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Validation of Three Cross-Section Libraries Used with the Scale System for Criticality Safety Analysis

A. M. Hathout
R. M. Westfall
H. L. Dodds

Prepared for the
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VALIDATION OF THREE CROSS-SECTION LIBRARIES USED WITH THE SCALE SYSTEM FOR CRITICALITY SAFETY ANALYSIS

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ABSTRACT

The calculations and analysis of two series of recently performed critical experiments are presented. Three cross-section libraries available in the SCALE system are used in the analyses. The results obtained are discussed in detail and are compared with MOPET code calculations. The comparison with experimental results validates the cross-section libraries and allows an optimistic approach to the results of future studies using the three libraries and the SCALE system.

I. INTRODUCTION

The purpose of this study is to validate three cross-section libraries provided with the SCALE system[1] for criticality safety analysis of fuel rod lattices. Of particular interest are problems which arise in the industrial fuel cycle for PWR and BWR type reactors. Such fuel lattice problems occur in pool storage, dry storage with hypothetical accidental moderation, shearing and dissolution of irradiated elements and packing and shipping cask designs.

In this report we present an analysis of two series of recent experiments[2] using three cross-section libraries available in the SCALE system.

II. DESCRIPTION OF CROSS-SECTION LIBRARIES

Four cross-section libraries have been assembled for use in the SCALE system. These include a 16-group cross-section set based on earlier Hansen-Roach data,[3] 123-group cross-section set based on earlier GAM-THERMOS data,[4] and a 218-group cross-section set based on ENDF/B-IV data.[5] A 27-group cross-section set collapsed from the 218-group data is also available.[6]

In this work we have used the following three cross-section libraries:

i - Hansen-Roach 16-group library:

The data for almost all the nuclides in the Hansen-Roach library is based on the original Los Alamos report by Hansen and Roach. While this data has been used widely with good results, it was developed primarily for the analysis of fast systems. Data for a few nuclides missing in the original library was generated by collapsing the 218-group ENDF/B-IV to 16 groups. This was done for the sake of completeness and to extend the utility of the present library. Resonance data is available for 71 of the nuclides in this library. Seven of these have Bondarenko factors in lieu of resonance parameters and must be self-shielded using the BONAMI Module (Appendix A).

ii - 27-group ENDF/B-IV:

The data for 27-group ENDF/B-IV library was collapsed from the 218-GROUPNDF4 data. This broad group library was developed specially for criticality analysis of a wide variety of thermal systems and has undergone extensive evaluation. Of the 27 groups, 12 groups are thermal ($E \leq 3.05$ ev).

iii - 123-group GAM-THERMOS:

