0 117 0 138 0 16
1 1 0 0 0 1 -1 0 4 1 1 0 2z 0
4z 0 -1 0 2r 1 0 5z e
62$$ a21 77 4s 2 2z 3 e
62$$ a62 -1 400 400 1 e
63** 144.0 1.0 1.0-4 1.0-6 1.0-6 e
63** a17 5.0-3 e

t
t
81** 0.0 2r 8.3333-2 q3 q2 q8
82** -.47140 -.33333 .33333
-.94281 -.88192 -.33333 .33333 .88192 q8
83** 3r -.88192 5r -.33333 3r .88192 5r .33333

t
1** 0.01910 0.19646 0.22405 0.12658 0.16461 0.17281
0.08288 0.01254 0.00090 0.00007 f 0.0
2** 9i -60.82 3i -37.55 3i -30.48 1i -25.40
1i -24.85 1i -22.75 4i -21.0 -11.0 -10.05 8i -9.0
9.0 10.05 4i 11.0 1i 21.0 1i 22.75 1i 24.85
3i 25.40 3i 30.48 9i 37.55 60.82
4** 0.0 3i 0.887 3i 3.547 1i 6.40 7.14 7.15 4i 7.50 12.50
12.59 12.60 13.34 14.41 15.15 15.16 4i 15.50 20.50
20.99 21.00 21.7678 3i 22.0238 1i 22.6588 3i 22.9868
23.6218 23.9668 9i 24.1268 9i 32.9764 9i 53.9764 78.9764
31$$ 1 2 6 16 12 11
17 18 2i 7 10 19 20 22 21 43 42 24 25 26
27 28 29 45 23 44 7i 51 59 7i 60 68
7i 71 79 7i 80 88 q18 7i 91 99 7i 100 108 q18
32** 3r 22.0238 3r 22.9868
2r 0.0 2r 7.14 2r 15.15 12.60 6.40 21.00 3.547 0.0
0.887 2r 0.0 21.7678 22.6588
23.6218 23.9668 2r 24.1268 32.9764
7.14 7.15 4i 7.50 12.50 12.59
15.15 15.16 4i 15.50 20.50 20.99 4q18
33** 3r 22.6588 3r 23.6218
2r 21.7678 2r 12.60 2r 21.00 15.15 7.14 21.7678 6.40
0.887 3r 3.547 22.0238 22.9868 23.9668
24.1268 78.9764 32.9764 53.9764
7.15 4i 7.50 12.50 12.59 12.60
15.16 4i 15.50 20.50 20.99 21.00 4q18
34** -60.82 -22.75 -10.05 -60.82 10.05 22.75 -60.82 25.40
-30.40 25.40 q2 3r -30.40 3r -25.40 -37.55 25.40 -60.82
3r -60.82 -60.82 2r -30.40 18r -25.40
18r -24.85 18r 22.75 18r -25.40 18r 24.85
35** -22.75 -10.05 60.82 10.05 22.75 60.82 -25.40 60.82
-25.40 30.40 q2 3r 30.40 3r 25.40 -25.40 37.55
2r 60.82 2r 60.82 60.82 2r 30.40 18r 22.75
```

```

18r -22.75 18r 24.85 18r -24.85 18r 25.40
9$$ 1 4r 3 5 4r 7 1 4r 3 5 2r 29 19 9 11 9
13 2r 15 3r 5 9 12r 17 21 23 25 27
5r 17 7i 31 47 7i 49 65 2r 27
7i 67 83 7i 85 101 2r 27 7i 103 119 7i 121 137
28$$ f 3
29$$ 49
30$$ 4
t
93** 11z 9r 1.0 3z 9r 1.0 f 0.0 t
94** 18z 35r 1.0 18z t
95** 0.01910 0.19646 0.22405 0.12658 0.16461 0.17281
0.08288 0.01254 0.00090 0.00007 f 0.0 t
=end

```

INTERNAL DISTRIBUTION

1. J. A. Bucholz	20. R. C. Ward
2-6. W. W. Engle, Jr.	21. J. D. White
7. H. A. Glover	22-26. L. R. Williams
8. H. T. Hunter	27-28. Laboratory Records
Department
9. D. T. Ingersoll	29. Laboratory Records,
ORNL-RC
10. G. E. Michaels	30. Document Reference
Section
11. C. E. Oliver	31. Central Research Library
12. J. V. Pace, III	32. ORNL Patent Section
13-17. R. B. Rothrock	
18. C. O. Slater	
19. R. R. Spencer	

EXTERNAL DISTRIBUTION

33. R. A. Hunter, Director of Facilities, Fuel Cycle and Test Programs, Office of Nuclear Energy, NE-47, F-424/GTN, Department of Energy, Washington, D. C. 20585
34. Matthew A. Hutmaker, Jr., Office of Nuclear Energy, NE-47, GTN, Department of Energy, Washington, D. C. 20585.
35. William F. Manning, Deputy Assistant Manager, Energy Research and Development, Advanced-Neutron Source, Department of Energy, Oak Ridge Operations, P. O. Box 2001, Oak Ridge, Tennessee 37831-8218.
36. Barry S. Willis, Director, Research Operations Division, Department of Energy, Oak Ridge Operations, Post Office Box 2008, Oak Ridge, Tennessee 37831-6300.
- 37-38. Office of Scientific and Technical Information, U.S. Department of Energy, P.O. Box 62, Oak Ridge, Tennessee 37831.
39. Assistant Manager of Energy Research and Development, DOE-ORO, P.O. Box 2008, Oak Ridge, TN 37831-6269