135
4/15/81
T.S.

(1)

R-3560

Dr. 2329

MASTER

Y-2234

UCC-ND

**NUCLEAR
DIVISION**

VALIDATION OF
THE MONTE CARLO CRITICALITY PROGRAM KENO IV
AND
THE HANSEN-ROACH
SIXTEEN-ENERGY-GROUP-CROSS SECTIONS
FOR HIGH-ASSAY URANIUM SYSTEMS

G. R. Handley
L. C. Masters
R. V. Stachowiak

April 1981

OPERATED BY
UNION CARBIDE CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

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.

Printed in the United States of America
Available from
National Technical Information Service
U. S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

NTIS price codes
Printed copy: A05
Microfiche copy: A01

— **DISCLAIMER** —

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.

Date of Issue: April 10, 1981
Distribution Category: UC-46

Y-2234

VALIDATION OF
THE MONTE CARLO CRITICALITY PROGRAM KENO IV
AND
THE HANSEN-ROACH
SIXTEEN-ENERGY-GROUP-CROSS SECTIONS
FOR HIGH-ASSAY URANIUM SYSTEMS

G. R. Handley
L. C. Masters
R. V. Stachowiak

Radiation Safety Department
Y-12 Technical Services Division

DISCLAIMER

This book 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.

Oak Ridge Y-12 Plant

P. O. Box Y, Oak Ridge, Tennessee 37830

Prepared for the Department of Energy
Under US Government Contract W-7405-eng 26

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

ABSTRACT

Validation of the Monte Carlo criticality code, KENO-IV, and the Hansen-Roach sixteen-energy-group cross sections was accomplished by calculating the effective neutron multiplication constant, k_{eff} , of 29 experimentally critical assemblies which had uranium enrichments of 92.6% or higher in the uranium-235 isotope. The experiments were chosen so that a large variety of geometries and of neutron energy spectra were covered.

Problems, calculating the k_{eff} of systems with high-uranium-concentration uranyl nitrate solution that were minimally reflected or unreflected, resulted in the separate examination of five cases.

CONTENTS

SUMMARY	4
INTRODUCTION	5
VALIDATION OF A CRITICALITY PROGRAM AND CROSS SECTIONS FOR A HIGH-ASSAY URANIUM SYSTEM	6
Validation	6
Method of Calculation	6
Results of Calculations	7
Conclusions	12
REFERENCES	13
ACKNOWLEDGMENTS	15
APPENDIX A. INPUT PARAMETERS	16
APPENDIX B. CROSS SECTIONS	27
APPENDIX C. NORMALIZED SPECTRA OF NEUTRONS CAUSING FISSION	66

SUMMARY

Validation of the Monte Carlo criticality code, KENO IV, and the Hansen-Roach sixteen-energy-group cross sections was accomplished by calculating the effective neutron multiplication constant, k_{eff} , of 29 experimentally critical assemblies which had uranium enrichments of 92.6% or higher in the uranium-235 (^{235}U) isotope. The experiments were chosen so that a large variety of geometries and of neutron energy spectra were covered.

Problems, calculating the k_{eff} of systems with high-uranium-concentration uranyl nitrate [$\text{UO}_2(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$] that were minimally reflected or unreflected, resulted in the separate examination of five cases. The results of the remaining 24 cases indicated that the previously accepted limit of $k_{eff} = 0.97$ gave a 99% confidence that 99.2% of the distribution of k_{eff} values will lie above the limit. A limit of $k_{eff} = 0.961025$ gave a 99% confidence that 99.9% of the distribution of k_{eff} values will lie above the limit.

Five unresolved cases involving less than fully reflected, high-uranium-concentration uranyl nitrate solutions indicate that this type of problem must be calculated as completely reflected in order to utilize the tolerance limits as stated.

It was concluded that (with the methods presented) the codes and cross sections are adequate for nuclear safety purposes, any $k_{eff} + 2\sigma$ which exceeds the limit must be considered critical, and all lower values may be considered subcritical.

INTRODUCTION

In the criticality safety field, calculative techniques are often used to determine the k_{eff} of a particular system. These calculative methods must each be correlated with experimental data in order to establish a bias which sets a limit on the credibility of a method. The experimental data to which the computations are compared must be selected to reflect the area where the technique is to be used. The chosen data produces a bias relevant only to the type of experiments examined. If the method used is extended into another area, a new bias must be established.

The KENO IV program¹ is a multigroup Monte Carlo criticality program devised by the Oak Ridge National Laboratory (ORNL) which includes several geometry and reflector options which enable complex configurations to be described. The ORNL and a large part of the nuclear industry have used KENO IV extensively since its inception in 1975 and have performed several checks¹⁻³ on the validity of the code, thus establishing its credibility. The possibility that the program or cross sections may be altered, which would also change the bias, requires a strict quality assurance program⁴ to deter such an occurrence. Therefore, the Oak Ridge Y-12 Plant^(a) Criticality Safety Group (CSG) has obtained a version of KENO IV from the ORNL which will be validated by this report and, thereafter, remain under the exclusive control of the CSG.

A total of 29 critical experimental systems were calculated. It was necessary to develop simplified calculative mock-ups since the use of exact representations, while possible with KENO IV, is usually prohibited by time and expense. In order to document the mock-ups, Appendix A includes a listing of the input parameters and Appendix B lists the cross sections.

(a) Operated by the Union Carbide Corporation, Nuclear Division, for the U.S. Department of Energy.

VALIDATION OF A CRITICALITY PROGRAM AND CROSS SECTIONS FOR A HIGH-ASSAY URANIUM SYSTEM

VALIDATION

Method of Calculation

Mock-ups employed the Hansen-Roach⁵ sixteen-energy-group cross sections with the few exceptions noted in Appendix B, where Hansen-Roach cross sections were not available. The uranium cross sections were corrected for resonance self-shielding; and the $X(E)$ weighted-hydrogen cross sections were utilized for systems having a hydrogen-to-uranium atomic ratio < 10 , while the dE/E weighted cross sections were used for ratios > 10 .

The calculations involved 203 batches of 300 neutrons each—of which, the first three batches were skipped to avoid any dependence upon the starting neutron distribution. This results in the tracking of 60,000 neutrons which, because of the large sample size, would give little statistical variation. A large sample size was chosen for the validation because the increased preciseness will better define the bias in the calculational method.

The neutrons were started in a flat distribution across the fissile material for both single units and arrays of similar units. In irregular geometries or when starting problems were encountered, the neutrons were started in a spike at the point in the system which was assumed to have the highest fission density. This technique prevents underestimating k_{eff} because there is a slow upward convergence, but it may slightly overestimate k_{eff} .² To check the validity of the reflector options included in KENO IV, case B-14 was run, utilizing both the automatic reflector and differential albedo options, and compared to the results of an unbiased representation. These options are very desirable because the computer time is greatly reduced. However, using the differential albedo option for arrays with an edge dimension < 100 cm should be avoided as the k_{eff} is overestimated.² A list of validated parameters is shown in Table 1.

Table 1

VALIDATION PARAMETERS

Materials considered:

Uranium metal
Uranium-molybdenum alloy
Uranyl nitrate
Uranyl fluoride

Reflectors considered:

Water	Steel
Graphite	Aluminum
Paraffin	Plexiglas
Oil	Polyethylene
Natural uranium	

Moderators considered:

Water
Oil
Steel
Plexiglas

Geometry packages considered:

A. KENO geometry

1. Single units
2. Arrays
 - a. Spheres
 - b. Cylinders
 - c. Cuboids
 - d. Hemisphere

B. Generalized geometry

Other options considered:

Differential albedo
Automatic reflector

Results of Calculations

The calculated k_{eff} s for the critical systems examined are presented in Table 2 along with a brief description of each system and references to the experiments.⁶⁻²¹ The standard deviation of k_{eff} is based entirely on the statistical analysis of the number of neutrons tracked and their histories and, thus, does not include any uncertainties in cross sections, dimensions, and densities. However, the uncertainties in cross sections is inherent in the program bias since the same cross-section set is always used.

The KENO IV output for each case included a balance table containing values for the system leakage, absorptions, and fissions per neutron energy group. The quantity chosen to examine a possible correlation to k_{eff} , thus establishing the bias, was:

$$\hat{E} = \frac{\sum_{i=1}^{16} i F(i)}{F(\text{total})}, \quad (1)$$

which is the average energy group of neutrons causing fission. This quantity and a spectrum of the neutron energy group causing fission are presented in Appendix C. Inspection of these spectra indicates there are three groups or families.

Family I consists entirely of unreflected metal units having, primarily, fast neutrons in Energy Groups 1 to 6 which cause fission. Cases A-1, -2, -7 and B-1, -2, -3, -4, -5 with average energy groups of 3.27, 3.31, 3.28, 3.25, 3.26, 3.26, 3.25, and 3.25, respectively, are included in this family. The average neutron energy group of Family I is 3.27.

Family II exhibits a bimodal nature. This family also contains all metal units; however, these units are reflected and/or moderated which accounts for the peak in the thermal region. The average neutron energy group of Family II is 6.09; and cases A-5, -6, -8, -9, -10 and B-6, -7, -8, -12 with average neutron energy groups of 7.74, 4.44, 6.93, 6.25, 5.64, 6.53, 6.74, 5.06, and 5.48, respectively, comprise Family II.

A slow neutron energy spectrum depicts the critical systems in Family III. This family contains all solution units both reflected and unreflected. The moderating effect of hydrogen accounts for the slow spectrum. Cases A-3, -4, -11 and B-9, -10, -11, -13, -14, -15, -16, -17, -18 with average neutron energy groups of 15.84, 15.84, 14.39, 14.25, 15.65, 14.11, 14.24, 14.60, 14.33, 13.90, 14.63, and 14.49, respectively, are part of Family III. The slower spectrum is indicated by the family average neutron energy group causing fission (being 14.67).

The calculated k_{eff} values from Table 2 have been plotted in Figure 1. The error bars are ± 1 standard deviation from the calculated k_{eff} . Note that the lower k_{eff} occurs in Family III at lower error bar value (0.96365, 0.96687, 0.96983, 0.98385, and 0.97930), corresponding to cases B-13, -9, -15, -16, and A-11, respectively. A look at Table 1 and the description of

Table 2
KENO CALCULATED k_{eff} RESULTS FOR EXPERIMENTALLY CRITICAL SYSTEMS

Experiment		Reference ⁽¹⁾	$k_{\text{eff}} \pm \sigma$
<u>Single Critical Units</u>			
1.	Unreflected spherical reactor (Godiva 1) of U(93.8), 8.731-cm radius.	6	1.00243 ± 0.00328
2.	Unreflected cylindrical annulus reactor of U(93.2) alloyed to 10 wt % Mo; 2.54-cm IR, 10.16-cm OR, 19.74-cm height.	7	1.00140 ± 0.00304
3.	Unreflected spherical reactor of U(93.2)O ₂ F ₂ and H ₂ O with an H/U-235 = 1,393. Solution radius of 34.6 cm and aluminum-container wall thickness of 0.32 cm.	8	1.01078 ± 0.00234
4.	Unreflected spherical reactor of U(93.18)O ₂ (NO ₃) ₂ and H ₂ O with an H/U-235 = 1,378. Solution radius of 34.6 cm and aluminum-container wall thickness of 0.32 cm.	9	1.00544 ± 0.00247
5.	Reflected hemispherical shell of U(93.5); 12.7-cm IR, 15.24-cm OR, and minimum H ₂ O reflector thickness of 15.2 cm.	10	1.01076 ± 0.00344
6.	Reflected cylindrical annulus reactor of U(93.2); 8.89-cm IR, 13.97-cm OR, and 6.88-cm height with graphite reflector thickness of 17.78 cm and graphite filling the central cavity.	11	1.01423 ± 0.00356
7.	Reflected rectangular prism reactor of U(94); 7.62 cm X 8.89 cm X 15.24 cm with a natural uranium reflector thickness of 22.2 cm.	10	0.99146 ± 0.00278
8.	Reflected hemispherical shell reactor of U(93.1); 6.679-cm IR, 10.5254-cm OR, with extrapolated full oil reflection and oil filling the central cavity.	12	1.00656 ± 0.00322
9.	Reflected hemispherical shell reactor of U(93.1); 6.012-cm IR, 10.488-cm OR with extrapolated full oil reflection and steel filling the central cavity.	12	1.00117 ± 0.00347
10.	Water-reflected U(97.67) sphere; 6.5537-cm radius.	13	0.99245 ± 0.00347
11.	Unreflected stainless steel cylindrical unit of uranyl nitrate with a concentration of 346.73-g U(93.17) per-liter. Cylinder dimensions were 14.28-cm OR, 42.24-cm height, and 0.32- and 0.64-cm-thick walls on the side and bottom respectively, critical solution height of 28.93 cm.	14	0.98342 ± 0.00412
<u>Critical Arrays</u>			
1.	Unreflected U(93.2) cylindrical annulus; 13.97-cm IR, 19.05-cm OR, 10.11-cm height with a U(93.2) cylinder, an 8.89-cm radius, and a 10.11-cm height, located in its central cavity touching the wall; the annulus and cylinder axes were parallel.	15	1.00001 ± 0.00323
2.	Unreflected U(93.2) cylindrical annulus; 13.97-cm IR, 19.05-cm OR, 12.98-cm height, with a U(93.2) rectangular prism, 12.70 cm X 12.70 cm X 12.98-cm height, located in its central cavity touching the wall with two edges.	15	0.99896 ± 0.00352
3.	Unreflected U(93.2) pieces of various geometries, arranged approximately as a circle with a center piece. Critical mass of 206.5 kgs U(93.2).	15	1.00097 ± 0.00339
4.	Cubic array of 27 U(93.2) cylinders. The average dimensions of the cylinders were: a 5.7545-cm radius, a 5.382-cm height, and a 10.484-kg mass. Unmoderated and unreflected. Using the notation of Thomas, this array is described: (2)	16	0.98460 ± 0.00306

$$A_{27}^2 [0; 2.007; 7.767; 0.55].$$

Table 2 (continued)

	Experiment	Reference ⁽¹⁾	$k_{\text{eff}} \pm \sigma$
5.	Cubic array of 8 U(93.2) stacked cylinder units. Each stacked cylinder unit consists of one Type E ³ cylinder stacked coaxially with and between two Type E ¹ cylinders. The average dimensions of a Type E ³ cylinder were 4.558-cm radius, 4.320-cm height, and 5.254-kg mass. The average dimensions of a Type E ¹ cylinder were 5.747-cm radius, 2.691-cm height, and 5.225-kg mass. Unmoderated and unreflected. Described as: $B_8^3 [0; 0.229; 11.497; 0.85]$.	16	0.99554 ± 0.00346
6.	Reflected cubic array of 8 Type B ³ units, as described under Item 5. Unmoderated but reflected by 15.2 cm of paraffin. Described as: $B_8^3 [15.2; 6.904; 2.792; 0.90]$.	16	1.00062 ± 0.00316
7.	Reflected cubic array of 8 U(93.2) cylinders. The average dimensions of the cylinders were 4.558-cm radius, 17.282-cm height, and 21.008-kg mass. Unmoderated but reflected by 15.2 cm of paraffin. Described as: $C_8^6 [15.2; 10.328; 2.013; 1.42]$.	16	1.00409 ± 0.00322
8.	Moderated cubic array of 8 U(93.2) cylinders. The cylinders were Type C ² and had average dimensions of 5.753-cm radius, 10.765-cm height, and 20.960-kg mass. The array was unreflected but moderated by enclosing the cylinders in Type P3 containers. These containers were Plexiglas ⁽³⁾ boxes of average dimensions; 17.9 cm X 17.9 cm X 17.2-cm height, 1.27-cm wall thickness. Described as: $(C^2 - P^3)_8 [0; 6.619; 3.670; 0.96]$.	16	0.99587 ± 0.00341
9.	Cubic array of 27 cylinders of U(92.6)O ₂ (NO ₃) ₂ and H ₂ O. The containers had average dimensions with 10.16-cm OR, 19.05-cm height, and 0.64-cm-thick walls. Each container was filled with 5 L of solution at an H/U-235 atomic ratio of 59 and an N/U-235 atomic ratio of 2.006 which corresponds to a uranium mass of 2.075 kgs. Unreflected and unmoderated. Described as: $F_{27}^1 [0; 6.48; 0.114; 0.95]$.	17	0.97120 ± 0.00433
10.	Cubic array of 27 cylinders of aqueous uranyl nitrate solution. The containers described in Item 9 were used. Each container was filled with 5 L of solution at an H/U-235 of 440 which corresponds to a uranium mass of 0.316 kgs. Unmoderated and unreflected. Described as: $F_{27}^3 [0; 2.41; 0.029; 0.95]$.	17	1.00756 ± 0.00343
11.	Array of 16 cylinders (6.8-cm radius X 61-cm height) position on a slab (120.7 cm X 120.7 cm X 3.8 cm) all of U(93.2)O ₂ (NO ₃) ₂ aqueous solution with a 505 g/L uranium concentration. Reflection was provided with a 10.2-cm-thick Plexiglas box (inside dimensions of approximately 120.85-cm wide X approximately 120.85-cm long X 160.0-cm height) which was closely fitted to the base of the slab.	18	1.01864 ± 0.00401
12.	Graphite moderated array of 8 U(93.2) cylinders with a 5.747-cm radius, 8.077-cm height, and weighing 15.692 kgs. Units had a uranium side surface-to-surface separation of 18.60 cm and an end surface-to-surface separation of 15.93 cm. The array was reflected with 15.24 cm of polyethylene.	19	1.01526 ± 0.00320

Table 2 (continued)

	Experiment	Reference ⁽¹⁾	$k_{\text{eff}} \pm \sigma$
13.	Cubic array of 64 cylinders of aqueous $\text{U}(92.6)\text{O}_2(\text{NO}_3)_2$ and H_2O . The containers had average dimensions with 10.16-cm OR, 19.05-cm height, 0.64-cm-thick Plexiglas walls. Each container was filled with 5 L of solution having a concentration of 415 g of uranium per liter and a specific gravity of 1.555. Unmoderated and unreflected. Described as: $F_{64}^1 [0; 10.67; 0.072; 0.96]$.	17	0.96777 ± 0.00412
14.	Cubic array of 27 cylinders of aqueous uranyl nitrate solution. The containers and solution composition described in Item 13 were used. Unmoderated but reflected by 15.24 cm of paraffin. Described as: $F_{27}^1 [15.24; 16.53; 0.043; 0.96]$.	17	1.00972 ± 0.00385 $0.99893 \pm 0.00421^{(4)}$ $1.00502 \pm 0.00421^{(5)}$
15.	Cubic array of 27 cylinders of aqueous uranyl nitrate solution. The containers and solution composition described in Item 13 were used. Unmoderated but reflected by 1.27 cm of Plexiglas. Described as: $F_{27}^1 [1.27; 8.76; 0.088; 0.96]$.	17	0.97392 ± 0.00409
16.	Eight cylindrical pipes that intersect with a central column. Aqueous uranyl nitrate fill all arms (cylindrical pipes) and the central column. The concentration of $\text{U}(93)$ is 450.8 g/L. The dimensions are: arms, 8.4074-cm OR, 137.16-cm length, and 0.2794-cm wall thickness; central column, square pipe with 17.78-cm internal side, 0.3175-cm thick walls. Critical edge spacing was 13.1826 cm. Unmoderated and unreflected.	20,21	0.98776 ± 0.00391
17.	Square array of 16 (4 X 4) aluminum cylinders filled with $\text{U}(93.17)\text{O}_2(\text{NO}_3)_2$ and H_2O with a concentration of 355.94-g $\text{U}(93.17)$ per liter. The cylinders had dimensions of: 10.96-cm OR, 119.42-cm height, 0.4- and 0.32-cm-thick side walls and bottom wall, respectively. Also, the critical solution height was 18.82 cm. Unmoderated but reflected by 20.6-cm-thick plastic shell.	14	1.00999 ± 0.00352
18.	Square array of 16 (4 X 4) aluminum cylinders filled with $\text{U}(93.17)\text{O}_2(\text{NO}_3)_2$ and H_2O with a concentration of 364.11-g $\text{U}(93.17)$ per liter. The cylinders had the same dimensions as described in Item 17. The critical solution height was 17.13 cm. Unmoderated but reflected by a 25.7-cm-thick concrete shell.	14	0.99771 ± 0.00422

(1) As shown in *References*, page 13.