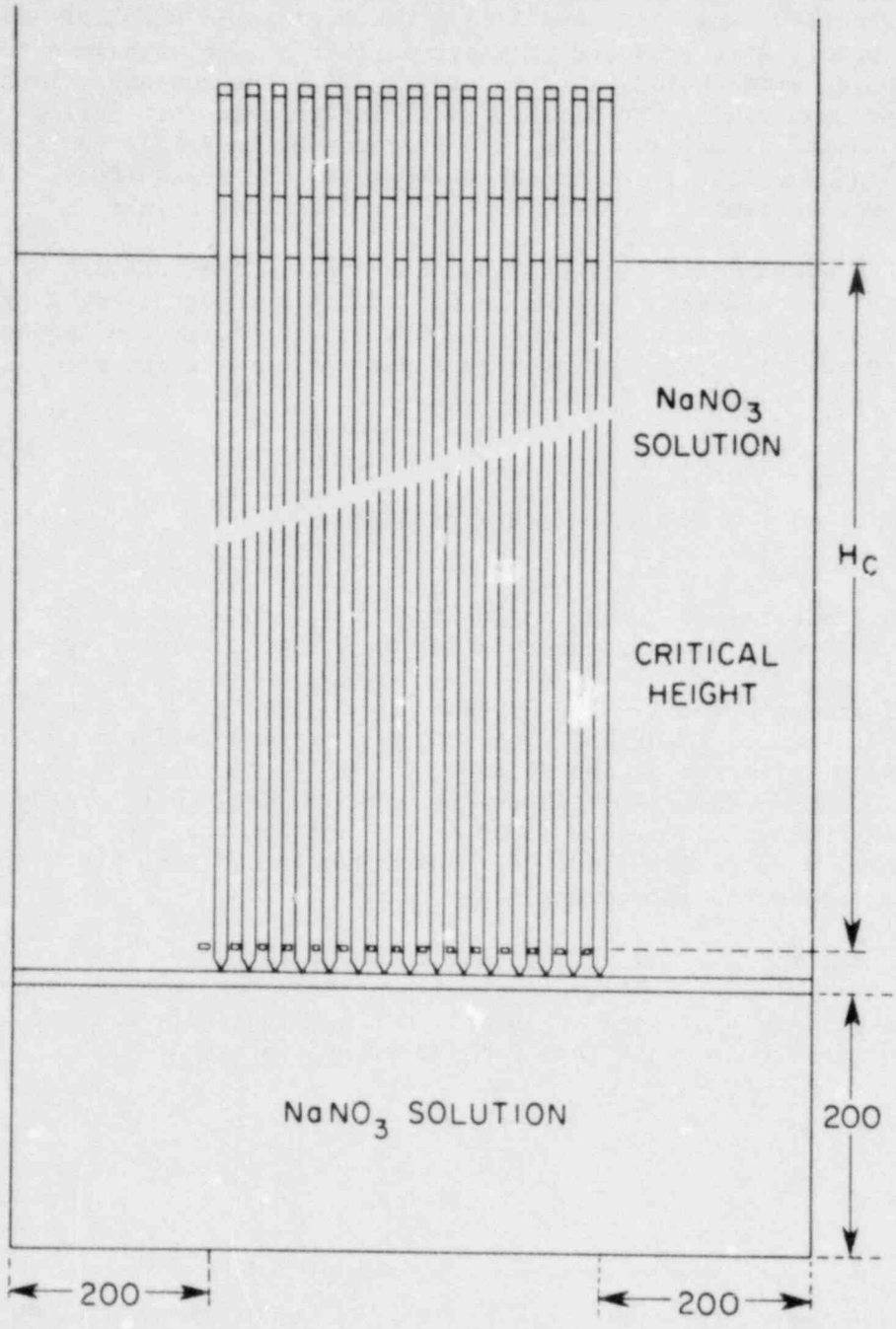
The 123 GROUPGMTH library is based on earlier data produced by the GAM-II and THERMOS codes. It has 93 fast and 30 thermal groups. The fast group boundaries are based on equal lethargy widths. Resonance data is available for only six nuclides. On the other hand, thermal scattering data for many nuclides is available over a wide range of temperatures.

III. ANALYSIS OF EXPERIMENTS

Two series of experiments[2] involving 4.75 wt. % enriched UO_2 rods were analyzed. The rods had a fuel diameter of 0.79 cm, an active fuel length of 90 cm, and an AG5 aluminum clad of 0.06 cm.

The first series of experiments utilized a square pitch lattice immersed in a sodium nitrate solution ($NaNO_3 + H_2O$) as shown in Fig. 1. The parametric variations in this series were lattice pitch, $NaNO_3$ concentration and the total number of rods in nearly square arrays. Criticality was determined by varying the height of the sodium nitrate solution.

ORNL-DWG 80-20369



NOTE: DIMENSIONS IN mm

Figure 1. Experimental setup for the first series

The second series of experiments utilized four assemblies of rods in an 18x18 square pitch lattice. Cross-shaped, water tight containers with various gap thickness (2.5, 5, and 10 cm) were positioned between the four assemblies Figs. 2(a) and 2(b). The containers were filled with either water, air, expanded polystyrene $(C_8H_8)_n$, polyethylene powder or polyethylene balls, thus providing different concentrations of hydrogenous material. The parameters of interest in this series were the composition and density of the hydrogenous materials and the separation distance (i.e., gap thickness) between the assemblies. Criticality was determined by varying the lattice water height.