(2) Notation is of the form:

$$X_n^i [t; \delta; \rho; r]$$

where:

 X^i represents the average unit in the array described in Table 1, n the number of units in the array, t the reflector thickness (centimeter), δ the surface separation of units (centimeter) equal in three directions, ρ the average uranium density in the array (grams of uranium per cubic centimeter), and r the ratio of the array height to the square root of its base area.

(3) Rohm and Haas trade mark.

(4) Albedo reflector.

(5) Automatic reflector.

these systems indicate a strong similarity. All of these cases have units of high-uranium-concentration uranyl nitrate that are minimally reflected or, more often, unreflected. Two factors seem to cause the low k_{eff} values: (1) the amount of reflection and (2) the array size.

Figure 1. THE k_{eff} VERSUS AVERAGE ENERGY CAUSING FISSION.

Unreflected systems, as in B-9, -13, -16, and A-11 (as well as minimally reflected systems as in B-15 which has a 1.27-cm Plexiglas^(b) reflector) produced low values for k_{eff} . On the other hand, case B-14 (which is an array of the same type of unit as B-9, -13, and -15 but reflected by 15.24 cm of paraffin) renders a reasonable k_{eff} (1.00972). The array size also affects the k_{eff} of this system type. The larger the array becomes, the lower the k_{eff} gets. Case B-13, which is an unreflected array of 64 F¹ units, produced the lowest k_{eff} . Dickinson² reports that an unreflected array of 125 F¹ units gave an even lower k_{eff} . Several reports^{3,18} have noted that Monte Carlo calculations with Hansen-Roach sixteen-energy-group cross sections produce low k_{eff} values for uranyl nitrate solution systems that have a high uranium concentration. Therefore, cases B-9, -13, -15, -16, and A-11 must be examined by themselves.

A statistical analysis by Lever²² of the data in Figure 1 (excluding the four cases already discussed) indicates that the k_{eff} values roughly resemble a normal distribution with a mean k_{eff} of 1.0031758 and a standard deviation of 0.0088274005. Figure 2 shows k_{eff} values versus frequency of occurrence which indicates the strong similarity to a normal distribution. In addition, a lower tolerance limit was estimated for the distribution of k_{eff} values. The lower tolerance of 0.961025 is such that one can say 99.9% of the distribution of k_{eff} values will lie above the lower tolerance limit with 99% confidence. However, traditionally,²³ the acceptable lower tolerance limit has been 0.97 which is such that one can say 99.2% of the distribution of k_{eff} values will lie above the lower tolerance limit with 99% confidence.

(b) Rohm & Haas Co.

Figure 2. THE k_{eff} VERSUS RELATIVE FREQUENCY FRACTION OF OCCURRENCE.

CONCLUSIONS

Based on the method presented, it is concluded that the requirements of validation standard according to the American National Standard (ANSI) N16.9 are met; and the code and cross sections are adequate for most highly enriched uranium systems. In order to apply the lower tolerance limits to high-uranium-concentration uranyl nitrate solution systems, full reflection must be required when KENO IV and Hansen-Roach sixteen-energy-group cross sections are used. In actual plant problems, the neutron population analyzed could be reduced significantly from the number tracked in this validation. The sample size may vary with the type of problem but should encompass anywhere from 53 to 103 batches of 300 neutrons each. The statistical nature of plant problems would be accounted for by the addition of two standard deviations to the k_{eff} . For nuclear safety purposes, any $k_{eff} + 2\sigma$ which exceeds the lower tolerance limit must be considered critical; while all lower values may be considered subcritical, provided that the fuel material and reflector are not significantly different in composition from the experiments in Table 2.

However, the safety of a system, which cannot be closely related to an experiment, should never be entirely determined by one calculation but should be based upon a series of calculations in which one parameter is varied and plotted versus k_{eff} . The same case could also be calculated more than once with a different starting random number. Either method can be used to expose unrealistic values requiring further study.

REFERENCES

1. L. M. Petrie and N. F. Cross, *KENO IV, An Improved Monte Carlo Criticality Program*, Oak Ridge National Laboratory, Oak Ridge, Tenn., ORNL-4938 (1975).
2. D. Dickinson and G. E. Whitesides, "The Monte Carlo Method for Array Criticality Calculations," *Nucl. Technol.* **30**, 166-189 (August 1976).
3. R. E. Rothe and I. Oh, "A Calculational Study of Benchmark Critical Experiments on High-Enriched Uranyl Nitrate Solution Systems," *Nucl. Technol.* **41**, 226-243 (December 1978).
4. G. R. Handley, "Quality Assurance for Computer Programs Used in Criticality Safety Analysis," *Trans. Am. Nucl. Soc.* **28**, 283 (1978).
5. G. E. Hansen and W. H. Roach, *Six and Sixteen Group Cross Sections for Fast and Intermediate Critical Assemblies*, Los Alamos National Laboratory, Los Alamos, N. Mex., (1961).
6. G. E. Hansen, "Properties of Elementary Fast Neutron Critical Assemblies," *Proc. U.N. Intern. Conf. Peaceful Uses At. Energy, 2nd Geneva, 1958* (United Nations, Geneva, 1958), vol 12, p 84.
7. J. T. Mihalcz and W. E. Kinney, *Trans. Am. Nucl. Soc.* **4**, 302 (1961).
8. J. K. Fox, L. W. Gilley, R. Gwin, and J. T. Thomas, *Neutron Physics Division Annual Progress Report*, Oak Ridge National Laboratory, Oak Ridge, Tenn., ORNL-2609, p 42 (1958).
9. R. Gwin and D. W. Magnuson, *Nucl. Sci. Eng.* **12**, 364 (1962).
10. H. C. Paxton, *Los Alamos Critical Mass Data*, Los Alamos National Laboratory, Los Alamos, N. Mex., LAMS-3067 (1964).
11. J. T. Mihalcz, *Trans. Am. Nucl. Soc.* **8**, 442 (1965).
12. G. Tuck, "Critical Masses of Spherical and Hemispherical Enriched Uranium Assemblies," *J. Nucl. Energy* **23**, 663 (1969).
13. C. C. Byers, J. J. Koelling, G. E. Hansen, D. R. Smith, and H. R. Dyer, "Critical Measurements of a Water-Reflected Enriched Uranium Sphere," *Trans. Am. Nucl. Soc.* **27**, 412 (1977).
14. R. E. Rothe and I. Oh, *Benchmark Critical Experiments on High Enriched Uranyl Nitrate Solutions Systems*, Rockwell International, Rocky Flats, Golden, Colo., RFP-2710 (April 1978).

15. D. C. Irving and J. T. Mihalzco, *Trans. Am. Nucl. Soc.* **7**, 287 (1964).
16. J. T. Thomas, *Critical Three-Dimensional Arrays of Neutron-Interacting Units, Part II - U(93.2) Metal*, Oak Ridge National Laboratory, Oak Ridge, Tenn., ORNL-TM-868 (1964).
17. J. T. Thomas, *Critical Three-Dimensional Arrays of Neutron-Interacting Units*, Oak Ridge National Laboratory, Oak Ridge, Tenn., ORNL-TM-719 (1963).
18. G. Tuck and H. E. Clark, "Critical Parameters of a Uranium Solution Slab-Cylinder System," *Nucl. Sci. Eng.* **40**, 407-413 (1970).
19. E. C. Crume and J. T. Thomas, *Critical and Near Critical Graphite Moderated Arrays of U(93.2) Cylinders*, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant, Oak Ridge, Tenn., Y-DD-32 (1969).
20. B. B. Ernst and C. L. Schuske, *Empirical Method for Calculating Pipe Intersections Containing Fissile Solution*, Rockwell International, Rocky Flats, Golden, Colo., RFP-1197 (September 1968).
21. D. Dickinson and C. L. Schuske, "An Empirical Model for Safe Pipe Interactions Containing Fissile Solution," *Nucl. Technol.* **10**, 179-187 (1971).
22. W. E. Lever, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant, Oak Ridge, Tenn., Private Communication (1980).
23. G. R. Handley and C. M. Hopper, *Validation Checks of the "ANISN" and "KENO" Codes by Correlation with Experimental Data*, Union Carbide Corporation, Nuclear Division, Oak Ridge Y-12 Plant, Oak Ridge, Tenn., Y-1858 (1972).

ACKNOWLEDGMENTS

The authors are very grateful to G. E. Whitesides and J. T. Thomas for their advice and help with this report, L. M. Petrie for making available the codes and cross sections and for giving assistance in their use, N. F. Landers, P. B. Fox, and R. M. Westfall for their aid in locating critical experiments and mocking them up. They are members of the Oak Ridge National Laboratory. Appreciation is also extended to W. E. Lever of the Computer Sciences Division in the Y-12 Plant for his statistical analysis of the output.

APPENDIX A

INPUT PARAMETERS

```

KENO-4 VALIDATION CASE A-1
2.0 203 300 3 16 6 2 1 2 1 0 3*1 2 0 0 0011 00 6*0 00 2*0
1 -92501 4.5060-2 1 92859 2.9408-3
SPHERE 1 8.73136 16*0.0
END CASE
KENO-4 VALIDATION CASE A-2
2.0 203 300 3 16 6 3 1 3 3 0 3*1 3 2*0 0011 00 6*0 00 2*0
1 42100 1.0721-2 1 -92500 3.6694-2 1 92860 2.690-3
CYLINDER 0 2.54 9.87 -9.87 16R0
CYLINDER 1 10.16 9.87 -9.87 16R0
CUBE 0 10.16 -10.16 16R0
END CASE
KENO-4 VALIDATION CASE A-3
26.0 203 300 3 16 6 7 2 7 3 0 3*1 7 2*0 0011 00 6*0 00 2*0
1 -92500 4.7894-5 1 92800 3.4496-6 1 1102 6.6892-2 1 8100 3.3596-2
1 9100 1.0299-4
2 13100 5.9880-2 2 26100 2.9222-4
SPHERE 1 34.6 16R0
SPHERE 2 34.92 16R0
CUBE 0 35.0 -35.0 16R0
END CASE
KENO-4 VALIDATION CASE A-4
26.0 203 300 3 16 6 7 2 7 3 0 3*1 7 2*0 0011 00 6*0 00 2*0
1 1102 6.6220-2 1 8100 3.3772-2 1 7100 1.8688-4 1 -92500 4.806-5
1 92800 2.8066-6
2 13100 5.9880-2 2 26100 2.9222-4
SPHERE 1 34.6 16R0
SPHERE 2 34.92 16R0
CUBE 0 35.0 -35.0 16R0
END CASE
KENO-4 VALIDATION CASE A-5
60.0 203 300 3 16 6 3 2 3 3 0 3*1 3 2*0 0011 00 6*0 00 2*0
1 -92501 4.4916-2 1 92860 3.0831-3
2 501 1.0
HEMISPHERE 2 12.7 16*0.0
HEMISPHERE 1 15.24 16*0.0
CUBOID 2 31.00 -31.00 31.00 -31.00 31.00 -16. 16R0
END CASE
KENO-4 VALIDATION CASE A-6
10.0 203 300 3 16 6 3 2 3 6 0 3*1 3 2*0 0011 00 6*0 00 2*0
1 6100 8.6736-2
2 -92501 4.4641-2 2 92860 3.1629-3
CYLINDER 1 8.89 3.425 -3.425 16R0
CYLINDER 2 11.43 3.425 -3.425 16R0
CYLINDER 1 11.43 3.495 -3.425 16R0
CYLINDER 2 13.97 3.495 -3.425 16R0
CYLINDER 1 31.75 21.275 -21.205 16R0
CUBE 0 32.0 -32.0 16R0
END CASE
KENO-4 VALIDATION CASE A-7
10.0 203 300 3 16 6 3 2 4 3 0 3*1 3 2*0 0011 00 6*0 00 2*0
1 -92501 4.5036-2 1 92860 2.8383-3
2 -92501 3.5097-4 2 92856 4.7783-2
CUBOID 1 3.81 -3.81 4.445 -4.445 7.62 -7.62 16R0

```

```

CUBOID      2 26.01 -26.01 26.645 -26.645 29.82 -29.82 16R0
CUBE        0 30.0 -30.0                                16R0
END CASE
KENO-4 VALIDATION CASE A-8
60.0 203 300 3 16 6 5 2 7 4 0 3*1 5 2*0 0011 00 6*0 00 2*0
1 1101 6.9184-2 1 6100 3.8305-2 1 16100 3.7495-6
2 -92501 4.3289-2 2 92860 3.1983-3 2 6100 1.0317-3
2 1101 1.8756-3
HEMISPHERE  1 6.679 16*0.0
HEMISPHERE  2 10.5254 16*0.0
SPHERE      1 40.5254 16R0
CUBE        0 42.0 -42.0 16R0
3*1 0.0 0.0 8.446
END CASE
KENO-4 VALIDATION CASE A-9
60.0 203 300 3 16 6 6 3 9 4 0 3*1 6 2*0 0011 00 3 5*0 00 2*0
1 1101 6.9184-2 1 6100 3.8305-2 1 16100 3.9994-6
2 -92501 4.3289-2 2 92860 3.1983-3 2 6100 1.0317-3 2 1101 1.8756-3
3 26100 8.1666-2 3 6100 3.6353-3
HEMISPHERE  3 6.012 16*0.0
HEMISPHERE  2 10.488 16*0.0
SPHERE      1 40.488 16R0
CUBE        0 41.0 -41.0 16R0
1 1 1 0.0 0.0 8.25
END CASE
KENO-4 VALIDATION CASE A-10
64.0 203 300 3 16 6 5 3 5 7 2 1 1 2 5 2*0 0011 00 6*0 00 2*0
1 -92501 4.703-2 1 92835 1.1077-3
2 1101 6.679-2 2 8100 3.340-2
3 601 1.0
BOX TYPE 1
SPHERE      1 6.5537 16*0.0
CUBOID      2 12.7 -12.7 12.7 -12.7 6.5537 -6.5537 16*0.0
BOX TYPE 2
CYLINDER    2 4.1275 1.27 -1.27 16*0.0
CYLINDER    3 12.7 1.27 -1.27 16*0.0
CUBOID      2 12.7 -12.7 12.7 -12.7 1.27 -1.27 16*0.0
CORR DDY    0 12.7 -12.7 12.7 12.7 7.0237 -7.0237 16*0.0
CYLINDER    2 30.48 24.3337 -39.5737 16*0.0
1 1 1 1 1 1 2 2 1 0
2 1 1 1 1 1 1 1 1
END CASE
KENO-4 VALIDATION CASE A-11
16.0 203 300 3 16 6 6 2 6 3 0 3*1 6 2*0 0011 00 6*0 00 2*0
1 -92508 8.278-4 1 92852 6.0-5 1 7100 2.1021-3 1 1102 5.8436-2
1 8100 3.7137-2
2 200 1.0
CYLINDER    1 13.96 14.465 -14.465 16*0.0
CYLINDER    0 13.96 27.135 -14.465 16*0.0
CYLINDER    2 14.28 27.135 -15.105 16*0.0
END CASE
KENO-4 VALIDATION CASE B-1
4.0 203 300 3 16 6 2 1 2 3 0 3*1 2 2*0 0011 00 3 5*0 00 2*0
1 -92501 4.4796-2 1 92860 3.2271-3

```

```

GENERAL      1 6R0
GENERAL      0 6R0
CUBOID       0 19.10 -19.10 19.10 -19.10 5.0546 -5.0546
              2      MALE      MARRIED
X ZONE       -19.10,      19.10
Y ZONE       -19.10,      19.10
Z ZONE       -5.0546,      5.0546
ZONE         1      1      1
X BLOCK      -19.10,      19.10
Y BLOCK      -19.10,      19.10
Z BLOCK      -5.0546,      5.0546
BLOCK        1      1      1
MEDIA        2,      1,      1,      2
SURFACES     1,      2,      3
SECTOR +1 -1 0
SECTOR -1 0 0
SECTOR 0 +1 -1
SECTOR 0 0 +1
              3
              1.0XSQ      1.0YSQ      10.16X      -53.2257      $
              1.0XSQ      1.0YSQ      -195.1609      $
              1.0XSQ      1.0YSQ      -362.9025      $
              1      1      1      -5.08      0.0      0.0
END CASE
KENO-4 VALIDATION CASE R-2
2.0 203 300 3 16 6 2 1 2 4 0 3*1 2 2*0 0011 00 3 5*0 00 2*0
1 -92501 4.4796-2 1 92860 3.2271-3
CUBOID       1 0.3434 -12.4434 6.35 -6.35 6.49 -6.49
CYLINDER     0 13.97 6.49 -6.49
CYLINDER     1 19.05 6.49 -6.49
CUBE         0 20.00 -20.00
              1      1      1      -6.0500      0.0      0.0
END CASE
KENO-4 VALIDATION CASE B-3
6.0 203 300 3 16 6 2 1 2 3 0 3*1 2 0 0 0011 00 6*0 00 0 0
1 -92501 4.4796-2 1 92860 3.2271-3
GENERAL      1 6R0
GENERAL      0 6R0
CUBOID       0 24.353 -23.319 21.686 -22.841 15.24 -1.755
              2      MALE      MARRIED
X ZONE       -23.319,      24.353
Y ZONE       -22.841,      21.686
Z ZONE       -1.755,      15.24
ZONE         1      1      1
X BLOCKS     -23.319,      -5.7569,      6.9433,      24.353
Y BLOCKS     -22.841,      -6.9433,      5.7569,      21.686
Z BLOCKS     -1.755,      15.24
BLOCK        1      1      1
MEDIA        1,      2,      2,      2
SURFACES     26,      27,      28
SECTOR -1 1 -1
SECTOR 0 0 1
SECTOR 1 0 0
SECTOR 0 -1 0