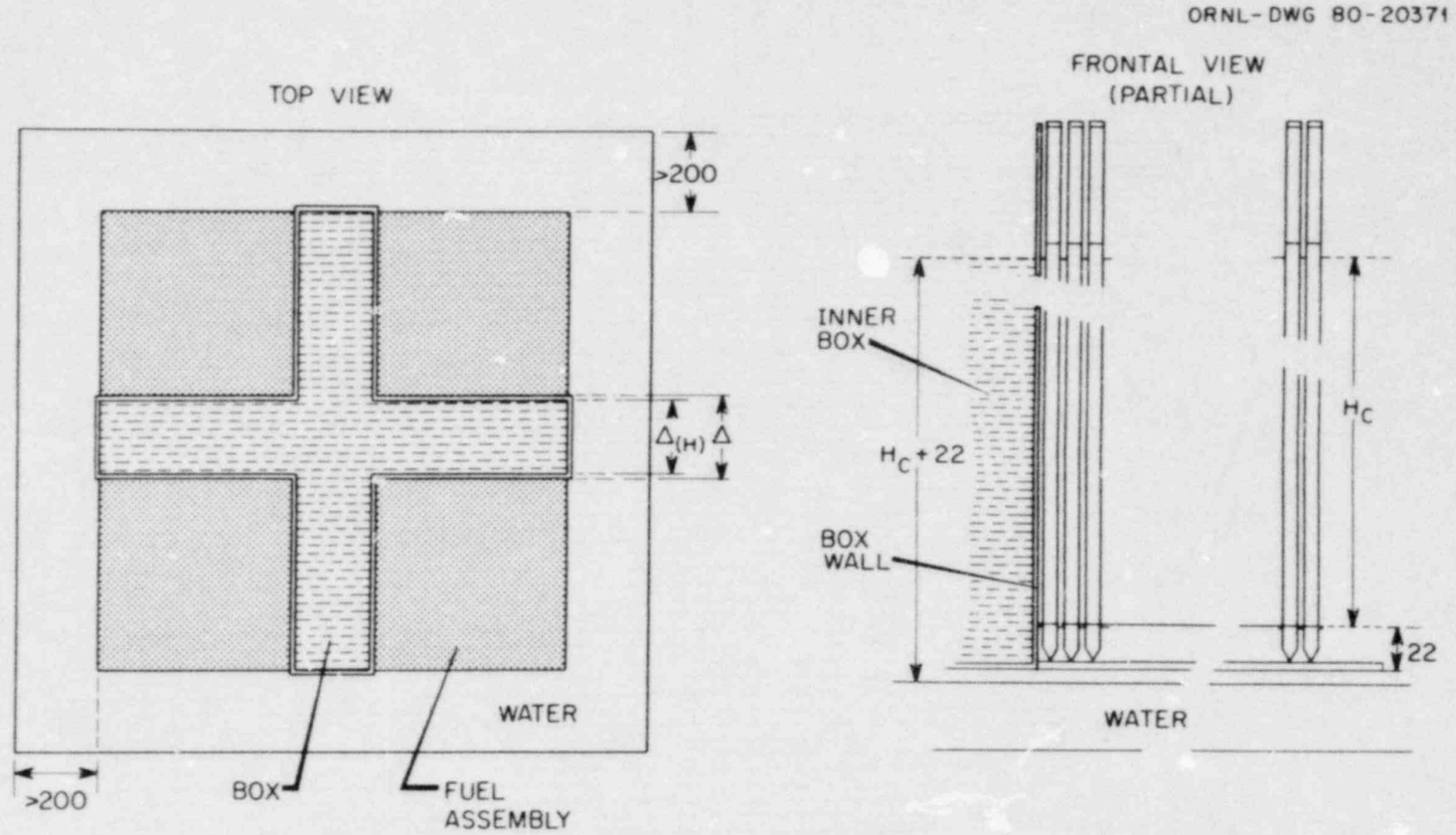
The SCALE system calculational sequence used in the analysis of both series of experiments is shown in Fig. 3. A more detailed description of the functional modules shown in Fig. 3 is presented in Appendix A and in Reference 1. The SCALE system input for both series of experiments is presented in Appendix B.

IV. RESULTS AND CONCLUSIONS

The results obtained using the SCALE system to analyze the two series of experiments are presented in Tables 1 and 2, respectively.

Table 1 presents the results obtained in the analysis of the six experiments in the first series. The sodium nitrate solution acts as a moderator and a reflector of the lattice. It is found that the average k_{eff} of the 27-group ENDF/B-IV library is 0.998 ± .004, that for the 123-group GAM-THERMOS library is 1.003 ± .004 and for the 16-group Hansen-Roach library is 1.007 ± .004. Results obtained with the MORET code are also presented for comparison.