```



```

SURFACES      8,      9,      10,      11,      12,      13
SECTOR -1 1 -1 0 0 0
SECTOR 0 0 0 -1 1 -1
SECTOR 0 0 1 0 0 1
SECTOR 1 0 0 0 0 1
SECTOR 0 -1 0 0 0 1
SECTOR 0 0 1 1 0 0
SECTOR 0 0 1 0 -1 0
BLOCK      3      2      1
MEDIA
2,      2,      2,      2,      2,      2,      2,      2,      2,      2,
SURFACES      11,      12,      13,      20,      21,      22,      34,      14,      35,      15,
16,      17,      18,      19
SECTOR -1 1 -1 0 0 0 0 0 0 0 0 0 0 0 0
SECTOR 0 0 0 -1 1 -1 0 0 0 0 0 0 0 0 0
SECTOR 0 0 0 0 0 0 0 -1 1 -1 0 0 0 0 0
SECTOR 0 0 0 0 0 0 0 0 -1 0 1 -1 1 -1 1
SECTOR 0 0 1 0 0 1 1 0 0 0 0 0 0 0 0
SECTOR 0 0 1 0 0 1 0 1 1 0 0 0 0 0 0
SECTOR 0 0 1 0 0 1 0 -1 0 0 1 0 0 0 0
SECTOR 0 0 1 0 0 1 0 -1 0 0 0 -1 0 0 0
SECTOR 0 0 1 0 0 1 0 -1 0 0 0 0 1 0 0
SECTOR 0 0 1 0 0 1 0 0 -1 0 0 0 0 0 -1
SECTOR 0 0 1 0 0 1 0 0 0 -1 0 0 0 0 0
SECTOR 1 0 -1 0 0 0 0 0 0 0 0 0 0 0 0
SECTOR 0 -1 -1 0 0 0 0 0 0 0 0 0 0 0 0
SECTOR 0 0 0 0 -1 -1 0 0 0 0 0 0 0 0 0
SECTOR 0 0 0 1 0 -1 0 0 0 0 0 0 0 0 0
BLOCK      2      2      1
MEDIA
2,      2,      1,      1,      1,      2,      2
SURFACES      31,      32,      33,      29,      30
SECTOR 0 -1 1 0 0
SECTOR -1 1 0 0 0
SECTOR 0 0 -1 1 0
SECTOR 0 0 0 -1 -1
SECTOR 1 0 1 0 0
SECTOR 0 0 0 -1 1
39 QUADRIC SURFACES IN GEOMETRY
.02356X .99972Z -13.1339 $
.02356X .99972Z -12.8151 $
.02356X .99972Z -10.9048 $
.02356X .99972Z .25011 $
1.487E-02X -1.938E-02Y 9.997E-01Z -1.262E 01 $
1.487E-02X -1.938E-02Y 9.997E-01Z 3.557E-01 $
9.998E-01XSQ 9.996E-01YSQ 5.969E-04ZSQ 5.766E-04XY
-2.974E-02XZ 3.876E-02YZ 1.772E 01X -2.309E 01Y
-7.112E-01Z 1.911E 02 $
-3.424E-03X -3.005E-02Y 9.995E-01Z -1.299E 01 $
-3.424E-03X -3.005E-02Y 9.995E-01Z 4.817E-01 $
1.000E 00XSQ 9.991E-01YSQ 9.149E-04ZSQ -2.058E-04XY
6.845E-03XZ 6.008E-02YZ -3.602E 00X -3.162E 01Y
-9.629E-01Z 2.202E 02 $
-2.610E-02X -2.229E-02Y 9.994E-01Z -1.246E 01 $
-2.610E-02X -2.229E-02Y 9.994E-01Z 5.056E-01 $

```


9.993E-01XSQ	9.995E-01YSQ	1.178E-03ZSQ	-1.163E-03XY
5.216E-02XZ	4.455E-02YZ	-2.238E 01X	-1.911E 01Y
-1.011E 00Z	1.960E 02	\$	
-.04507X	.99898Z	-8.3852	\$
-.04507X	.99898Z	.5252	\$
.99898X	.04507Z	-24.34	\$
.99898X	.04507Z	-11.64	\$
1.0Y	-3.2168	\$	
1.0Y	4.4032	\$	
-2.183E-02X	1.966E-02Y	9.996E-01Z	-1.252E 01 \$
-2.183E-02X	1.966E-02Y	9.996E-01Z	4.557E-01 \$
9.995E-01XSQ	9.996E-01YSQ	8.629E-04ZSQ	8.582E-04XY
4.364E-02XZ	-3.929E-02YZ	-2.304E 01X	2.074E 01Y
-9.110E-01Z	2.197E 02	\$	
-2.129E-03X	2.434E-02Y	9.997E-01Z	-1.306E 01 \$
-2.129E-03X	2.434E-02Y	9.997E-01Z	4.176E-01 \$
1.000E 00XSQ	9.994E-01YSQ	5.969E-04ZSQ	1.037E-04XY
4.258E-03XZ	-4.866E-02YZ	-2.977E 00X	3.403E 01Y
-8.349E-01Z	2.589E 02	\$	
1.182E-02X	1.513E-02Y	9.998E-01Z	-1.266E 01 \$
1.182E-02X	1.513E-02Y	9.998E-01Z	2.966E-01 \$
9.999E-01XSQ	9.998E-01YSQ	3.685E-04ZSQ	-3.576E-04XY
-2.363E-02XZ	-3.025E-02YZ	1.902E 01X	2.434E 01Y
-5.932E-01Z	2.179E 02	\$	
1.0Z	-.9374	\$	
1.0XSQ	1.0YSQ	-33.142	\$
1.0XSQ	1.0YSQ	1.0ZSQ	-1.7226X
.6502Y	-13.3122Z	8.1601	\$
1.0XSQ	1.0YSQ	1.0ZSQ	-1.7226X
.6502Y	-13.3122Z	45.0945	\$
1.0Z	-6.6562	\$	
-4.507E-02X	9.990E-01Z	-1.270E 01	\$
9.980E-01XSQ	1.000E 00YSQ	2.032E-03ZSQ	9.005E-02XZ
-3.239E 01X	1.186E 00Y	-1.461E 00Z	2.422E 02 \$
.99972X	-.02356Z	10.613	\$
.99972X	-.02356Z	15.693	\$
.99972X	-.02356Z	20.773	\$
.99972X	-.02356Z	23.316	\$
1 1 1 0.0 0.0		5.08	

END CASE

KENO-4 VALIDATION CASE B-4

10.0 203 300 3 16 6 11 3 11 5 1 3*4 11 2*0 0011 00 6*0 00 2*0

1 -92501 4.4772-2 1 92860 3.2509-3 2 200 1.0 3 28100 6.3285-4

3 24100 1.5433-2 3 26100 9.0747-3 3 25100 9.2241-4 3 6100 6.3285-4

3 29100 3.9873-4 3 14100 9.0215-4 3 16100 2.3706-5

GENERAL 1 6R0

16R0

GENERAL 2 6R0

16R0

GENERAL 3 6R0

16R0

GENERAL 0 6R0

16R0

CUBOID 0 7.71 -7.71 7.71 -7.71 4.6605 -4.6605 16*0.0

2 MALE MARRIED

X ZONE -7.71, 7.71

Y ZONE -7.71, 7.71

Z ZONE -4.6605, 4.6605

```

ZONE      1      1      1
X BLOCK   -7.71,      7.71
Y BLOCK   -7.71,      7.71
Z BLOCK   -4.6605, -2.691, 2.691, 4.6605
BLOCK      1      1
MEDIA      2,      2,      3,      3,      4
SURFACES   2,      3,      4,      5
SECTOR     -1
SECTOR -1
SECTOR      1      -1
SECTOR      1      -1
SECTOR      1      1
BLOCK      1      1      2
MEDIA      1,      2,      2,      4
SURFACES   1,      2,      3
SECTOR     -1      1      1
SECTOR     -1
SECTOR     -1
SECTOR      1
BLOCK      1      1      3
MEDIA      2,      2,      3,      3,      4
SURFACES   2,      3,      4,      5
SECTOR     -1
SECTOR -1
SECTOR      1      -1
SECTOR      1      -1
SECTOR      1      1
5

```

```

1.0XSQ      1.0YSQ      -32.9533      $
1.0XSQ      1.0YSQ      -8.547X      18.198286      $
1.0XSQ      1.0YSQ      8.547X      18.198286      $
1.0XSQ      1.0YSQ      -8.547X      18.117641      $
1.0XSQ      1.0YSQ      8.547X      18.117641      $

```

END CASE

KENO-4 VALIDATION CASE B-7

```

60.0 203 300 3 16 6 4 2 4 6 1 3*2 4 2*0 0011 00 6*0 00 2*0
1 -92501 4.4598-2 1 92860 3.2128-3 2 1101 8.2571-2 2 6100 3.9697-2

```

BOX TYPE

```

1 4.558 2.160 -2.160 16R0
0 5.747 2.160 -2.160 16R0
1 5.747 4.851 -4.851 16R0
0 9.2083 -9.2083 9.2083 -9.2083 8.2875 -8.2875 16R0
0 18.4166 -18.4166 18.4166 -18.4166 16.575 -16.575 16R0
2 33.617 -33.617 33.617 -33.617 31.775 -31.775 16R0

```

END CASE

KENO-4 VALIDATION CASE B-5

```

2.0 203 300 3 16 6 2 1 2 4 1 4*2 2*0 0011 00 6*0 00 2*0
1 -92501 4.4617-2 1 92860 3.2142-3

```

BOX TYPE

```

1 4.558 2.16 -2.16 16R0
0 5.747 2.16 -2.16 16R0
1 5.747 4.851 -4.851 16R0
0 5.8554 -5.8554 5.8554 -5.8554 4.9771 -4.9771 16R0

```

END CASE

KENO-4 VALIDATION CASE B-6

54.0 203 300 3 16 6 4 2 4 5 1 3*2 4 2*0 0011 00 6*0 00 2*0

1 -92501 4.4474-2 1 92860 3.2039-3 2 6100 3.9697-2 2 1101 8.2571-2

BOX TYPE 1

CYLINDER 1 4.558 8.641 -8.641 16R0

CUBOID 0 9.7212 -9.7212 9.7212 -9.7212 13.8041 -13.8041 16R0

CORE BDY 0 19.4424 -19.4424 19.4424 -19.4424 27.6082 -27.6082 16R0

CUBOID 2 34.6424 -34.6424 34.6424 -34.6424 42.8082 -42.8082 16R0

CUBE 0 43.0 -43.0 16R0

END CASE

KENO-4 VALIDATION CASE B-8

4.0 203 300 3 16 6 3 2 3 4 1 3*2 3 2*0 0011 00 6*0 00 2*0

1 -92501 4.4714-2 1 92860 3.2212-3

2 601 1.0

BOX TYPE 1

CYLINDER 1 5.753 5.3825 -5.3825 16R0

CUBOID 0 7.68 -7.68 7.68 -7.68 7.33 -7.33 16R0

CUBOID 2 8.95 -8.95 8.95 -8.95 8.6 -8.6 16R0

CUBOID 0 9.0599 -9.0599 9.0599 -9.0599 8.6975 -8.6975 16R0

END CASE

KENO-4 VALIDATION CASE B-9

6.0 203 300 3 16 6 6 2 6 4 1 3*3 6 2*0 0011 00 6*0 00 2*0

1 -92508 9.8435-4 1 92852 7.7660-5 1 7100 1.9746-3 1 8100 3.7086-2

1 1102 5.8076-2 2 602 1.0

BOX TYPE 1

CYLINDER 1 9.52 8.7804 -8.7804 16R0

CYLINDER 0 9.52 8.9896 -8.7804 16R0

CYLINDER 2 10.16 9.6296 -9.4204 16R0

CUBOID 0 13.4 -13.4 13.4 -13.4 12.8696 -12.6604 16*0.0

END CASE

KENO-4 VALIDATION CASE B-10

14.0 203 300 3 16 6 6 2 6 4 1 3*3 6 0 0 0011 00 6*0 00 2*0

1 -92512 1.5017-4 1 92855 1.1850-5 1 7100 3.2404-4 1 8100 3.4334-2

1 1102 6.6076-2 2 602 1.0

BOX TYPE 1

CYLINDER 1 9.52 8.7804 -8.7804 16R0

CYLINDER 0 9.52 8.9895 -8.7804 16R0

CYLINDER 2 10.16 9.6295 -9.4204 16R0

CUBOID 0 11.282 -11.282 11.282 -11.282 10.7179 -10.7179 16R0

END CASE

KENO-4 VALIDATION CASE B-11

28.0 203 300 3 16 6 10 3 10 11 2 4 4 2 10 2*0 0011 00 6*0 00 2*0

1 -92508 1.2059-3 1 92852 8.6869-5 1 7100 2.5855-3 1 8100 3.7582-2

1 1102 5.4480-2

2 602 1.0

3 26100 5.7987-2 3 24100 1.6511-2 3 28100 1.1373-2 3 6100 3.9709-4

BOX TYPE 1

CYLINDER 1 6.8 1.76 -1.76 16R0

CYLINDER 3 7.08 1.76 -2.04 16R0

CUBOID 1 15.0875 -15.0875 15.0875 -15.0875 1.76 -2.04 16*0.0

BOX TYPE 2

CYLINDER 1 6.8 30.5 -30.5 16R0

CYLINDER 0 6.8 96.7 -30.5 16R0

CYLINDER 3 7.08 96.7 -30.5 16R0

```

CUBOID 0 15.0875 -15.0875 15.0875 -15.0875 125.7 -30.5 16*0.0
CORE BDY 0 60.35 -60.35 60.35 -60.35 80.0 -80.0 16*0.0
CUBOID 3 60.35 -60.35 60.35 -60.35 80.0 -80.635 16*0.0
CUBOID 2 70.55 -70.55 70.55 -70.55 90.2 -90.835 16*0.0
CUBE 0 95.0 -95.0 16R0
1 1 4 1 1 4 1 1 1 0
2 1 4 1 1 4 1 2 2 1 1
END CASE
KENO-4 VALIDATION CASE B-12
62.0 203 300 3 16 6 7 3 7 7 1 3*2 7 2*0 0011 00 6*0 00 2*0
1 -92501 4.4772-2 1 92860 3.2509-3 2 1101 3.4366-6 2 5100 1.1799-7
2 6100 9.5673-2 2 26100 1.9034-4 3 402 1.0
BOX TYPE 1
CYLINDER 1 5.747 3.9699 -4.1071 16R0
CYLINDER 0 5.777 4.1071 -4.1071 16R0
CUBOID 2 10.9195 -10.9195 10.9195 -10.9195 7.8755 -7.8755 16R0
CUBOID 0 15.047 -15.047 15.047 -15.047 12.0035 -12.0035 16R0
CORE BDY 0 30.094 -30.094 30.094 -30.094 24.007 -24.007 16R0
CUBOID 3 45.334 -45.334 45.334 -45.334 39.247 -39.247 16R0
CUBE 0 46.0 -46.0 16R0
END CASE
KENO-4 VALIDATION CASE B-13
10. 203 300 3 16 6 6 2 6 4 1 3*4 6 2*0 0011 00 6*0 00 2*0
1 -92508 9.8435-4 1 92852 7.7660-5 1 7100 1.9746-3 1 8100 3.7086-2
1 1102 5.8076-2
2 602 1.0
CYLINDER 1 9.52 8.7804 -8.7804 16*0.0
CYLINDER 0 9.52 8.9896 -8.7804 16*0.0
CYLINDER 2 10.16 9.6296 -9.4204 16*0.0
CUBOID 0 15.495 -15.495 15.495 -15.495 14.9646 -14.7554 16*0.0
END CASE
KENO-4 VALIDATION CASE B-14
60.0 203 300 3 16 6 7 3 8 6 1 3*3 7 2*0 0011 00 6*0 00 2*0
1 -92508 9.8435-4 1 92852 7.7660-5 1 7100 1.9746-3 1 8100 3.7086-2
1 1102 5.8076-2
2 602 1.0
3 1102 8.2571-2 3 6100 3.9697-2
CYLINDER 1 9.52 8.7804 -8.7804 16*0.0
CYLINDER 0 9.52 8.9896 -8.7804 16*0.0
CYLINDER 2 10.16 9.6296 -9.4204 16*0.0
CUBOID 0 18.425 -18.425 18.425 -18.425 17.8946 -17.6854 16*0.0
CORE BDY 0 55.275 -55.275 55.275 -55.275 53.37 -53.37 16*0.0
CUBOID 3 70.515 -70.515 70.515 -70.515 68.61 -68.61 16*0.0
END CASE
KENO-4 VALIDATION CASE B-14 ALBEDO REFLECTOR
58.0 203 300 3 16 6 7 3 8 4 1 3*3 7 2 0 0011 00 6*0 00 2*0
6*2012
1 -92508 9.8435-4 1 92852 7.7660-5 1 7100 1.9746-3 1 8100 3.7086-2
1 1102 5.8076-2
2 602 1.0
3 1102 8.2571-2 3 6100 3.9697-2
CYLINDER 1 9.52 8.7804 -8.7804 16*0.0
CYLINDER 0 9.52 8.9896 -8.7804 16*0.0
CYLINDER 2 10.16 9.6296 -9.4204 16*0.0

```

```

CUBOID 0 18.425 -18.425 18.425 -18.425 17.8946 -17.6854 16*0.0
END CASE
KENO-4 VALIDATION CASE B-14 AUTOMATIC REFLECTOR
58. 203 300 3 16 6 7 3 8 10 1 3*3 7 2*0 0011 00 6*0 00 2*0
1 -92508 9.8435-4 1 92852 7.7660-5 1 7100 1.9746-3 1 8100 3.7086-2
1 1102 5.8076-2
2 602 1.0
3 1102 8.2571-2 3 6100 3.9697-2
CYLINDER 1 9.52 8.7804 -8.7804 16*0.0
CYLINDER 0 9.52 8.9896 -8.7804 16*0.0
CYLINDER 2 10.16 9.6296 -9.4204 16*0.0
CUBOID 0 18.425 -18.425 18.425 -18.425 17.8946 -17.6854 16*0.0
REFLECTOR 3 6*15.24 400
END CASE
KENO-4 VALIDATION CASE B-15
60.0 203 300 3 16 6 6 2 6 6 1 3*3 6 2*0 0011 00 6*0 00 2*0
1 -92508 9.8435-4 1 92852 7.7660-5 1 7100 1.9746-3 1 8100 3.7086-2
1 1102 5.8076-2
2 602 1.0
CYLINDER 1 9.52 8.7804 -8.7804 16*0.0
CYLINDER 0 9.52 8.9896 -8.7804 16*0.0
CYLINDER 2 10.16 9.6296 -9.4204 16*0.0
CUBOID 0 18.54 -14.54 14.54 -14.54 14.0096 -13.8004 16*0.0
CORE BDY 0 43.62 -43.62 43.62 -43.62 41.715 -41.715 16*0.0
CUBOID 2 44.89 -44.89 44.89 -44.89 42.985 -42.985 16*0.0
END CASE
KENO-4 VALIDATION CASE B-16
10.0 203 300 3 16 6 11 2 11 18 8 3 3 2 11 4*0 1 8*0
1 -92508 1.07686-3 1 92852 7.7695-5 1 1102 5.5006-2 1 7100 2.7429-3
1 8100 3.78239-2
2 6100 1.1884-4 2 24100 1.6471-2 2 25100 1.7321-3 2 26100 6.036-2
2 28100 6.4834-3 2 14100 1.694-3
BOX TYPE 1
XCYLINDER 1 8.128 68.3006 -68.3006 16*0.5
XCYLINDER 2 8.4074 68.58 -68.58 16*0.5
CUBOID 0 68.58 -68.58 9.2075 -9.2075 14.999 -110.32 16*0.5
BOX TYPE 2
YCYLINDER 1 8.128 68.3006 -68.3006 16*0.5
YCYLINDER 2 8.4074 68.58 -68.58 16*0.5
CUBOID 0 9.2075 -9.2075 68.58 -68.58 14.999 -110.32 16*0.5
BOX TYPE 3
XCYLINDER 1 8.128 68.3006 -68.3006 16*0.5
XCYLINDER 2 8.4074 68.58 -68.58 16*0.5
CUBOID 0 68.58 -68.58 9.2075 -9.2075 125.09 -14.999 16*0.5
BOX TYPE 4
YCYLINDER 1 8.128 68.3006 -68.3006 16*0.5
YCYLINDER 2 8.4074 68.58 -68.58 16*0.5
CUBOID 0 9.2075 -9.2075 68.58 -68.58 125.09 -14.999 16*0.5
BOX TYPE 5
CUBOID 1 8.89 -8.89 8.89 -8.89 14.999 -110.00 16*0.5
CUBOID 2 9.2075 -9.2075 9.2075 -9.2075 14.999 -110.32 16*0.5
BOX TYPE 6
CUBOID 1 8.89 -8.89 8.89 -8.89 125.09 -14.999 16*0.5
CUBOID 2 9.2075 -9.2075 9.2075 -9.2075 125.09 -14.999 16*0.5

```

```

BOX TYPE      7
CUBOID        0 68.58 -68.58 68.58 -68.58 14.999 -110.32 16*0.5
BOX TYPE      8
CUBOID        0 68.58 -68.58 68.58 -68.58 125.09 -14.999 16*0.5
1 1 3 2 2 2 1 1 1 0 2 2 2 1 1 3 2 1 1 1 0 3 1 3 2 2 2 1 2 2 1 0
4 2 2 1 1 3 2 2 2 1 0 5 2 2 1 2 2 1 1 1 1 0 6 2 2 1 2 2 1 2 2 1 0
7 1 3 2 1 3 2 1 1 1 0 8 1 3 2 1 3 2 2 2 1 8
END CASE
KENO-4 VALIDATION CASE B-17
60.0 203 300 3 16 6 15 3 15 7 1 4 4 1 15 2*0 0011 00 6*0 00 2*0
1 -92509 8.4966-4 1 92852 6.1499-5 1 1102 5.8421-2 1 7100 2.21204-3
1 8100 3.7246-2
2 24100 5.39-5 2 26100 1.387-4 2 29100 6.49-5 2 30100 1.51-5 2 25100 2.10-5
2 12100 6.78-4 2 13100 5.9473-2 2 14100 3.521-4 2 22100 1.03-5
3 602 1.0
CYLINDER 1 10.56 9.41 -9.41 16*0.0
CYLINDER 0 10.56 109.69 -9.41 16*0.0
CYLINDER 2 10.96 109.69 -9.73 16*0.0
CUBOID 0 15.24 -15.24 15.24 -15.24 113.17 -9.73 16*0.0
CORE BDY 0 60.96 -60.96 60.96 -60.96 61.45 -61.45 16*0.0
CUBOID 0 61.45 -61.45 61.45 -61.45 61.45 -61.45 16*0.0
CUBE 3 82.05 -82.05 16*0.0
END CASE
KENO-4 VALIDATION CASE B-18
60.0 203 300 3 16 6 19 3 27 15 3 4 4 1 19 2*0 0011 00 6*0 00 2*0
1 -92509 8.6916-4 1 92852 6.2911-5 1 1102 5.805-2 1 7100 2.2164-3
1 8100 3.7363-2
2 24100 5.39-5 2 26100 1.387-4 2 29100 6.49-5 2 30100 1.51-5 2 25100 2.10-5
2 12100 6.78-4 2 13100 5.9473-2 2 14100 3.521-4 2 22100 1.03-5
3 1102 1.0401-2 3 6100 6.459-3 3 7100 1.0-5 3 8100 4.3063-2
3 11100 2.554-4 3 12100 8.509-4 3 13100 1.0672-3 3 14100 7.8138-3
3 16100 7.41-5 3 19100 2.681-4 3 20100 8.004-3 3 22100 1.46-5
3 26100 2.052-4
BOX TYPE 1
CYLINDER 1 10.56 8.565 -8.565 16*0.0
CYLINDER 0 10.56 110.535 -8.565 16*0.0
CYLINDER 2 10.96 110.535 -8.885 16*0.0
CUBOID 0 15.25 -15.15 15.25 -15.25 115.515 -8.885 16*0.0
BOX TYPE 2
CYLINDER 1 10.56 8.565 -8.565 16*0.0
CYLINDER 0 10.56 110.535 -8.565 16*0.0
CYLINDER 2 10.96 110.535 -8.885 16*0.0
CUBOID 0 15.15 -15.25 15.25 -15.25 115.515 -8.885 16*0.0
BOX TYPE 3
CYLINDER 1 10.56 8.565 -8.565 16*0.0
CYLINDER 0 10.56 110.535 -8.565 16*0.0
CYLINDER 2 10.96 110.535 -8.885 16*0.0
CUBOID 0 15.25 -15.25 15.25 -15.25 115.515 -8.885 16*0.0
CORE BDY 0 60.9 -60.9 61.0 -61.0 62.2 -62.2 16*0.0
CUBOID 0 60.9 -60.9 61.1 -61.1 62.2 -62.2 16*0.0
CUBOID 3 86.6 -86.6 86.8 -86.8 87.9 -87.9 16*0.0
1 1 1 1 1 4 1 1 1 1 0
2 4 4 1 1 4 1 1 1 1 0
3 2 3 1 1 4 1 1 1 1 1
END CASE

```

APPENDIX B

CROSS SECTIONS

Energy range of the 16 energy groups:

Group	Energy Range	Group	Energy Range
1	3 - ∞ MeV	9	100 - 550 eV
2	1.4 - 3 MeV	10	30 - 100 eV
3	0.9 - 1.4 MeV	11	10 - 30 eV
4	0.4 - 0.9 MeV	12	3 - 10 eV
5	0.1 - 0.4 MeV	13	1 - 3 eV
6	17 - 100 keV	14	0.4 - 1 eV
7	3 - 17 keV	15	0.1 - 0.4 eV
8	0.55 - 3 keV	16	Thermal (0.025 eV)

The choice of ^{235}U and ^{238}U cross sections was determined by the nuclear fuel's total scattering cross section in the resonance range, per ^{235}U or ^{238}U atom, respectively; i.e.:

$$\sigma_{pn} = \frac{\sum_{i=1}^j (\sigma_i) (N_i)}{N_n}$$

where N_i is the atomic density of each respective element in the fuel; σ_i the individual element's scattering cross section in the resonance range, was taken from the following tabular information:

Element	σ_i	Element	σ_i
Al	1.4	Mn	4.0
B	4.0	Mo	6.0
C	4.6	N	10.0
Cd	5.0	Na	3.1
Cl	6.0	Nb	6.3
Co	7.0	Ni	17.5
Cr	4.3	O	3.7
Cu	7.5	Pu	12.0
F	3.4	Si	2.2
Fe	11.4	Th	12.0
H	21.0	U-235	10.0
K	2.2	U-238	12.0
Li-7	1.0	Zr	6.2

NUCLIDE = 200 TYPE 304 STAINLESS STEEL 7.9G/CC CONTAINS C,CR,MN,FE,NI,SI

GP.	ABSORPTION	NU FISSION	TOTAL
1	2.4541E-03	0.0	2.0124E-01
2	1.2844E-03	0.0	1.9827E-01
3	1.0047E-03	0.0	1.8220E-01
4	1.0059E-03	0.0	2.1011E-01
5	1.3453E-03	0.0	2.4304E-01
6	2.6103E-03	0.0	2.3949E-01
7	4.2484E-03	0.0	6.8752E-01
8	2.0572E-03	0.0	6.7720E-01
9	9.9427E-03	0.0	1.1688E 00
10	5.5413E-03	0.0	8.7588E-01
11	9.7624E-03	0.0	8.7931E-01
12	1.6972E-02	0.0	8.7980E-01
13	3.0780E-02	0.0	8.8332E-01
14	5.0467E-02	0.0	8.9353E-01
15	9.1197E-02	0.0	9.2527E-01
16	2.5400E-01	0.0	1.0558E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.2187E-01	4.4863E-02	1.8568E-02	1.1549E-02	1.7762E-03	1.6471E-04
2	1.3355E-01	3.3381E-02	2.0275E-02	9.5738E-03	2.1126E-04	0.0
3	1.4195E-01	2.2058E-02	1.5763E-02	1.4211E-03	1.0535E-06	0.0
4	1.9719E-01	1.1833E-02	7.7848E-05	1.6728E-06	8.9754E-08	0.0
5	2.3425E-01	7.4337E-03	2.8516E-06	1.5043E-07	4.6374E-09	0.0
6	2.3193E-01	4.9490E-03	0.0	0.0	0.0	0.0
7	6.6960E-01	1.3672E-02	0.0	0.0	0.0	0.0
8	6.6149E-01	1.3647E-02	0.0	0.0	0.0	0.0
9	1.1407E 00	1.8135E-02	0.0	0.0	0.0	0.0
10	8.4457E-01	2.5766E-02	0.0	0.0	0.0	0.0
11	8.4115E-01	2.8395E-02	0.0	0.0	0.0	0.0
12	8.3731E-01	2.5522E-02	0.0	0.0	0.0	0.0
13	8.2470E-01	2.7835E-02	1.3823E-10	0.0	0.0	0.0
14	8.0960E-01	3.3380E-02	1.1238E-11	0.0	0.0	0.0
15	8.1433E-01	1.9713E-02	0.0	0.0	0.0	0.0
16	8.0139E-01	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 402 DE/E POLYETHYLENE 0.92G/CC H=.079433, C=.039716

GP.	ABSORPTION	NU FISSION	TOTAL
1	0.0	0.0	1.6403E-01
2	0.0	0.0	2.2916E-01
3	0.0	0.0	3.5189E-01
4	0.0	0.0	4.4403E-01
5	0.0	0.0	6.7875E-01
6	0.0	0.0	1.0982E 00
7	0.0	0.0	1.3083E 00
8	7.9433E-05	0.0	1.3639E 00
9	3.1773E-04	0.0	1.3639E 00
10	6.3546E-04	0.0	1.3639E 00
11	1.1121E-03	0.0	1.3639E 00
12	1.9858E-03	0.0	1.3678E 00
13	3.5745E-03	0.0	1.3678E 00
14	5.5603E-03	0.0	1.6061E 00
15	1.0354E-02	0.0	2.1621E 00
16	2.3155E-02	0.0	3.7508E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	2.9191E-02	8.1538E-02	1.8985E-02	1.8985E-02	1.1438E-02	3.8922E-03
2	6.3308E-02	6.7280E-02	5.4809E-02	3.2965E-02	9.2142E-03	1.5887E-03
3	6.0845E-02	1.7666E-01	8.5470E-02	2.3830E-02	4.1305E-03	9.5319E-04
4	1.2074E-01	2.4854E-01	6.2037E-02	1.0485E-02	1.7475E-03	4.7660E-04
5	2.7480E-01	3.3819E-01	5.4332E-02	9.2936E-03	1.7475E-03	3.9717E-04
6	5.0269E-01	4.9427E-01	8.3007E-02	1.4854E-02	2.3830E-03	9.5319E-04
7	5.7469E-01	6.0258E-01	1.0716E-01	1.6601E-02	4.8454E-03	2.3830E-03
8	5.8153E-01	6.4293E-01	9.6908E-02	2.8596E-02	9.6908E-03	4.1305E-03
9	5.8343E-01	5.5071E-01	1.5251E-01	5.4014E-02	1.5251E-02	7.6256E-03
10	4.1436E-01	6.4011E-01	2.1598E-01	6.1950E-02	1.8428E-02	1.2392E-02
11	3.7445E-01	7.0100E-01	1.9207E-01	5.7112E-02	2.8596E-02	9.5319E-03
12	4.0098E-01	6.5246E-01	1.8778E-01	9.3890E-02	3.0741E-02	0.0
13	3.5757E-01	6.1541E-01	2.9263E-01	9.8656E-02	0.0	0.0
14	5.1977E-01	8.1867E-01	2.6213E-01	0.0	0.0	0.0
15	1.7333E 00	4.1845E-01	0.0	0.0	0.0	0.0
16	3.7276E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 501 X(E) WATER 0.9982G/CC R=.066742, O=.033371

GP.	ABSORPTION	NU FISSION	TOTAL
1	1.3349E-03	0.0	1.4009E-01
2	0.0	0.0	1.8221E-01
3	0.0	0.0	3.3298E-01
4	0.0	0.0	3.9499E-01
5	0.0	0.0	5.6305E-01
6	0.0	0.0	8.8968E-01
7	0.0	0.0	1.0696E 00
8	6.6743E-05	0.0	1.1226E 00
9	2.6697E-04	0.0	1.1226E 00
10	5.3394E-04	0.0	1.1226E 00
11	9.3440E-04	0.0	1.1226E 00
12	1.6686E-03	0.0	1.1226E 00
13	3.0034E-03	0.0	1.1226E 00
14	4.6720E-03	0.0	1.3229E 00
15	8.6766E-03	0.0	1.7900E 00
16	1.9362E-02	0.0	3.1250E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	3.2104E-02	6.3473E-02	1.5418E-02	1.5418E-02	9.2773E-03	3.0702E-03
2	3.9212E-02	5.5163E-02	4.8789E-02	2.9300E-02	8.0759E-03	1.6686E-03
3	9.0571E-02	1.4804E-01	7.0747E-02	1.9622E-02	3.2704E-03	7.3417E-04
4	1.3455E-01	1.9996E-01	5.0191E-02	8.4764E-03	1.4683E-03	3.3371E-04
5	2.7949E-01	2.3730E-01	3.8110E-02	6.6743E-03	1.2014E-03	2.6697E-04
6	3.9502E-01	4.0964E-01	6.9746E-02	1.2481E-02	2.0023E-03	8.3429E-04
7	4.5896E-01	5.0054E-01	9.0036E-02	1.3949E-02	4.0713E-03	2.0023E-03
8	4.7054E-01	5.3495E-01	8.1426E-02	2.4028E-02	8.1426E-03	3.4706E-03
9	4.7214E-01	4.5746E-01	1.2815E-01	4.5385E-02	1.2815E-02	6.4073E-03
10	3.3225E-01	5.3041E-01	1.8147E-01	5.2060E-02	1.5484E-02	1.0412E-02
11	2.9954E-01	5.8073E-01	1.6138E-01	4.7988E-02	2.4028E-02	8.0092E-03
12	3.1810E-01	5.4035E-01	1.5778E-01	7.8890E-02	2.5830E-02	0.0
13	2.8253E-01	5.0831E-01	2.4588E-01	8.2895E-02	0.0	0.0
14	4.2055E-01	6.7737E-01	2.2025E-01	0.0	0.0	0.0
15	1.4366E 00	3.4476E-01	0.0	0.0	0.0	0.0
16	3.1056E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 601 X(E) PLEXIGLAS 1.182G/CC H=.056884, C=.035552, O=.014221

GP.	ABSORPTION	NU FISSION	TOTAL
1	5.6884E-04	0.0	1.4421E-01
2	0.0	0.0	1.8900E-01
3	0.0	0.0	3.1821E-01
4	0.0	0.0	3.8918E-01
5	0.0	0.0	5.5475E-01
6	0.0	0.0	8.6300E-01
7	0.0	0.0	1.0189E 00
8	5.6884E-05	0.0	1.0593E 00
9	2.2754E-04	0.0	1.0593E 00
10	4.5507E-04	0.0	1.0593E 00
11	7.9638E-04	0.0	1.0593E 00
12	1.4221E-03	0.0	1.0629E 00
13	2.5598E-03	0.0	1.0629E 00
14	3.9819E-03	0.0	1.2335E 00
15	7.4198E-03	0.0	1.6317E 00
16	1.6606E-02	0.0	2.7694E 00

TRANSFER CROSS SECTIONS

FROM I	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
1	8.0466E-02	6.6376E-02	1.3140E-02	1.3140E-02	7.9069E-03	2.6167E-03
2	5.8675E-02	5.5462E-02	4.1582E-02	2.4972E-02	6.8830E-03	1.4221E-03
3	9.4000E-02	1.4377E-01	6.0297E-02	1.6724E-02	2.7873E-03	6.2572E-04
4	1.5366E-01	1.8399E-01	4.2777E-02	7.2243E-03	1.2515E-03	2.8442E-04
5	3.0247E-01	2.1285E-01	3.2481E-02	5.6884E-03	1.0239E-03	2.2754E-04
6	4.3043E-01	3.6010E-01	5.9444E-02	1.0637E-02	1.7065E-03	7.1105E-04
7	4.8694E-01	4.3819E-01	7.6737E-02	1.1889E-02	3.4699E-03	1.7065E-03
8	4.9219E-01	4.6730E-01	6.9398E-02	2.0478E-02	6.9398E-03	2.9580E-03
9	4.9355E-01	4.0126E-01	1.0922E-01	3.8691E-02	1.0922E-02	5.4609E-03
10	3.6967E-01	4.6809E-01	1.5467E-01	4.4370E-02	1.3197E-02	8.8739E-03
11	3.4018E-01	5.1259E-01	1.3754E-01	4.0900E-02	2.0478E-02	6.8261E-03
12	3.6070E-01	4.7703E-01	1.3447E-01	6.7237E-02	2.2014E-02	0.0
13	3.2869E-01	4.5141E-01	2.0956E-01	7.0650E-02	0.0	0.0
14	4.4269E-01	5.9914E-01	1.8772E-01	0.0	0.0	0.0
15	1.3161E 00	3.0819E-01	0.0	0.0	0.0	0.0
16	2.7528E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 602 DE/E PLEXIGLAS 1.182G/CC H=.056884, C=.035552, O=.014221

GP.	ABSORPTION	NU FISSION	TOTAL
1	5.6884E-04	0.0	1.4512E-01
2	0.0	0.0	1.9099E-01
3	0.0	0.0	3.1400E-01
4	0.0	0.0	3.9044E-01
5	0.0	0.0	5.6436E-01
6	0.0	0.0	8.6300E-01
7	0.0	0.0	1.0189E 00
8	5.6884E-05	0.0	1.0593E 00
9	2.2754E-04	0.0	1.0593E 00
10	4.5507E-04	0.0	1.0593E 00
11	7.9638E-04	0.0	1.0593E 00
12	1.4221E-03	0.0	1.0629E 00
13	2.5598E-03	0.0	1.0629E 00
14	3.9819E-03	0.0	1.2335E 00
15	7.4198E-03	0.0	1.6317E 00
16	1.6606E-02	0.0	2.7694E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	3.8304E-02	6.8083E-02	1.3595E-02	1.3595E-02	8.1913E-03	2.7873E-03
2	6.7265E-02	5.3130E-02	3.9250E-02	2.3607E-02	6.5985E-03	1.1377E-03
3	8.6662E-02	1.4542E-01	6.1207E-02	1.7065E-02	2.9580E-03	6.8261E-04
4	1.4672E-01	1.9019E-01	4.4426E-02	7.5087E-03	1.2515E-03	3.4130E-04
5	2.6720E-01	2.5006E-01	3.8909E-02	6.6554E-03	1.2515E-03	2.8442E-04
6	4.3043E-01	3.6010E-01	5.9444E-02	1.0637E-02	1.7065E-03	6.8261E-04
7	4.8694E-01	4.3819E-01	7.6737E-02	1.1889E-02	3.4699E-03	1.7065E-03
8	4.9219E-01	4.6730E-01	6.9398E-02	2.0478E-02	6.9398E-03	2.9580E-03
9	4.9355E-01	4.0126E-01	1.0922E-01	3.8681E-02	1.0922E-02	5.4609E-03
10	3.6967E-01	4.6809E-01	1.5467E-01	4.4370E-02	1.3197E-02	8.8739E-03
11	3.4018E-01	5.1259E-01	1.3754E-01	4.0900E-02	2.0478E-02	6.8261E-03
12	3.6070E-01	4.7703E-01	1.3447E-01	6.7237E-02	2.2014E-02	0.0
13	3.2869E-01	4.5141E-01	2.0956E-01	7.0650E-02	0.0	0.0
14	4.4269E-01	5.9914E-01	1.8772E-01	0.0	0.0	0.0
15	1.3161E 00	3.0818E-01	0.0	0.0	0.0	0.0
16	2.7528E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 1101 HYDROGEN X(E) HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	0.0	0.0	1.4340E 00
2	0.0	0.0	2.1400E 00
3	0.0	0.0	3.3740E 00
4	0.0	0.0	4.1030E 00
5	0.0	0.0	6.5810E 00
6	0.0	0.0	1.1700E 01
7	0.0	0.0	1.4250E 01
8	1.0000E-03	0.0	1.5000E 01
9	4.0000E-03	0.0	1.5000E 01
10	8.0000E-03	0.0	1.5000E 01
11	1.4000E-02	0.0	1.5000E 01
12	2.5000E-02	0.0	1.5000E 01
13	4.5000E-02	0.0	1.5000E 01
14	7.0000E-02	0.0	1.8000E 01
15	1.3000E-01	0.0	2.5000E 01
16	2.9000E-01	0.0	4.5000E 01