We see that the 24- and 123-group results of the three libraries are more accurate than the 16-group results. Therefore, the 27-group ENDF/B-IV library is preferred because it has substantially smaller computer storage requirements than the 123-group library.



NOTE: DIMENSIONS IN mm

P = PITCH - (13.5 mm)
H_C = CRITICAL HEIGHT

Figure 2(a). Experimental setup for the second series - top view and partial frontal view

ORNL-DWG 80-20370

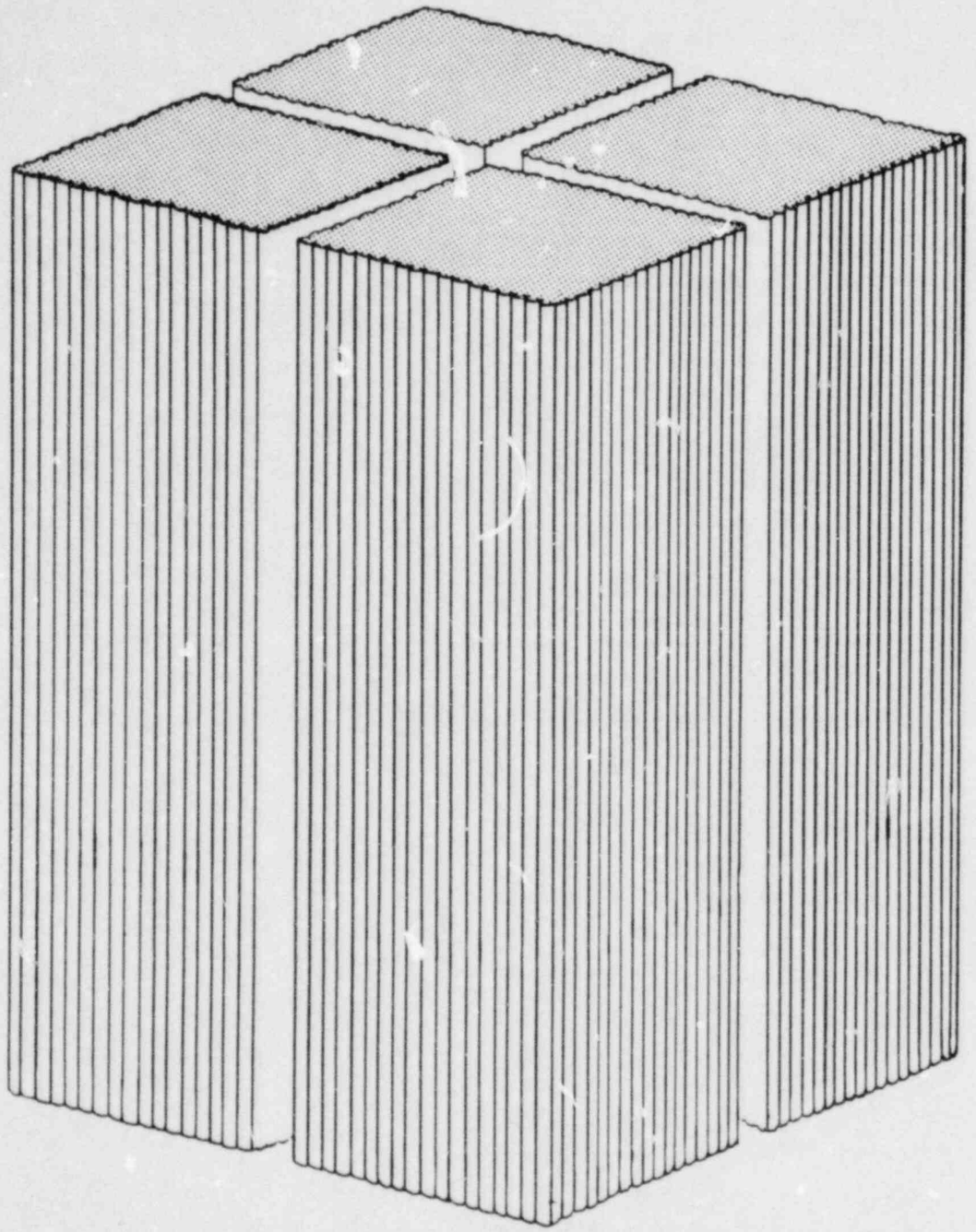


Figure 2(b). Experimental setup for the second series isometric frontal view

ORNL-DWG 81-6528

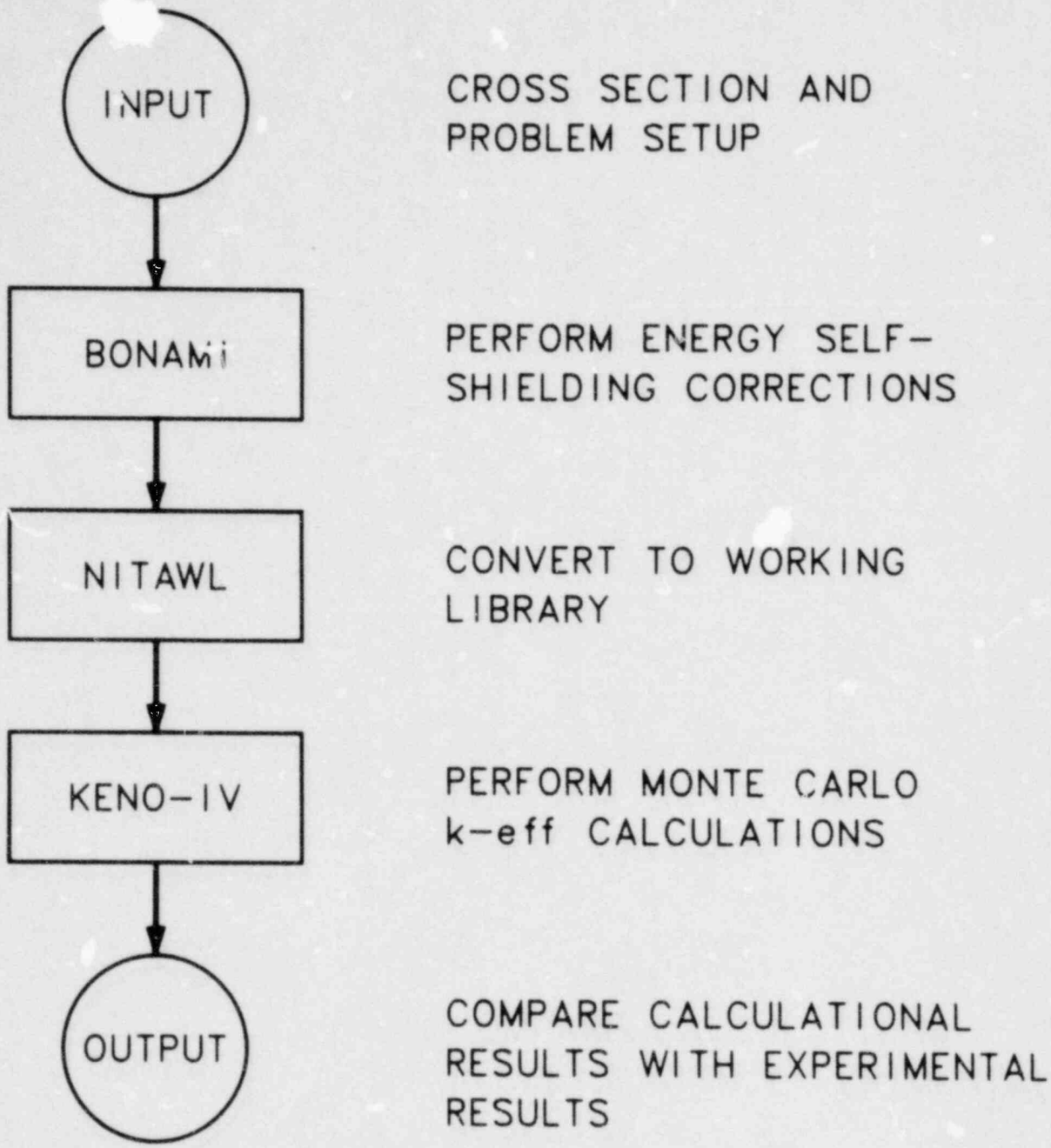


Figure 3. SCALE system calculational sequence used in the analysis of both series of experiments

Table 1. CSAS2 Analysis of 4.75% UO_2 Rods in Sodium Nitrate Solution

Lattice		Solution			Calculated k-eff ± 1 σ			
Lattice Pitch cm	Array Size	Density g/cm³	NaNO Conc. g/cm³	Critical Height cm	27-Group ENDF/B-IV	123-Group GAM-THERMOS	16-Group Hansen-Roach	Apollo-Moret*
1.26	24x25	1.1521	0.247	80.9	0.99598 ± 0.00464	1.00401 ± 0.00477	0.98823 ± 0.00478	1.005 ± .005
1.6	18x18	1.1503	0.243	76.1	0.98728 ± 0.00478	1.00216 ± 0.00453	0.99259 ± 0.00484	.998 ± .0055
2.1	17x17	1.1523	0.246	76.2	0.99817 ± 0.00402	1.00846 ± 0.00379	1.01476 ± 0.00421	.993 ± .005
2.1	16x16	1.1094	0.178	89.5	1.00157 ± 0.00442	0.99509 ± 0.00430	1.01586 ± 0.00421	
2.1	15x16	1.0565	0.090	84.8	1.00586 ± 0.00416	1.00658 ± 0.00389	1.0128 ± 0.00477	.996 ± .008
2.52	20x21	1.1523	0.246	85.9	0.99812 ± 0.00385	1.00239 ± 0.00418	1.01895 ± 0.00363	1.003 ± .0045

*Values taken from Reference 2

In Table 2, results are presented for the 19 experiments of the second series. For assemblies with water only as the interstitial material, the 27-group library gives better agreement with experiment than the two other libraries.

For assemblies separated by the aluminum container filled with different materials, the calculated K_{eff}'s using all three libraries are, for the most part, equal or slightly greater than unity. Also, considering statistical uncertainties, K_{eff} increases slightly with increasing hydrogen concentration for gap thickness of 2.5 and 5.0 cm, but not for 10.0 cm gap.

Finally, for this series of experiments, the three libraries give essentially the same value for K_{eff}. So, either the 16-group Hansen-Roach or the 27-group ENDF/B-IV library would be preferred over the 123-group library because of their smaller computer storage requirement (approximate factor of 5).

As may be observed in Tables 1 and 2, the results obtained with the MORET code[2] are limited in that only some of the cases have been calculated. For the cases presented, the agreement between the SCALE system results and the MORET code results appears to be reasonable.

Table 2. CSAS2 Analysis of Four Assemblies of 18x18 U(4.75%)O_2 Rods of Lattice Pitch, Separated by Various Hydrogenous Materials