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	4.8000E-02	7.3900E-01	2.3100E-01	2.3100E-01	1.3900E-01	4.6000E-02
2	9.3000E-02	7.3100E-01	7.3100E-01	4.3900E-01	1.2100E-01	2.5000E-02
3	1.9300E-01	1.7670E 00	1.0600E 00	2.9400E-01	4.9000E-02	1.1000E-02
4	4.7900E-01	2.7180E 00	7.5200E-01	1.2700E-01	2.2000E-02	5.0000E-03
5	2.5010E 00	3.3870E 00	5.7100E-01	1.0000E-01	1.8000E-02	4.0000E-03
6	4.4040E 00	6.0220E 00	1.0450E 00	1.8700E-01	3.0000E-02	1.2500E-02
7	5.2290E 00	7.3720E 00	1.3490E 00	2.0900E-01	6.1000E-02	3.0000E-02
8	5.3650E 00	7.8800E 00	1.2200E 00	3.6000E-01	1.2200E-01	5.2000E-02
9	5.3890E 00	6.7190E 00	1.9200E 00	6.8000E-01	1.9200E-01	9.6000E-02
10	3.3480E 00	7.7570E 00	2.7190E 00	7.8000E-01	2.3200E-01	1.5600E-01
11	2.8750E 00	8.4940E 00	2.4180E 00	7.1900E-01	3.6000E-01	1.2000E-01
12	3.1360E 00	7.9060E 00	2.3640E 00	1.1820E 00	3.8700E-01	0.0
13	2.6200E 00	7.4090E 00	3.6840E 00	1.2420E 00	0.0	0.0
14	4.7300E 00	9.9000E 00	3.3000E 00	0.0	0.0	0.0
15	1.9870E 01	5.0000E 00	0.0	0.0	0.0	0.0
16	4.4710E 01	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 1102 HYDROGEN DE/E HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	0.0	0.0	1.4500E 00
2	0.0	0.0	2.1750E 00
3	0.0	0.0	3.3000E 00
4	0.0	0.0	4.1250E 00
5	0.0	0.0	6.7500E 00
6	0.0	0.0	1.1700E 01
7	0.0	0.0	1.4250E 01
8	1.0000E-03	0.0	1.5000E 01
9	4.0000E-03	0.0	1.5000E 01
10	8.0000E-03	0.0	1.5000E 01
11	1.4000E-02	0.0	1.5000E 01
12	2.5000E-02	0.0	1.5000E 01
13	4.5000E-02	0.0	1.5000E 01
14	7.0000E-02	0.0	1.8000E 01
15	1.3000E-01	0.0	2.5000E 01
16	2.9000E-01	0.0	4.5000E 01

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.0000E-02	7.6900E-01	2.3900E-01	2.3900E-01	1.4400E-01	4.9000E-02
2	2.4400E-01	6.9000E-01	6.9000E-01	4.1500E-01	1.1600E-01	2.0000E-02
3	6.4000E-02	1.7960E 00	1.0760E 00	3.0000E-01	5.2000E-02	1.2000E-02
4	3.5700E-01	2.8270E 00	7.8100E-01	1.3200E-01	2.2000E-02	6.0000E-03
5	1.8810E 00	4.0410E 00	6.8400E-01	1.1700E-01	2.2000E-02	5.0000E-03
6	4.4040E 00	6.0220E 00	1.0450E 00	1.8700E-01	3.0000E-02	1.2000E-02
7	5.2290E 00	7.3720E 00	1.3490E 00	2.0900E-01	6.1000E-02	3.0000E-02
8	5.3650E 00	7.8800E 00	1.2200E 00	3.6000E-01	1.2200E-01	5.2000E-02
9	5.3890E 00	6.7190E 00	1.9200E 00	6.8000E-01	1.9200E-01	9.6000E-02
10	3.3480E 00	7.7570E 00	2.7190E 00	7.8000E-01	2.3200E-01	1.5600E-01
11	2.8750E 00	8.4940E 00	2.4180E 00	7.1900E-01	3.6000E-01	1.2000E-01
12	3.1360E 00	7.9060E 00	2.3640E 00	1.1820E 00	3.8700E-01	0.0
13	2.6200E 00	7.4090E 00	3.6840E 00	1.2420E 00	0.0	0.0
14	4.7300E 00	9.9000E 00	3.3000E 00	0.0	0.0	0.0
15	1.9870E 01	5.0000E 00	0.0	0.0	0.0	0.0
16	4.4710E 01	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 5100 BORON

HANSEN ROACH

	GP. ABSORPTION	NU FISSION	TOTAL
1	4.0000E-02	0.0	1.5200E 00
2	6.0000E-02	0.0	1.7900E 00
3	4.0000E-02	0.0	2.1400E 00
4	8.0000E-02	0.0	2.2700E 00
5	2.7000E-01	0.0	3.1600E 00
6	6.1000E-01	0.0	4.0800E 00
7	1.5000E 00	0.0	4.9700E 00
8	3.4000E 00	0.0	6.8700E 00
9	8.0000E 00	0.0	1.1470E 01
10	1.6400E 01	0.0	1.9870E 01
11	2.9000E 01	0.0	3.2470E 01
12	5.2000E 01	0.0	5.5470E 01
13	9.2000E 01	0.0	9.5470E 01
14	1.5100E 02	0.0	1.5447E 02
15	2.7300E 02	0.0	2.7647E 02
16	6.6930E 02	0.0	6.7277E 02

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	8.1000E-01	6.7000E-01	0.0	0.0	0.0	0.0
2	1.3100E 00	4.2000E-01	0.0	0.0	0.0	0.0
3	1.2200E 00	8.8000E-01	0.0	0.0	0.0	0.0
4	1.6900E 00	5.0000E-01	0.0	0.0	0.0	0.0
5	2.5100E 00	3.8000E-01	0.0	0.0	0.0	0.0
6	3.1100E 00	3.6000E-01	0.0	0.0	0.0	0.0
7	3.1000E 00	3.7000E-01	0.0	0.0	0.0	0.0
8	3.0900E 00	3.8000E-01	0.0	0.0	0.0	0.0
9	3.0900E 00	3.8000E-01	0.0	0.0	0.0	0.0
10	2.9400E 00	5.3000E-01	0.0	0.0	0.0	0.0
11	2.8900E 00	5.8000E-01	0.0	0.0	0.0	0.0
12	2.9400E 00	5.3000E-01	0.0	0.0	0.0	0.0
13	2.8900E 00	5.8000E-01	0.0	0.0	0.0	0.0
14	2.7700E 00	7.0000E-01	0.0	0.0	0.0	0.0
15	3.0100E 00	4.6000E-01	0.0	0.0	0.0	0.0
16	3.4700E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 6100 CARBON

HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	0.0	0.0	1.2300E 00
2	0.0	0.0	1.4200E 00
3	0.0	0.0	2.2600E 00
4	0.0	0.0	2.9300E 00
5	0.0	0.0	3.5900E 00
6	0.0	0.0	4.2500E 00
7	0.0	0.0	4.4400E 00
8	0.0	0.0	4.3400E 00
9	0.0	0.0	4.3400E 00
10	0.0	0.0	4.3400E 00
11	0.0	0.0	4.3400E 00
12	0.0	0.0	4.4400E 00
13	0.0	0.0	4.4400E 00
14	0.0	0.0	4.4400E 00
15	7.0000E-04	0.0	4.4387E 00
16	3.0000E-03	0.0	4.4390E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	7.1500E-01	5.1500E-01	0.0	0.0	0.0	0.0
2	1.1060E 00	3.1400E-01	0.0	0.0	0.0	0.0
3	1.4040E 00	8.5600E-01	0.0	0.0	0.0	0.0
4	2.3260E 00	6.0400E-01	0.0	0.0	0.0	0.0
5	3.1570E 00	4.3300E-01	0.0	0.0	0.0	0.0
6	3.8490E 00	4.0100E-01	0.0	0.0	0.0	0.0
7	4.0120E 00	4.2800E-01	0.0	0.0	0.0	0.0
8	3.9120E 00	4.2800E-01	0.0	0.0	0.0	0.0
9	3.9120E 00	4.2800E-01	0.0	0.0	0.0	0.0
10	3.7370E 00	6.0300E-01	0.0	0.0	0.0	0.0
11	3.6780E 00	6.6200E-01	0.0	0.0	0.0	0.0
12	3.8240E 00	6.1600E-01	0.0	0.0	0.0	0.0
13	3.7630E 00	6.7700E-01	0.0	0.0	0.0	0.0
14	3.6270E 00	8.1300E-01	0.0	0.0	0.0	0.0
15	3.9020E 00	5.3600E-01	0.0	0.0	0.0	0.0
16	4.4360E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 7100 NITROGEN HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	2.5000E-01	0.0	9.7000E-01
2	1.1000E-01	0.0	1.4800E 00
3	4.0000E-02	0.0	1.6900E 00
4	4.0000E-02	0.0	2.1700E 00
5	2.0000E-03	0.0	3.2940E 00
6	2.0000E-03	0.0	5.4360E 00
7	4.0001E-03	0.0	7.3590E 00
8	8.0000E-03	0.0	8.0920E 00
9	1.9000E-02	0.0	8.4930E 00
10	4.0000E-02	0.0	9.3300E 00
11	7.0000E-02	0.0	9.5900E 00
12	1.2000E-01	0.0	9.6400E 00
13	2.2000E-01	0.0	9.7400E 00
14	3.6000E-01	0.0	9.8800E 00
15	6.4000E-01	0.0	1.0160E 01
16	1.6700E 00	0.0	1.1190E 01

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
1	3.9000E-01	3.3000E-01	0.0	0.0	0.0	0.0
2	1.0100E 00	3.6000E-01	0.0	0.0	0.0	0.0
3	1.2000E 00	4.5000E-01	0.0	0.0	0.0	0.0
4	1.7800E 00	3.5000E-01	0.0	0.0	0.0	0.0
5	3.1220E 00	1.7000E-01	0.0	0.0	0.0	0.0
6	4.9940E 00	4.4000E-01	0.0	0.0	0.0	0.0
7	6.7450E 00	6.1000E-01	0.0	0.0	0.0	0.0
8	7.4040E 00	6.8000E-01	0.0	0.0	0.0	0.0
9	7.7640E 00	7.1000E-01	0.0	0.0	0.0	0.0
10	8.1800E 00	1.1100E 00	0.0	0.0	0.0	0.0
11	8.2800E 00	1.2400E 00	0.0	0.0	0.0	0.0
12	8.3800E 00	1.1400E 00	0.0	0.0	0.0	0.0
13	8.2800E 00	1.2400E 00	0.0	0.0	0.0	0.0
14	8.0300E 00	1.4900E 00	0.0	0.0	0.0	0.0
15	8.5300E 00	9.9000E-01	0.0	0.0	0.0	0.0
16	9.5290E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 8100 OXYGEN

HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	4.0000E-02	0.0	1.3300E 00
2	0.0	0.0	1.1800E 00
3	0.0	0.0	3.2300E 00
4	0.0	0.0	3.6300E 00
5	0.0	0.0	3.7100E 00
6	0.0	0.0	3.2600E 00
7	0.0	0.0	3.5500E 00
8	0.0	0.0	3.6400E 00
9	0.0	0.0	3.6400E 00
10	0.0	0.0	3.6400E 00
11	0.0	0.0	3.6400E 00
12	0.0	0.0	3.6400E 00
13	0.0	0.0	3.6400E 00
14	0.0	0.0	3.6400E 00
15	0.0	0.0	3.6400E 00
16	2.0000E-04	0.0	3.6412E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	8.6600E-01	4.2400E-01	0.0	0.0	0.0	0.0
2	9.8900E-01	1.9100E-01	0.0	0.0	0.0	0.0
3	2.3280E 00	9.0200E-01	0.0	0.0	0.0	0.0
4	3.0740E 00	5.5600E-01	0.0	0.0	0.0	0.0
5	3.3730E 00	3.3700E-01	0.0	0.0	0.0	0.0
6	3.0290E 00	2.3100E-01	0.0	0.0	0.0	0.0
7	3.2950E 00	2.5500E-01	0.0	0.0	0.0	0.0
8	3.3700E 00	2.7000E-01	0.0	0.0	0.0	0.0
9	3.3700E 00	2.7000E-01	0.0	0.0	0.0	0.0
10	3.2600E 00	3.8000E-01	0.0	0.0	0.0	0.0
11	3.2260E 00	4.1400E-01	0.0	0.0	0.0	0.0
12	3.2600E 00	3.8000E-01	0.0	0.0	0.0	0.0
13	3.2260E 00	4.1400E-01	0.0	0.0	0.0	0.0
14	3.1420E 00	4.9800E-01	0.0	0.0	0.0	0.0
15	3.3090E 00	3.3100E-01	0.0	0.0	0.0	0.0
16	3.6410E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 9100 FLUORINE HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	1.0000E-01	0.0	1.4000E 00
2	0.0	0.0	1.9000E 00
3	0.0	0.0	2.0900E 00
4	2.0003E-04	0.0	3.2002E 00
5	2.0003E-04	0.0	4.6102E 00
6	0.0	0.0	3.7800E 00
7	0.0	0.0	3.5700E 00
8	0.0	0.0	3.5700E 00
9	0.0	0.0	3.4700E 00
10	0.0	0.0	3.2800E 00
11	0.0	0.0	2.9900E 00
12	0.0	0.0	3.1800E 00
13	1.0000E-03	0.0	3.2810E 00
14	2.0000E-03	0.0	3.2820E 00
15	4.0000E-03	0.0	3.4740E 00
16	8.0000E-03	0.0	3.4680E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	8.8000E-01	4.2000E-01	0.0	0.0	0.0	0.0
2	1.2800E 00	3.2000E-01	2.1000E-01	9.0000E-02	0.0	0.0
3	1.4100E 00	6.8000E-01	8.0000E-08	0.0	0.0	0.0
4	2.1400E 00	1.0600E 00	0.0	0.0	0.0	0.0
5	3.9530E 00	6.5000E-01	7.0000E-03	0.0	0.0	0.0
6	3.5300E 00	2.5000E-01	0.0	0.0	0.0	0.0
7	3.3600E 00	2.1000E-01	0.0	0.0	0.0	0.0
8	3.3500E 00	2.2000E-01	0.0	0.0	0.0	0.0
9	3.2500E 00	2.2000E-01	0.0	0.0	0.0	0.0
10	2.9900E 00	2.2000E-01	0.0	0.0	0.0	0.0
11	2.7100E 00	2.8000E-01	0.0	0.0	0.0	0.0
12	2.9000E 00	2.8000E-01	0.0	0.0	0.0	0.0
13	2.9700E 00	3.1000E-01	0.0	0.0	0.0	0.0
14	2.9100E 00	3.7000E-01	0.0	0.0	0.0	0.0
15	3.2100E 00	2.6000E-01	0.0	0.0	0.0	0.0
16	3.4600E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 11100 SODIUM

HANSEN BOACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	3.0000E-02	0.0	1.6070E 00
2	0.0	0.0	2.2600E 00
3	1.9999E-04	0.0	2.9902E 00
4	5.0002E-04	0.0	3.1194E 00
5	9.0003E-04	0.0	3.1072E 00
6	9.9999E-04	0.0	3.8840E 00
7	1.0000E-03	0.0	6.0890E 00
8	1.0000E-03	0.0	4.5450E 00
9	5.0000E-03	0.0	3.0100E 00
10	1.1000E-02	0.0	3.0100E 00
11	1.8000E-02	0.0	3.0300E 00
12	3.2000E-02	0.0	3.0690E 00
13	5.7000E-02	0.0	3.0990E 00
14	1.0000E-01	0.0	3.2100E 00
15	1.9000E-01	0.0	3.3500E 00
16	4.4700E-01	0.0	3.7470E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.1370E 00	4.4000E-01	0.0	0.0	0.0	0.0
2	1.7040E 00	5.5600E-01	0.0	0.0	0.0	0.0
3	1.7990E 00	1.1910E 00	0.0	0.0	0.0	0.0
4	2.4709E 00	6.0400E-01	3.6000E-02	8.0000E-03	0.0	0.0
5	2.9113E 00	1.9500E-01	1.0000E-08	0.0	0.0	0.0
6	3.6950E 00	1.8800E-01	0.0	0.0	0.0	0.0
7	5.7870E 00	3.0100E-01	0.0	0.0	0.0	0.0
8	4.3100E 00	2.3400E-01	0.0	0.0	0.0	0.0
9	2.8500E 00	1.5500E-01	0.0	0.0	0.0	0.0
10	2.7830E 00	2.1600E-01	0.0	0.0	0.0	0.0
11	2.7760E 00	2.3600E-01	0.0	0.0	0.0	0.0
12	2.8180E 00	2.1900E-01	0.0	0.0	0.0	0.0
13	2.8040E 00	2.3800E-01	0.0	0.0	0.0	0.0
14	2.8160E 00	2.9400E-01	0.0	0.0	0.0	0.0
15	2.9620E 00	1.9800E-01	0.0	0.0	0.0	0.0
16	3.3000E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 12100 PO MAGNESIUM ENDF/B-IV MAT 1280

GP.	ABSORPTION	NU FISSION	TOTAL
1	2.0362E-02	0.0	1.9108E 00
2	8.0251E-04	0.0	2.4978E 00
3	9.3136E-04	0.0	2.9209E 00
4	1.4765E-03	0.0	4.6292E 00
5	1.0125E-04	0.0	5.2518E 00
6	6.2210E-04	0.0	4.3424E 00
7	1.8122E-04	0.0	3.3792E 00
8	2.9977E-04	0.0	3.3851E 00
9	6.6678E-04	0.0	3.3996E 00
10	1.3695E-03	0.0	3.4000E 00
11	2.4403E-03	0.0	3.3999E 00
12	4.3784E-03	0.0	3.3999E 00
13	7.7599E-03	0.0	3.3993E 00
14	1.2798E-02	0.0	3.3960E 00
15	2.3413E-02	0.0	3.3894E 00
16	5.8797E-02	0.0	3.3969E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.1626E 00	6.0271E-01	5.8137E-02	4.7004E-02	1.9449E-02	1.1101E-03
2	1.9682E 00	2.9969E-01	1.4827E-01	6.9845E-02	1.0514E-02	4.6256E-04
3	2.5878E 00	3.2235E-01	9.2851E-03	6.0302E-04	3.7631E-06	6.6142E-08
4	4.2832E 00	3.4416E-01	3.0914E-04	4.8229E-06	2.3770E-07	0.0
5	4.9417E 00	3.1002E-01	0.0	0.0	0.0	0.0
6	4.1443E 00	1.9750E-01	0.0	0.0	0.0	0.0
7	3.2218E 00	1.5718E-01	0.0	0.0	0.0	0.0
8	3.2236E 00	1.6111E-01	0.0	0.0	0.0	0.0
9	3.2380E 00	1.6099E-01	0.0	0.0	0.0	0.0
10	3.1706E 00	2.2791E-01	0.0	0.0	0.0	0.0
11	3.1477E 00	2.4968E-01	0.0	0.0	0.0	0.0
12	3.1647E 00	2.3080E-01	0.0	0.0	0.0	0.0
13	3.1507E 00	2.4080E-01	0.0	0.0	0.0	0.0
14	3.0884E 00	2.9485E-01	0.0	0.0	0.0	0.0
15	3.0913E 00	2.7470E-01	0.0	0.0	0.0	0.0
16	3.3381E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 13100 ALUMINUM

HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	1.5900E-02	0.0	1.8059E 00
2	0.0	0.0	2.0223E 00
3	3.8001E-04	0.0	2.1404E 00
4	7.0000E-04	0.0	2.7207E 00
5	2.0000E-03	0.0	2.8320E 00
6	5.0000E-03	0.0	1.4350E 00
7	2.0000E-03	0.0	1.4630E 00
8	1.0000E-03	0.0	1.3650E 00
9	3.0000E-03	0.0	1.3660E 00
10	6.0000E-03	0.0	1.3660E 00
11	1.0000E-02	0.0	1.3660E 00
12	1.7000E-02	0.0	1.3850E 00
13	3.0000E-02	0.0	1.4100E 00
14	5.0000E-02	0.0	1.4600E 00
15	8.0000E-02	0.0	1.4600E 00
16	2.3000E-01	0.0	1.5700E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.1000E 00	5.6000E-01	1.0000E-01	3.0000E-02	0.0	0.0
2	1.6614E 00	2.3000E-01	1.1000E-01	2.0000E-02	9.0000E-04	0.0
3	1.6100E 00	3.8000E-01	1.4000E-01	1.0000E-02	0.0	0.0
4	2.4700E 00	2.5000E-01	1.0000E-01	0.0	0.0	0.0
5	2.6900E 00	1.4000E-01	0.0	0.0	0.0	0.0
6	1.3600E 00	7.0000E-02	0.0	0.0	0.0	0.0
7	1.3980E 00	6.3000E-02	0.0	0.0	0.0	0.0
8	1.3040E 00	6.0000E-02	0.0	0.0	0.0	0.0
9	1.3030E 00	6.0000E-02	0.0	0.0	0.0	0.0
10	1.2760E 00	8.4000E-02	0.0	0.0	0.0	0.0
11	1.2640E 00	9.2000E-02	0.0	0.0	0.0	0.0
12	1.2840E 00	8.4000E-02	0.0	0.0	0.0	0.0
13	1.2860E 00	9.4000E-02	0.0	0.0	0.0	0.0
14	1.2950E 00	1.1500E-01	0.0	0.0	0.0	0.0
15	1.3060E 00	7.4000E-02	0.0	0.0	0.0	0.0
16	1.3400E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 14100 P0 SILICON ENDF/B-IV MAT 1194

	GP.	ABSORPTION	NU	FISSION	TOTAL
1		4.8675E-02	0.0		2.2154E 00
2		6.5337E-04	0.0		2.9523E 00
3		6.5994E-04	0.0		3.0127E 00
4		6.6473E-04	0.0		3.1731E 00
5		6.7735E-04	0.0		1.4087E 00
6		4.3206E-03	0.0		1.5330E 00
7		3.0812E-04	0.0		1.9975E 00
8		7.3707E-04	0.0		2.1507E 00
9		1.7186E-03	0.0		2.1517E 00
10		3.5095E-03	0.0		2.1535E 00
11		6.2366E-03	0.0		2.1562E 00
12		1.1013E-02	0.0		2.1610E 00
13		1.9591E-02	0.0		2.1693E 00
14		3.2472E-02	0.0		2.1825E 00
15		5.9636E-02	0.0		2.2095E 00
16		1.4968E-01	0.0		2.2997E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.5146E 00	4.9628E-01	1.2358E-01	2.3493E-02	7.9743E-03	9.6600E-04
2	2.5303E 00	2.4735E-01	1.0884E-01	5.8306E-02	6.5353E-03	2.6129E-04
3	2.7015E 00	3.1002E-01	1.3302E-01	4.0456E-04	2.5236E-05	1.7867E-06
4	2.9180E 00	2.5394E-01	0.0	0.0	0.0	0.0
5	1.3372E 00	7.0728E-02	0.0	0.0	0.0	0.0
6	1.4676E 00	6.1043E-02	0.0	0.0	0.0	0.0
7	1.9168E 00	8.0499E-02	0.0	0.0	0.0	0.0
8	2.0613E 00	8.8675E-02	0.0	0.0	0.0	0.0
9	2.0624E 00	8.7597E-02	0.0	0.0	0.0	0.0
10	2.0257E 00	1.2421E-01	0.0	0.0	0.0	0.0
11	2.0142E 00	1.3581E-01	0.0	0.0	0.0	0.0
12	2.0239E 00	1.2613E-01	0.0	0.0	0.0	0.0
13	2.0139E 00	1.3586E-01	0.0	0.0	0.0	0.0
14	1.9820E 00	1.6793E-01	0.0	0.0	0.0	0.0
15	1.9839E 00	1.6605E-01	0.0	0.0	0.0	0.0
16	2.1501E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 16100 PO SULFUR-32 LENDL MAT 7020

GP.	ABSORPTION	NU FISSION	TOTAL
1	3.8777E-01	0.0	2.8436E 00
2	9.6537E-02	0.0	2.6756E 00
3	5.1427E-03	0.0	2.3100E 00
4	4.2174E-03	0.0	2.2314E 00
5	3.8251E-03	0.0	3.3697E 00
6	5.4664E-03	0.0	7.6192E-01
7	2.3750E-02	0.0	1.1080E 00
8	7.3205E-02	0.0	1.1357E 00
9	8.7034E-02	0.0	1.1716E 00
10	9.1142E-02	0.0	1.1822E 00
11	9.4415E-02	0.0	1.1868E 00
12	9.8916E-02	0.0	1.1917E 00
13	1.0206E-01	0.0	1.1949E 00
14	1.2638E-01	0.0	1.2368E 00
15	2.1125E-01	0.0	1.3608E 00
16	4.6154E-01	0.0	1.6584E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.9556E 00	1.8034E-01	2.3502E-02	5.4146E-02	1.1110E-01	2.2969E-01
2	2.4207E 00	1.0843E-01	0.0	0.0	0.0	5.1482E-02
3	2.1208E 00	1.8565E-01	0.0	0.0	0.0	0.0
4	2.1090E 00	1.1941E-01	0.0	0.0	0.0	0.0
5	3.2006E 00	1.6539E-01	0.0	0.0	0.0	0.0
6	7.3020E-01	2.6282E-02	0.0	0.0	0.0	0.0
7	1.0458E 00	3.8566E-02	0.0	0.0	0.0	0.0
8	9.9717E-01	6.5584E-02	0.0	0.0	0.0	0.0
9	1.0443E 00	4.0431E-02	0.0	0.0	0.0	0.0
10	1.0516E 00	4.0083E-02	0.0	0.0	0.0	0.0
11	1.0361E 00	5.6375E-02	0.0	0.0	0.0	0.0
12	1.0274E 00	6.5575E-02	0.0	0.0	0.0	0.0
13	1.0521E 00	4.0738E-02	0.0	0.0	0.0	0.0
14	1.0336E 00	7.6830E-02	0.0	0.0	0.0	0.0
15	1.0701E 00	7.9440E-02	0.0	0.0	0.0	0.0
16	1.1969E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 19100 POTASSIUM HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	0.0	0.0	2.1100E 00
2	0.0	0.0	2.2200E 00
3	0.0	0.0	1.6900E 00
4	0.0	0.0	1.8400E 00
5	0.0	0.0	1.9700E 00
6	1.0000E-03	0.0	1.8670E 00
7	3.0000E-03	0.0	1.4250E 00
8	9.0000E-03	0.0	1.5230E 00
9	1.7000E-02	0.0	1.7000E 00
10	3.8000E-02	0.0	1.8680E 00
11	6.8000E-02	0.0	1.9660E 00
12	1.2000E-01	0.0	2.1100E 00
13	2.1000E-01	0.0	2.2600E 00
14	3.6000E-01	0.0	2.3600E 00
15	6.1000E-01	0.0	2.6600E 00
16	1.7500E 00	0.0	2.0000E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.7950E 00	3.1500E-01	0.0	0.0	0.0	0.0
2	2.0710E 00	1.4900E-01	0.0	0.0	0.0	0.0
3	1.4950E 00	1.9500E-01	0.0	0.0	0.0	0.0
4	1.7240E 00	1.1600E-01	0.0	0.0	0.0	0.0
5	1.8980E 00	7.2000E-02	0.0	0.0	0.0	0.0
6	1.8130E 00	5.3000E-02	0.0	0.0	0.0	0.0
7	1.3800E 00	4.2000E-02	0.0	0.0	0.0	0.0
8	1.4700E 00	4.5000E-02	0.0	0.0	0.0	0.0
9	1.6330E 00	5.0000E-02	0.0	0.0	0.0	0.0
10	1.7520E 00	7.8000E-02	0.0	0.0	0.0	0.0
11	1.8090E 00	8.9000E-02	0.0	0.0	0.0	0.0
12	1.9050E 00	8.5000E-02	0.0	0.0	0.0	0.0
13	1.9540E 00	9.6000E-02	0.0	0.0	0.0	0.0
14	1.8880E 00	1.1200E-01	0.0	0.0	0.0	0.0
15	1.9750E 00	7.5000E-02	0.0	0.0	0.0	0.0
16	2.2500E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 20100 CALCIUM

GAM-2

GP.	ABSORPTION	NU FISSION	TOTAL
1	4.7805E-01	0.0	2.4477E 00
2	3.6504E-02	0.0	2.2829E 00
3	2.5572E-03	0.0	2.3254E 00
4	1.2961E-03	0.0	1.7144E 00
5	1.3781E-03	0.0	1.6893E 00
6	3.3378E-04	0.0	1.3455E 00
7	4.2678E-04	0.0	1.3455E 00
8	8.0005E-04	0.0	1.4057E 00
9	2.2963E-03	0.0	1.4968E 00
10	8.4526E-02	0.0	1.5790E 00
11	4.5662E-02	0.0	1.5401E 00
12	2.9101E-02	0.0	1.5236E 00
13	5.0863E-02	0.0	1.5454E 00
14	8.2522E-02	0.0	1.5770E 00
15	1.2000E-01	0.0	2.1400E 00
16	3.8100E-01	0.0	3.5810E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
1	1.5763E 00	3.1820E-01	1.7454E-02	3.5951E-02	1.9228E-02	2.5505E-03
2	1.9924E 00	2.1402E-01	1.0000E-20	1.0000E-20	1.0000E-20	0.0
3	2.0198E 00	3.0413E-01	1.0000E-20	1.0000E-20	0.0	0.0
4	1.6055E 00	1.0755E-01	1.0000E-20	0.0	0.0	0.0
5	1.6271E 00	6.0820E-02	0.0	0.0	0.0	0.0
6	1.3116E 00	3.3499E-02	0.0	0.0	0.0	0.0
7	1.3007E 00	4.4382E-02	0.0	0.0	0.0	0.0
8	1.3653E 00	3.9590E-02	0.0	0.0	0.0	0.0
9	1.4532E 00	4.1323E-02	0.0	0.0	0.0	0.0
10	1.4828E 00	1.1717E-02	0.0	0.0	0.0	0.0
11	1.4279E 00	6.6615E-02	0.0	0.0	0.0	0.0
12	1.4470E 00	4.7527E-02	0.0	0.0	0.0	0.0
13	1.4385E 00	5.5948E-02	0.0	0.0	0.0	0.0
14	1.4475E 00	4.6979E-02	0.0	0.0	0.0	0.0
15	2.0000E 00	2.0000E-02	0.0	0.0	0.0	0.0
16	3.2000E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 22100 TITANIUM GAM-2

GP.	ABSORPTION	NU FISSION	TOTAL
1	9.5766E-03	0.0	2.0597E 00
2	6.8350E-04	0.0	2.6420E 00
3	2.0737E-03	0.0	2.2150E 00
4	4.0205E-03	0.0	1.9955E 00
5	5.7430E-03	0.0	2.4463E 00
6	1.2539E-02	0.0	2.9362E 00
7	2.0088E-01	0.0	1.4299E 01
8	1.4566E-01	0.0	4.9076E 00
9	5.2926E-02	0.0	4.2527E 00
10	1.1531E-01	0.0	4.3007E 00
11	2.0199E-01	0.0	4.4020E 00
12	3.3486E-01	0.0	4.5009E 00
13	6.0292E-01	0.0	4.9101E 00
14	1.0568E 00	0.0	5.5241E 00
15	2.4000E 00	0.0	6.7100E 00
16	5.4000E 00	0.0	9.4000E 00

TRANSFER CROSS SECTIONS

FROM I	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
1	9.1919E-01	8.0585E-01	1.4753E-01	1.5028E-01	2.4501E-02	2.7875E-03
2	2.0319E 00	3.1993E-01	2.3290E-01	5.3699E-02	2.6959E-03	1.9040E-04
3	1.8311E 00	2.6271E-01	1.0070E-01	1.7564E-02	7.0660E-04	1.4592E-04
4	1.8707E 00	1.2075E-01	1.0000E-20	1.0000E-20	1.0000E-20	0.0
5	2.3284E 00	1.1217E-01	1.0000E-20	1.0000E-20	0.0	0.0
6	2.9075E 00	1.6108E-02	1.0000E-20	0.0	0.0	0.0
7	1.3967E 01	1.3080E-01	0.0	0.0	0.0	0.0
8	4.6646E 00	9.7346E-02	0.0	0.0	0.0	0.0
9	4.1489E 00	5.0842E-02	0.0	0.0	0.0	0.0
10	4.1043E 00	8.1056E-02	0.0	0.0	0.0	0.0
11	4.1072E 00	9.2856E-02	0.0	0.0	0.0	0.0
12	4.1271E 00	3.8946E-02	0.0	0.0	0.0	0.0
13	4.2890E 00	1.8177E-02	0.0	0.0	0.0	0.0
14	4.4674E 00	6.0658E-02	0.0	0.0	0.0	0.0
15	4.2000E 00	1.1000E-01	0.0	0.0	0.0	0.0
16	4.0000E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 24100 CHROMIUM

AEROJET

GP.	ABSORPTION	NU FISSION	TOTAL
1	1.0000E-02	0.0	2.4400E 00
2	2.0000E-02	0.0	2.3600E 00
3	2.0000E-02	0.0	2.1700E 00
4	2.0000E-02	0.0	2.6200E 00
5	4.0000E-02	0.0	3.5500E 00
6	1.1000E-01	0.0	3.1700E 00
7	7.0000E-02	0.0	1.2920E 01
8	2.0000E-02	0.0	4.6700E 00
9	3.0000E-02	0.0	4.2400E 00
10	6.0000E-02	0.0	4.2500E 00
11	1.1000E-01	0.0	4.3000E 00
12	1.9000E-01	0.0	4.3500E 00
13	3.4000E-01	0.0	4.4700E 00
14	5.5000E-01	0.0	4.6400E 00
15	9.9000E-01	0.0	5.2100E 00
16	3.1000E 00	0.0	6.1000E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
1	1.2500E 00	5.7000E-01	2.6000E-01	2.5000E-01	9.0000E-02	1.0000E-02
2	1.4700E 00	3.5000E-01	3.6000E-01	1.5000E-01	1.0000E-02	0.0
3	1.7900E 00	2.8000E-01	7.0000E-02	1.0000E-02	0.0	0.0
4	2.4500E 00	1.5000E-01	1.0000E-07	0.0	0.0	0.0
5	3.3800E 00	1.3000E-01	0.0	0.0	0.0	0.0
6	3.0000E 00	6.0000E-02	0.0	0.0	0.0	0.0
7	1.2680E 01	1.7000E-01	0.0	0.0	0.0	0.0
8	4.5600E 00	9.0000E-02	0.0	0.0	0.0	0.0
9	4.1200E 00	9.0000E-02	0.0	0.0	0.0	0.0
10	4.0600E 00	1.3000E-01	0.0	0.0	0.0	0.0
11	4.0500E 00	1.4000E-01	0.0	0.0	0.0	0.0
12	4.0300E 00	1.3000E-01	0.0	0.0	0.0	0.0
13	3.9900E 00	1.4000E-01	0.0	0.0	0.0	0.0
14	3.9200E 00	1.7000E-01	0.0	0.0	0.0	0.0
15	4.1000E 00	1.2000E-01	0.0	0.0	0.0	0.0
16	3.0000E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 25100 PO MANGANESE-55 ENDF/B-IV MAT 1197

	GP. ABSORPTION	NU FISSION	TOTAL
1	7.2195E-03	0.0	3.6840E 00
2	1.9367E-03	0.0	3.5483E 00
3	2.6868E-03	0.0	3.3563E 00
4	3.6887E-03	0.0	3.3436E 00
5	8.8602E-03	0.0	4.5903E 00
6	4.4616E-02	0.0	1.1503E 01
7	5.3254E-02	0.0	2.3862E 01
8	7.6022E-01	0.0	1.1368E 02
9	4.7034E 00	0.0	2.0240E 02
10	3.9014E-01	0.0	3.2590E 00
11	5.5940E-01	0.0	2.5907E 00
12	9.3722E-01	0.0	2.7709E 00
13	1.6346E 00	0.0	3.4156E 00
14	2.6910E 00	0.0	4.4561E 00
15	4.9256E 00	0.0	6.6868E 00
16	1.2409E 01	0.0	1.4184E 01

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
1	2.4080E 00	7.6649E-01	2.4398E-01	1.8944E-01	6.4838E-02	5.3330E-03
2	2.8608E 00	3.5079E-01	2.4053E-01	8.2962E-02	1.0654E-02	7.4174E-04
3	2.8778E 00	3.7344E-01	8.2698E-02	1.7937E-02	1.7122E-03	1.1362E-04
4	3.0992E 00	2.4059E-01	0.0	0.0	0.0	0.0
5	4.4320E 00	1.3893E-01	9.5151E-03	9.7531E-04	6.7550E-05	4.3619E-06
6	1.1390E 01	6.9080E-02	0.0	0.0	0.0	0.0
7	2.2498E 01	1.3105E 00	0.0	0.0	0.0	0.0
8	1.1250E 02	4.1573E-01	0.0	0.0	0.0	0.0
9	1.9760E 02	9.1076E-02	0.0	0.0	0.0	0.0
10	2.4010E 00	6.7574E-02	0.0	0.0	0.0	0.0
11	1.9686E 00	6.2533E-02	0.0	0.0	0.0	0.0
12	1.7786E 00	5.4959E-02	0.0	0.0	0.0	0.0
13	1.7189E 00	6.2132E-02	0.0	0.0	0.0	0.0
14	1.6894E 00	7.5811E-02	0.0	0.0	0.0	0.0
15	1.6761E 00	8.5122E-02	0.0	0.0	0.0	0.0
16	1.7744E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 26100 IRON

HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	7.0000E-03	0.0	2.2470E 00
2	5.0000E-03	0.0	2.2000E 00
3	1.0000E-02	0.0	1.9600E 00
4	1.0000E-02	0.0	2.2900E 00
5	1.0000E-02	0.0	2.4400E 00
6	1.0000E-02	0.0	2.2300E 00
7	1.0000E-02	0.0	5.6500E 00
8	1.1000E-02	0.0	7.1140E 00
9	2.7000E-02	0.0	1.0968E 01
10	5.5000E-02	0.0	1.1364E 01
11	9.8000E-02	0.0	1.1364E 01
12	1.7000E-01	0.0	1.1370E 01
13	3.1000E-01	0.0	1.1370E 01
14	5.1000E-01	0.0	1.1370E 01
15	9.1000E-01	0.0	1.1570E 01
16	2.5300E 00	0.0	1.3070E 01

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.4400E 00	5.0000E-01	2.0000E-01	1.0000E-01	0.0	0.0
2	1.4950E 00	4.0000E-01	2.0000E-01	1.0000E-01	0.0	0.0
3	1.4700E 00	2.3000E-01	2.3000E-01	2.0000E-02	0.0	0.0
4	2.1570E 00	1.2300E-01	1.0000E-08	0.0	0.0	0.0
5	2.3590E 00	7.1000E-02	0.0	0.0	0.0	0.0
6	2.1700E 00	5.0000E-02	0.0	0.0	0.0	0.0
7	5.5200E 00	1.2000E-01	0.0	0.0	0.0	0.0
8	6.9520E 00	1.5100E-01	0.0	0.0	0.0	0.0
9	1.0708E 01	2.3300E-01	0.0	0.0	0.0	0.0
10	1.0977E 01	3.3200E-01	0.0	0.0	0.0	0.0
11	1.0901E 01	3.6500E-01	0.0	0.0	0.0	0.0
12	1.0871E 01	3.2900E-01	0.0	0.0	0.0	0.0
13	1.0702E 01	3.5800E-01	0.0	0.0	0.0	0.0
14	1.0431E 01	4.2900E-01	0.0	0.0	0.0	0.0
15	1.0390E 01	2.7000E-01	0.0	0.0	0.0	0.0
16	1.0540E 01	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 28100 NICKEL

HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	2.7000E-01	0.0	2.2900E 00
2	1.0000E-01	0.0	2.3400E 00
3	1.0000E-02	0.0	2.5300E 00
4	1.0000E-02	0.0	2.4500E 00
5	1.0000E-02	0.0	3.3800E 00
6	2.0000E-02	0.0	5.1700E 00
7	3.8000E-01	0.0	1.4580E 01
8	4.0000E-02	0.0	1.5680E 01
9	5.0000E-02	0.0	1.6680E 01
10	1.0000E-01	0.0	1.6730E 01
11	1.8000E-01	0.0	1.7300E 01
12	3.1000E-01	0.0	1.7310E 01
13	5.6000E-01	0.0	1.7510E 01
14	9.4000E-01	0.0	1.8200E 01
15	1.6000E 00	0.0	1.9000E 01
16	4.6000E 00	0.0	2.1210E 01

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.2200E 00	5.0000E-01	2.0000E-01	1.0000E-01	0.0	0.0
2	1.6400E 00	3.0000E-01	2.0000E-01	1.0000E-01	0.0	0.0
3	2.2200E 00	2.5000E-01	5.0000E-02	0.0	0.0	0.0
4	2.3400E 00	1.0000E-01	0.0	0.0	0.0	0.0
5	3.2900E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	5.0500E 00	1.0000E-01	0.0	0.0	0.0	0.0
7	1.3910E 01	2.9000E-01	0.0	0.0	0.0	0.0
8	1.5320E 01	3.2000E-01	0.0	0.0	0.0	0.0
9	1.6300E 01	3.3000E-01	0.0	0.0	0.0	0.0
10	1.6160E 01	4.7000E-01	0.0	0.0	0.0	0.0
11	1.6590E 01	5.3000E-01	0.0	0.0	0.0	0.0
12	1.6520E 01	4.8000E-01	0.0	0.0	0.0	0.0
13	1.6420E 01	5.3000E-01	0.0	0.0	0.0	0.0
14	1.6620E 01	6.4000E-01	0.0	0.0	0.0	0.0
15	1.6970E 01	4.3000E-01	0.0	0.0	0.0	0.0
16	1.6610E 01	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 29100 COPPER

XSDRN

GP.	ABSORPTION	NU FISSION	TOTAL
1	4.9979E-02	0.0	3.6672E 00
2	1.3446E-02	0.0	3.1969E 00
3	5.7319E-03	0.0	3.3878E 00
4	2.3848E-02	0.0	3.9259E 00
5	2.7296E-02	0.0	5.0213E 00
6	7.2279E-02	0.0	7.0516E 00
7	2.3525E-01	0.0	9.0448E 00
8	7.0604E-01	0.0	9.7082E 00
9	4.0044E-02	0.0	7.0465E 00
10	7.9954E-02	0.0	7.4199E 00
11	1.4496E-01	0.0	7.5650E 00
12	2.5371E-01	0.0	7.8374E 00
13	4.6451E-01	0.0	7.8824E 00
14	7.4410E-01	0.0	7.9863E 00
15	1.5751E 00	0.0	8.7852E 00
16	3.3517E 00	0.0	1.0602E 01

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
1	2.1433E 00	6.0475E-01	3.8675E-01	3.4158E-01	1.4260E-01	0.0
2	2.3310E 00	3.6618E-01	3.2363E-01	1.4597E-01	1.6654E-02	0.0
3	2.9969E 00	2.9316E-01	8.1509E-02	1.0211E-02	2.2040E-04	0.0
4	3.7473E 00	1.5204E-01	2.6505E-03	5.6204E-05	2.9912E-06	0.0
5	4.9012E 00	9.2805E-02	0.0	0.0	0.0	0.0
6	6.8482E 00	1.3103E-01	0.0	0.0	0.0	0.0
7	8.6219E 00	1.8760E-01	0.0	0.0	0.0	0.0
8	8.8811E 00	1.2105E-01	0.0	0.0	0.0	0.0
9	6.8778E 00	1.2866E-01	0.0	0.0	0.0	0.0
10	7.1563E 00	1.8369E-01	0.0	0.0	0.0	0.0
11	7.1881E 00	2.3192E-01	0.0	0.0	0.0	0.0
12	7.3946E 00	1.8903E-01	0.0	0.0	0.0	0.0
13	7.2986E 00	1.1930E-01	0.0	0.0	0.0	0.0
14	7.1387E 00	6.2115E-02	0.0	0.0	0.0	0.0
15	7.1763E 00	3.3430E-02	0.0	0.0	0.0	0.0
16	7.1626E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 30100 ZINC

GAM-2

GP.	ABSORPTION	NU FISSION	TOTAL
1	1.8765E-03	0.0	3.6476E 00
2	2.7631E-03	0.0	3.0578E 00
3	4.0000E-03	0.0	3.4595E 00
4	5.6485E-03	0.0	4.3725E 00
5	1.0017E-02	0.0	5.5844E 00
6	2.5667E-02	0.0	6.6546E 00
7	6.6350E-02	0.0	7.4222E 00
8	1.0755E-01	0.0	1.1133E 01
9	5.2846E-02	0.0	1.3525E 01
10	2.4971E-02	0.0	3.9627E 00
11	4.3470E-02	0.0	4.0135E 00
12	7.5439E-02	0.0	4.0455E 00
13	1.4119E-01	0.0	4.1112E 00
14	2.3059E-01	0.0	4.2006E 00
15	4.4000E-01	0.0	4.6000E 00
16	9.7000E-01	0.0	5.0700E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	2.0791E 00	7.1630E-01	3.2210E-01	3.7123E-01	1.4229E-01	1.4573E-02
2	2.2557E 00	3.0743E-01	3.2492E-01	1.4973E-01	1.6937E-02	3.3611E-04
3	3.0247E 00	3.4642E-01	7.4589E-02	9.5226E-03	1.9634E-04	1.0170E-05
4	4.2053E 00	1.5872E-01	2.7305E-03	5.8450E-05	3.0401E-06	6.4852E-08
5	5.4737E 00	1.0065E-01	0.0	0.0	0.0	0.0
6	6.5150E 00	1.1397E-01	0.0	0.0	0.0	0.0
7	7.2123E 00	1.4356E-01	0.0	0.0	0.0	0.0
8	1.0880E 01	1.4465E-01	0.0	0.0	0.0	0.0
9	1.3407E 01	6.5047E-02	0.0	0.0	0.0	0.0
10	3.8424E 00	9.5383E-02	0.0	0.0	0.0	0.0
11	3.8504E 00	1.1967E-01	0.0	0.0	0.0	0.0
12	3.8752E 00	9.4801E-02	0.0	0.0	0.0	0.0
13	3.8749E 00	9.5167E-02	0.0	0.0	0.0	0.0
14	3.8128E 00	1.5727E-01	0.0	0.0	0.0	0.0
15	4.0000E 00	1.6000E-01	0.0	0.0	0.0	0.0
16	4.1000E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 42100 MOLYBDENUM

HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	1.0000E-02	0.0	2.4000E 00
2	2.0000E-02	0.0	2.9000E 00
3	4.0000E-02	0.0	3.9000E 00
4	7.0000E-02	0.0	6.2000E 00
5	9.0000E-02	0.0	8.2000E 00
6	1.7000E-01	0.0	7.9000E 00
7	4.0000E-01	0.0	7.1000E 00
8	1.5000E 00	0.0	8.0500E 00
9	2.9000E 00	0.0	9.1600E 00
10	1.3400E 01	0.0	1.9360E 01
11	5.0000E-02	0.0	5.5600E 00
12	8.0000E-02	0.0	5.6600E 00
13	1.5000E-01	0.0	5.9600E 00
14	2.5000E-01	0.0	6.4600E 00
15	9.0000E-01	0.0	6.6600E 00
16	2.5000E 00	0.0	7.5600E 00

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.3900E 00	5.0000E-01	3.0000E-01	2.0000E-01	0.0	0.0
2	2.1300E 00	4.0000E-01	2.5000E-01	1.0000E-01	0.0	0.0
3	3.4600E 00	3.0000E-01	1.0000E-01	0.0	0.0	0.0
4	5.9300E 00	2.0000E-01	0.0	0.0	0.0	0.0
5	7.9800E 00	1.3000E-01	0.0	0.0	0.0	0.0
6	7.6300E 00	1.0000E-01	0.0	0.0	0.0	0.0
7	6.6200E 00	8.0000E-02	0.0	0.0	0.0	0.0
8	6.4700E 00	8.0000E-02	0.0	0.0	0.0	0.0
9	6.1800E 00	8.0000E-02	0.0	0.0	0.0	0.0
10	5.8600E 00	1.0000E-01	0.0	0.0	0.0	0.0
11	5.4100E 00	1.0000E-01	0.0	0.0	0.0	0.0
12	5.4800E 00	1.0000E-01	0.0	0.0	0.0	0.0
13	5.7000E 00	1.1000E-01	0.0	0.0	0.0	0.0
14	6.0700E 00	1.4000E-01	0.0	0.0	0.0	0.0
15	5.6700E 00	9.0000E-02	0.0	0.0	0.0	0.0
16	5.0600E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 92500 U-235 YR

HANSEN ROACH

	GP. ABSORPTION	NU FISSION	TOTAL
1	1.2600E 00	3.5570E 00	4.2500E 00
2	1.3000E 00	3.1960E 00	4.5000E 00
3	1.3300E 00	3.0870E 00	4.6500E 00
4	1.3500E 00	2.9880E 00	5.2000E 00
5	1.6600E 00	3.5180E 00	7.9000E 00
6	3.1500E 00	6.1250E 00	1.2400E 01
7	5.5000E 00	1.0290E 01	1.5100E 01
8	1.1100E 01	1.9360E 01	2.1100E 01
9	2.7200E 01	4.5815E 01	3.7200E 01
10	5.8000E 01	9.3100E 01	6.8000E 01
11	7.9000E 01	1.0690E 02	8.9000E 01
12	7.4000E 01	8.2600E 01	8.4000E 01
13	3.9000E 01	7.3500E 01	4.9000E 01
14	8.0000E 01	1.7150E 02	9.0000E 01
15	2.2400E 02	4.5325E 02	2.3400E 02
16	6.1100E 02	1.2642E 03	6.2100E 02

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.2000E 00	2.7000E-01	3.7000E-01	6.5000E-01	4.4000E-01	6.0000E-02
2	1.7700E 00	2.4000E-01	6.7000E-01	4.5000E-01	7.0000E-02	0.0
3	2.3000E 00	5.5000E-01	4.0000E-01	7.0000E-02	0.0	0.0
4	3.4200E 00	3.5000E-01	8.0000E-02	0.0	0.0	0.0
5	6.1600E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	9.2000E 00	5.0000E-02	0.0	0.0	0.0	0.0
7	9.5500E 00	5.0000E-02	0.0	0.0	0.0	0.0
8	9.9500E 00	5.0000E-02	0.0	0.0	0.0	0.0
I = 9 THRU I= 14	SAME AS ABOVE					
15	9.9600E 00	4.0000E-02	0.0	0.0	0.0	0.0
16	1.0000E 01	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 92501 U-235-1R SIG P = 20 HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	1.2600E 00	3.5570E 00	4.2500E 00
2	1.3000E 00	3.1960E 00	4.5000E 00
3	1.3300E 00	3.0870E 00	4.6500E 00
4	1.3500E 00	2.9880E 00	5.2000E 00
5	1.6600E 00	3.5180E 00	7.9000E 00
6	3.1500E 00	6.1250E 00	1.2400E 01
7	5.5000E 00	1.0290E 01	1.5100E 01
8	1.1100E 01	1.9360E 01	2.1100E 01
9	2.7200E 01	4.5815E 01	3.7200E 01
10	5.2500E 01	8.4280E 01	6.2500E 01
11	2.6000E 01	4.0300E 01	3.6000E 01
12	2.6600E 01	3.0100E 01	3.6600E 01
13	2.5600E 01	4.9245E 01	3.5600E 01
14	8.0000E 01	1.7150E 02	9.0000E 01
15	2.2400E 02	4.5325E 02	2.3400E 02
16	6.1100E 02	1.2642E 03	6.2100E 02

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.2000E 00	2.7000E-01	3.7000E-01	6.5000E-01	4.4000E-01	6.0000E-02
2	1.7700E 00	2.4000E-01	6.7000E-01	4.5000E-01	7.0000E-02	0.0
3	2.3000E 00	5.5000E-01	4.0000E-01	7.0000E-02	0.0	0.0
4	3.4200E 00	3.5000E-01	8.0000E-02	0.0	0.0	0.0
5	6.1600E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	9.2000E 00	5.0000E-02	0.0	0.0	0.0	0.0
7	9.5500E 00	5.0000E-02	0.0	0.0	0.0	0.0
8	9.9500E 00	5.0000E-02	0.0	0.0	0.0	0.0
I = 9 THRU I= 14	SAME AS ABOVE					
15	9.9600E 00	4.0000E-02	0.0	0.0	0.0	0.0
16	1.0000E 01	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 92508 U-235-8R SIG P = 1000 HANSEN BOACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	1.2600E 00	3.5570E 00	4.2500E 00
2	1.3000E 00	3.1960E 00	4.5000E 00
3	1.3300E 00	3.0870E 00	4.6500E 00
4	1.3500E 00	2.9880E 00	5.2000E 00
5	1.6600E 00	3.5180E 00	7.9000E 00
6	3.1500E 00	6.1250E 00	1.2400E 01
7	5.5000E 00	1.0290E 01	1.5100E 01
8	1.1100E 01	1.9360E 01	2.1100E 01
9	2.7200E 01	4.5815E 01	3.7200E 01
10	5.7500E 01	9.1875E 01	6.7500E 01
11	5.7900E 01	8.4100E 01	6.7900E 01
12	6.2600E 01	6.8300E 01	7.2600E 01
13	3.9000E 01	7.3500E 01	4.9000E 01
14	8.0000E 01	1.7150E 02	9.0000E 01
15	2.2400E 02	4.5325E 02	2.3400E 02
16	6.1100E 02	1.2642E 03	6.2100E 02

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.2000E 00	2.7000E-01	3.7000E-01	6.5000E-01	4.4000E-01	6.0000E-02
2	1.7700E 00	2.4000E-01	6.7000E-01	4.5000E-01	7.0000E-02	0.0
3	2.3000E 00	5.5000E-01	4.0000E-01	7.0000E-02	0.0	0.0
4	3.4200E 00	3.5000E-01	8.0000E-02	0.0	0.0	0.0
5	6.1600E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	9.2000E 00	5.0000E-02	0.0	0.0	0.0	0.0
7	9.5500E 00	5.0000E-02	0.0	0.0	0.0	0.0
8	9.9500E 00	5.0000E-02	0.0	0.0	0.0	0.0
9	9 THRU I=	14 SAME AS ABOVE				
15	9.9600E 00	4.0000E-02	0.0	0.0	0.0	0.0
16	1.0000E 01	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 92509 U-235-9R SIG P = 2000 HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	1.2600E 00	3.5570E 00	4.2500E 00
2	1.3000E 00	3.1960E 00	4.5000E 00
3	1.3300E 00	3.0870E 00	4.6500E 00
4	1.3500E 00	2.9880E 00	5.2000E 00
5	1.6600E 00	3.5180E 00	7.9000E 00
6	3.1500E 00	6.1250E 00	1.2400E 01
7	5.5000E 00	1.0290E 01	1.5100E 01
8	1.1100E 01	1.9360E 01	2.1100E 01
9	2.7200E 01	4.5815E 01	3.7200E 01
10	5.7800E 01	9.2610E 01	6.7800E 01
11	6.5500E 01	9.3600E 01	7.5500E 01
12	6.7100E 01	7.4100E 01	7.7100E 01
13	3.9000E 01	7.3500E 01	4.9000E 01
14	8.0000E 01	1.7150E 02	9.0000E 01
15	2.2400E 02	4.5325E 02	2.3400E 02
16	6.1100E 02	1.2642E 03	6.2100E 02

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.2000E 00	2.7000E-01	3.7000E-01	6.5000E-01	4.4000E-01	6.0000E-02
2	1.7700E 00	2.4000E-01	6.7000E-01	4.5000E-01	7.0000E-02	0.0
3	2.3000E 00	5.5000E-01	4.0000E-01	7.0000E-02	0.0	0.0
4	3.4200E 00	3.5000E-01	8.0000E-02	0.0	0.0	0.0
5	6.1600E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	9.2000E 00	5.0000E-02	0.0	0.0	0.0	0.0
7	9.5500E 00	5.0000E-02	0.0	0.0	0.0	0.0
8	9.9500E 00	5.0000E-02	0.0	0.0	0.0	0.0
I = 9 THRU I= 14	SAME AS ABOVE					
15	9.9600E 00	4.0000E-02	0.0	0.0	0.0	0.0
16	1.0000E 01	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 92512 U-235-12R SIG P = 10000 HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	1.2600E 00	3.5570E 00	4.2500E 00
2	1.3000E 00	3.1960E 00	4.5000E 00
3	1.3300E 00	3.0870E 00	4.6500E 00
4	1.3500E 00	2.9880E 00	5.2000E 00
5	1.6600E 00	3.5180E 00	7.9000E 00
6	3.1500E 00	6.1250E 00	1.2400E 01
7	5.5000E 00	1.0290E 01	1.5100E 01
8	1.1100E 01	1.9360E 01	2.1100E 01
9	2.7200E 01	4.5815E 01	3.7200E 01
10	5.8000E 01	9.3100E 01	6.8000E 01
11	7.5200E 01	1.0380E 02	8.5200E 01
12	7.2200E 01	8.0700E 01	8.2200E 01
13	3.9000E 01	7.3500E 01	4.9000E 01
14	8.0000E 01	1.7150E 02	9.0000E 01
15	2.2400E 02	4.5325E 02	2.3400E 02
16	6.1100E 02	1.2642E 03	6.2100E 02

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.2000E 00	2.7000E-01	3.7000E-01	6.5000E-01	4.4000E-01	6.0000E-02
2	1.7700E 00	2.4000E-01	6.7000E-01	4.5000E-01	7.0000E-02	0.0
3	2.3000E 00	5.5000E-01	4.0000E-01	7.0000E-02	0.0	0.0
4	3.4200E 00	3.5000E-01	8.0000E-02	0.0	0.0	0.0
5	6.1600E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	9.2000E 00	5.0000E-02	0.0	0.0	0.0	0.0
7	9.5500E 00	5.0000E-02	0.0	0.0	0.0	0.0
8	9.9500E 00	5.0000E-02	0.0	0.0	0.0	0.0
I = 9 THRU I= 14	SAME AS ABOVE					
15	9.9600E 00	4.0000E-02	0.0	0.0	0.0	0.0
16	1.0000E 01	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 92800 U-238 Y

HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	5.6600E-01	1.7250E 00	4.0000E 00
2	5.3500E-01	1.2130E 00	4.4000E 00
3	1.4400E-01	1.0900E-01	4.5000E 00
4	1.4000E-01	0.0	5.2500E 00
5	1.6000E-01	0.0	8.2000E 00
6	4.5000E-01	0.0	1.2000E 01
7	7.0000E-01	0.0	1.4000E 01
8	2.0000E 00	0.0	1.5000E 01
9	1.1000E 01	0.0	2.2000E 01
10	5.0000E 01	0.0	5.9000E 01
11	5.6000E 01	0.0	6.5000E 01
12	1.1000E 02	0.0	1.1900E 02
13	4.0000E-01	0.0	9.4000E 00
14	5.5000E-01	0.0	9.5500E 00
15	1.0000E 00	0.0	1.0000E 01
16	2.4400E 00	0.0	1.1440E 01

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.2540E 00	3.3000E-01	4.6000E-01	7.9000E-01	5.3000E-01	7.0000E-02
2	1.8250E 00	3.5000E-01	9.6000E-01	6.4000E-01	9.0000E-02	0.0
3	2.9060E 00	8.0000E-01	5.5000E-01	1.0000E-01	0.0	0.0
4	4.5300E 00	5.0000E-01	8.0000E-02	0.0	0.0	0.0
5	7.9600E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	1.1450E 01	1.0000E-01	0.0	0.0	0.0	0.0
7	1.3240E 01	6.0000E-02	0.0	0.0	0.0	0.0
8	1.2940E 01	6.0000E-02	0.0	0.0	0.0	0.0
9	1.0950E 01	5.0000E-02	0.0	0.0	0.0	0.0
10	8.9400E 00	6.0000E-02	0.0	0.0	0.0	0.0
I = 11 THRU I= 14	SAME AS ABOVE					
15	8.9500E 00	5.0000E-02	0.0	0.0	0.0	0.0
16	9.0000E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 92852 U-238 SIG P = 20000

HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	5.6600E-01	1.7250E 00	4.0000E 00
2	5.3500E-01	1.2130E 00	4.4000E 00
3	1.4400E-01	1.0800E-01	4.5000E 00
4	1.4000E-01	0.0	5.2500E 00
5	1.6000E-01	0.0	8.2000E 00
6	4.5000E-01	0.0	1.2000E 01
7	7.0000E-01	0.0	1.4000E 01
8	2.0000E 00	0.0	1.5000E 01
9	1.0600E 01	0.0	2.1600E 01
10	3.7800E 01	0.0	4.6800E 01
11	3.7800E 01	0.0	4.6800E 01
12	7.4800E 01	0.0	8.3800E 01
13	4.0000E-01	0.0	9.4000E 00
14	5.5000E-01	0.0	9.5500E 00
15	1.0000E 00	0.0	1.0000E 01
16	2.4400E 00	0.0	1.1440E 01

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.2540E 00	3.3000E-01	4.6000E-01	7.9000E-01	5.3000E-01	7.0000E-02
2	1.8250E 00	3.5000E-01	9.6000E-01	6.4000E-01	9.0000E-02	0.0
3	2.9060E 00	8.0000E-01	5.5000E-01	1.0000E-01	0.0	0.0
4	4.5300E 00	5.0000E-01	8.0000E-02	0.0	0.0	0.0
5	7.9600E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	1.1450E 01	1.0000E-01	0.0	0.0	0.0	0.0
7	1.3240E 01	6.0000E-02	0.0	0.0	0.0	0.0
8	1.2940E 01	6.0000E-02	0.0	0.0	0.0	0.0
9	1.0950E 01	5.0000E-02	0.0	0.0	0.0	0.0
10	8.9400E 00	6.0000E-02	0.0	0.0	0.0	0.0
I = 11 THRU I= 14	SAME AS ABOVE					
15	8.9500E 00	5.0000E-02	0.0	0.0	0.0	0.0
16	9.0000E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 92855 U-238 SIG P = 100000

HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	5.6600E-01	1.7250E 00	4.0000E 00
2	5.3500E-01	1.2130E 00	4.4000E 00
3	1.4400E-01	1.0800E-01	4.5000E 00
4	1.4000E-01	0.0	5.2500E 00
5	1.6000E-01	0.0	8.2000E 00
6	4.5000E-01	0.0	1.2000E 01
7	7.0000E-01	0.0	1.4000E 01
8	2.0000E 00	0.0	1.5000E 01
9	1.1000E 01	0.0	2.2000E 01
10	4.6600E 01	0.0	5.5600E 01
11	5.0400E 01	0.0	5.9400E 01
12	9.9000E 01	0.0	1.0900E 02
13	4.0000E-01	0.0	9.4000E 00
14	5.5000E-01	0.0	9.5500E 00
15	1.0000E 00	0.0	1.0000E 01
16	2.4400E 00	0.0	1.1440E 01

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.2540E 00	3.3000E-01	4.6000E-01	7.9000E-01	5.3000E-01	7.0000E-02
2	1.8250E 00	3.5000E-01	9.6000E-01	6.4000E-01	9.0000E-02	0.0
3	2.9060E 00	8.0000E-01	5.5000E-01	1.0000E-01	0.0	0.0
4	4.5300E 00	5.0000E-01	8.0000E-02	0.0	0.0	0.0
5	7.9600E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	1.1450E 01	1.0000E-01	0.0	0.0	0.0	0.0
7	1.3240E 01	6.0000E-02	0.0	0.0	0.0	0.0
8	1.2940E 01	6.0000E-02	0.0	0.0	0.0	0.0
9	1.0950E 01	5.0000E-02	0.0	0.0	0.0	0.0
10	8.9400E 00	6.0000E-02	0.0	0.0	0.0	0.0
I = 11 THRU I= 14	SAME AS ABOVE					
15	8.9500E 00	5.0000E-02	0.0	0.0	0.0	0.0
16	9.0000E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 92856 U-238-1R SIG P = 20 HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	5.6600E-01	1.7250E 00	4.0000E 00
2	5.3500E-01	1.2130E 00	4.4000E 00
3	1.4400E-01	1.0800E-01	4.5000E 00
4	1.4000E-01	0.0	5.2500E 00
5	1.6000E-01	0.0	8.2000E 00
6	4.5000E-01	0.0	1.2000E 01
7	7.0000E-01	0.0	1.4000E 01
8	8.0000E-01	0.0	1.3800E 01
9	1.3000E 00	0.0	1.2300E 01
10	2.2000E 00	0.0	1.1200E 01
11	2.0000E 00	0.0	1.1000E 01
12	4.0000E 00	0.0	1.3000E 01
13	4.0000E-01	0.0	9.4000E 00
14	5.5000E-01	0.0	9.5500E 00
15	1.0000E 00	0.0	1.0000E 01
16	2.4400E 00	0.0	1.1440E 01

TRANSFER CROSS SECTIONS

FROM	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
I						
1	1.2540E 00	3.3000E-01	4.6000E-01	7.9000E-01	5.3000E-01	7.0000E-02
2	1.8250E 00	3.5000E-01	9.6000E-01	6.4000E-01	9.0000E-02	0.0
3	2.9060E 00	8.0000E-01	5.5000E-01	1.0000E-01	0.0	0.0
4	4.5300E 00	5.0000E-01	8.0000E-02	0.0	0.0	0.0
5	7.9600E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	1.1450E 01	1.0000E-01	0.0	0.0	0.0	0.0
7	1.3240E 01	6.0000E-02	0.0	0.0	0.0	0.0
8	1.2940E 01	6.0000E-02	0.0	0.0	0.0	0.0
9	1.0950E 01	5.0000E-02	0.0	0.0	0.0	0.0
10	8.9400E 00	6.0000E-02	0.0	0.0	0.0	0.0
I = 11 THRU I= 14	SAME AS ABOVE					
15	8.9500E 00	5.0000E-02	0.0	0.0	0.0	0.0
16	9.0000E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 92859 U-238-4R SIG P = 100 HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	5.6600E-01	1.7250E 00	4.0000E 00
2	5.3500E-01	1.2130E 00	4.4000E 00
3	1.4400E-01	1.0800E-01	4.5000E 00
4	1.4000E-01	0.0	5.2500E 00
5	1.6000E-01	0.0	8.2000E 00
6	4.5000E-01	0.0	1.2000E 01
7	7.0000E-01	0.0	1.4000E 01
8	1.0000E 00	0.0	1.4000E 01
9	2.9000E 00	0.0	1.3900E 01
10	4.9000E 00	0.0	1.3900E 01
11	4.5000E 00	0.0	1.3500E 01
12	8.0000E 00	0.0	1.7000E 01
13	4.0000E-01	0.0	9.4000E 00
14	5.5000E-01	0.0	9.5500E 00
15	1.0000E 00	0.0	1.0000E 01
16	2.4400E 00	0.0	1.1440E 01

TRANSFER CROSS SECTIONS

FROM I	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
1	1.2540E 00	3.3000E-01	4.6000E-01	7.9000E-01	5.3000E-01	7.0000E-02
2	1.8250E 00	3.5000E-01	9.6000E-01	6.4000E-01	9.0000E-02	0.0
3	2.9060E 00	8.0000E-01	5.5000E-01	1.0000E-01	0.0	0.0
4	4.5300E 00	5.0000E-01	8.0000E-02	0.0	0.0	0.0
5	7.9600E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	1.1450E 01	1.0000E-01	0.0	0.0	0.0	0.0
7	1.3240E 01	6.0000E-02	0.0	0.0	0.0	0.0
8	1.2940E 01	6.0000E-02	0.0	0.0	0.0	0.0
9	1.0950E 01	5.0000E-02	0.0	0.0	0.0	0.0
10	8.9400E 00	6.0000E-02	0.0	0.0	0.0	0.0
I = 11 THRU I= 14 SAME AS ABOVE						
15	8.9500E 00	5.0000E-02	0.0	0.0	0.0	0.0
16	9.0000E 00	0.0	0.0	0.0	0.0	0.0

NUCLIDE = 92860 U-238-SR SIG P = 200 HANSEN ROACH

GP.	ABSORPTION	NU FISSION	TOTAL
1	5.6600E-01	1.7250E 00	4.0000E 00
2	5.3500E-01	1.2130E 00	4.4000E 00
3	1.4400E-01	1.0800E-01	4.5000E 00
4	1.4000E-01	0.0	5.2500E 00
5	1.6000E-01	0.0	8.2000E 00
6	4.5000E-01	0.0	1.2000E 01
7	7.0000E-01	0.0	1.4000E 01
8	1.5000E 00	0.0	1.4500E 01
9	3.9000E 00	0.0	1.4900E 01
10	6.9000E 00	0.0	1.5900E 01
11	6.0000E 00	0.0	1.5000E 01
12	1.1200E 01	0.0	2.0200E 01
13	4.0000E-01	0.0	9.4000E 00
14	5.5000E-01	0.0	9.5500E 00
15	1.0000E 00	0.0	1.0000E 01
16	2.4400E 00	0.0	1.1440E 01

TRANSFER CROSS SECTIONS

FROM I	TO I+ 0	I+ 1	I+ 2	I+ 3	I+ 4	I+ 5
1	1.2540E 00	3.3000E-01	4.6000E-01	7.9000E-01	5.3000E-01	7.0000E-02
2	1.8250E 00	3.5000E-01	9.6000E-01	6.4000E-01	9.0000E-02	0.0
3	2.9060E 00	8.0000E-01	5.5000E-01	1.0000E-01	0.0	0.0
4	4.5300E 00	5.0000E-01	8.0000E-02	0.0	0.0	0.0
5	7.9600E 00	8.0000E-02	0.0	0.0	0.0	0.0
6	1.1450E 01	1.0000E-01	0.0	0.0	0.0	0.0
7	1.3240E 01	6.0000E-02	0.0	0.0	0.0	0.0
8	1.2940E 01	6.0000E-02	0.0	0.0	0.0	0.0
9	1.0950E 01	5.0000E-02	0.0	0.0	0.0	0.0
10	8.9400E 00	6.0000E-02	0.0	0.0	0.0	0.0
T = 11 THRU I= 14 SAME AS ABOVE						
15	8.9500E 00	5.0000E-02	0.0	0.0	0.0	0.0
16	9.0000E 00	0.0	0.0	0.0	0.0	0.0

APPENDIX C

NORMALIZED SPECTRA OF NEUTRONS CAUSING FISSION

The spectra have been arranged by families (I, II, and III) and by decreasing energy within each family.

FAMILY I		
Case	$k_{\text{eff}} \pm \sigma$	$\hat{E} \pm \sigma$
B-4	0.98460 ± 0.00306	3.25 ± 0.0913
B-5	0.99554 ± 0.00346	3.25 ± 0.0923
B-1	1.00001 ± 0.00323	3.25 ± 0.0929
B-2	0.99896 ± 0.00352	3.26 ± 0.0928
B-3	1.00077 ± 0.00339	3.26 ± 0.0931
A-1	1.00243 ± 0.00328	3.27 ± 0.0928
A-7	0.99146 ± 0.00278	3.28 ± 0.0923
A-2	1.00140 ± 0.00304	3.31 ± 0.0925
Average	0.99692 ± 0.00694	3.27 ± 0.0948

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

FAMILY II

Case	$k_{\text{eff}} \pm \sigma$	$\hat{E} \pm \sigma$
A-6	1.01423 ± 0.00356	4.44 ± 0.0697
B-8	0.99587 ± 0.00341	5.06 ± 0.0645
B-12	1.01526 ± 0.00320	5.48 ± 0.0710
A-10	0.99245 ± 0.00347	5.64 ± 0.0627
A-9	1.00117 ± 0.00347	6.25 ± 0.0575
B-6	1.00062 ± 0.00316	6.53 ± 0.0678
B-7	1.00409 ± 0.00322	6.74 ± 0.0645
A-8	1.00656 ± 0.00322	6.93 ± 0.0532
A-5	1.01076 ± 0.00344	7.74 ± 0.0541
Average	1.00456 ± 0.00859	6.09 ± 1.0280

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

FAMILY III

Case	$k_{\text{eff}} \pm \sigma$	$\hat{E} \pm \sigma$
B-16	0.98776 ± 0.00391	13.90 ± 0.1157
B-11	1.01864 ± 0.00401	14.11 ± 0.1310
B-13	0.96777 ± 0.00412	14.24 ± 0.1275
B-9	0.97120 ± 0.00433	14.25 ± 0.1284
B-15	0.97392 ± 0.00409	14.33 ± 0.1321
A-11	0.98342 ± 0.00412	14.39 ± 0.1353
B-18	0.99771 ± 0.00422	14.49 ± 0.1437
B-14A	0.99893 ± 0.00421	14.58 ± 0.1509
B-14B	1.00502 ± 0.00521	14.59 ± 0.1521
B-14	1.00972 ± 0.00385	14.60 ± 0.1539
B-17	1.00999 ± 0.00352	14.63 ± 0.1544
B-10	1.00756 ± 0.00343	15.65 ± 0.2193
A-4	1.00544 ± 0.00247	15.84 ± 0.2354
A-3	1.01078 ± 0.00234	15.84 ± 0.2369
Average	0.00531 ± 0.01635	14.67 ± 0.6539

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Neutron Group No. vs.
Group Fission Fraction

Distribution

Aerojet Nuclear - Idaho Falls

Morfitt, J. W.
Morrison, W. G.

Battelle Pacific Northwest

Brown, C. L.

Control Data Corporation - Gaithersburg

Winklebeck, J.

Department of Energy - Oak Ridge

Hickman, H. D.
Poteat, R. M.
Pryor, W. A.
Travis, W. H.

Department of Energy - Washington

Stevenson, R. L.

Goodyear Atomic - Portsmouth

Feuerbacher, J. L.
Thompson, W. B.

Lawrence Livermore National Laboratory

Arnold, W. F.
Köponen, D. L.

Los Alamos National Laboratory

Hansen, G. E.
Hoyt, H. C.
Paxton, H. E.

Oak Ridge Gaseous Diffusion Plant

Armstrong, R. C.
Dyer, H. R.
Stief, S. S.
Wilcox, W. J., Jr.

Oak Ridge National Laboratory

Dabbs, R. D.
Greene, S. R.
Hopkins, C. C.
Johnson, E. B.
Knight, J. R.
Landers, N. F.
Lever, W. E.
Petrie, L. M.

Thomas, J. T.
Westfall, M.
Whitesides, G. E.

Oak Ridge Y-12 Plant

Dodson, W. H./Googin, J. M.
Handley, G. R. (10)
Hopper, C. M.
Keith, A.
Kite, H. T.
Mason, D. L.
Masters, L. C. (10)
McLendon, J. D.
Mee, W. T.
Mills, J. M., Jr.
Montgomery, N. J.
Perry, A. E.
Robinette, B. K.
Smith, R. D.
Snow, S. G.
Stachowiak, R. V. (10)
Strohecker, J. W.
Ward, G. L.
Williams, R. D.
Y-12 Central Files (master copy)
Y-12 Central Files (route copy)
Y-12 Central Files (Y-12RC)
Y-12 Central Files (5)

Paducah Gaseous Diffusion Plant

Baker, R. C.
Bewley, H. D.

Rockwell International - Rocky Flats

Pecora, D.

Sandia National Laboratories - Albuquerque

Spencer, W. J.

State of Maryland

Magette, T. E.

Texas Instruments, Inc. - Attleboro

Schwensfeir, R.

Union Carbide Corporation - New York

Tinsley, S. W.

University of California

Pigford, T. H.

In addition, this report is distributed in accordance with the Category UC-46, **Criticality Studies**, as given in the *Standard Distribution for Unclassified Scientific and Technical Reports*, DOE/TIC-4500.