Assembly Configuration					Calculated k-eff ± 1 σ			
		Compounds		Water Critical				
Δ cm*	Interstitial Material	Density gm/cm³	Conc. II gm/cm³	Height cm	27-Group ENDF/B-IV	123-Group GAM THERMOS	16-Group Hansen-Roach	Apollo-Moret
0	Water	1.0	0.1119	23.8	1.00806 ± 0.00507	1.02868 ± 0.00515	1.01481 ± 0.00514	1.010 ± .0055
2.5	Box + Air	0	0	29.03	1.01663 ± 0.00488	1.01591 ± 0.00476	1.00460 ± 0.00504	1.005 ± .005
	Box + $(C_3H_4)_n$	0.0323	0.0025	28.61	1.00506 ± 0.00499	1.01608 ± 0.00491	0.99856 ± 0.00517	0.987 ± 0.005
	Box + Powder $(CH_2)_n$	0.2879	0.0414	26.98	1.02348 ± 0.00472	1.02786 ± 0.00455	1.00797 ± 0.00471	
	Box + Ball $(CH_2)_n$	0.5540	0.0800	25.54	1.03263 ± 0.00504	1.03542 ± 0.00457	1.02599 ± 0.00461	0.995 ± .005
	Box + Water	1.0	0.1119	25.66	1.02827 ± 0.00454	1.03379 ± 0.00474	1.02991 ± 0.00425	
	Water	1.0	0.1119	24.48	1.00391 ± 0.00399	1.02718 ± 0.00481	1.00673 ± 0.00376	1.006 ± .005
5	Box + Air	0	0	34.48	0.99886 ± 0.00462	1.01276 ± 0.00495	1.00366 ± 0.00451	
	Box + $(C_8H_8)_n$	0.0262	0.002	34.39	1.00614 ± 0.00537	1.01100 ± 0.00477	1.00696 ± 0.00472	
	Box + Powder $(CH_2)_n$	0.3335	0.0480	30.16	1.02215 ± 0.00527	1.03381 ± 0.00412	1.0290 ± 0.00464	
	Box + Balls $(CH_2)_n$	0.5796	0.0833	30.73	1.02913 ± 0.00446	1.02881 ± 0.00494	1.03299 ± 0.00519	
	Box + Water	1.0	0.1119	32.78	1.02257 ± 0.00415	1.03349 ± 0.00463	1.02909 ± 0.00478	
	Water	1.0	0.1119	31.47	0.99973 ± 0.00451	1.01139 ± 0.00473	1.01094 ± 0.00424	1.000 ± .006
10	Box + Air	0	0	46.08	0.99138 ± 0.00441	1.01345 ± 0.00498	0.99519 ± 0.00537	0.996 ± .005
	Box + $(C_8H_8)_n$	0.0288	0.0022	45.62	1.01184 ± 0.00488	1.01393 ± 0.00526	0.98867 ± 0.00579	0.987 ± .005
	Box + Powder $(CH_2)_n$	0.3216	0.0464	42.05	1.01247 ± 0.00424	1.03046 ± 0.00454	1.02375 ±0.00444	1.011 ± .006
	Box + Balls $(CH_2)_n$	0.5680	0.0816	49.94	1.01674 ± 0.00450	1.00612 ± 0.00514	1.00898 ± 0.00499	1.010 ± .005
	Box + Water	1.0	0.1119	64.12	0.99758 ± 0.00453	0.99949 ± 0.005	1.00396 ± 0.00512	
	Water	1.0	0.1119	64.34	0.99352 ± 0.00446	0.98991 ± 0.00499	0.99659 ± 0.00521	0.998 ± .0055

*Δ is the value of the gap width between the assemblies, including 0.6 cm which is twice the wall thickness of the aluminum container box.
** Results taken from Ref. 2.

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3. G. E. Hansen, et al., "Six and Sixteen Group Cross-Section for Fast and Intermediate Critical Assemblies," LAMS-2543 (1961).

4. Undocumented ORNL library of ancient vintage.

5. W. E. Ford, et al., "A 218-Group Neutron Cross-Section Library in AMPX Master Interface Format for Criticality Safety Studies," ORNL/CSD/TM-4, Oak Ridge National Laboratory, Oak Ridge, TN 37830 (1976).

6. R. M. Westfall, et al., "Procedure for Determining Broad-Group Energy Structure or Criticality Safety Calculations," Trans. Am. Nucl. Soc., 22, 291 (1975).

APPENDICES

APPENDIX A

SCALE SYSTEM OVERVIEW

The SCALE system[1] draws heavily from basic neutron transport. It consists of a driver module, control modules, functional modules and a data base.

1. The driver module:

The driver module resides in-core at all times and, upon various types of commands, loads and unloads the control and functional modules from the central processor unit. Thus the core storage requirement for a sequence involving the execution of several modules corresponds roughly to the largest needs of any single module in the sequence. The intermodular execution paths are normally determined by the control modules. The control modules communicate with the system driver through a small common block of special parameters. Ordinarily, the user specifies the control module to be executed on a data card read by the driver. For example, in our case, to execute Criticality Safety Analytical Sequence 2 (CSAS2), we submit = CSAS2 to the driver which in turn, loads CSAS2 into the central processor unit.

2. The control module:

Six control modules have been developed for the initial version of SCALE. One of the control modules is CSAS2 which performs data processing and criticality safety analysis on systems which must be modeled in three-dimensional geometry. The execution path includes the functional modules BONAMI, NITAWL and KENO-IV.

3. The functional modules:

The functional modules included in the initial version of the SCALE system are eight modules. The modules perform data processing, radiation source determination, criticality safety analysis and radiation shielding analysis. Here, we present a brief summary of the functional modules included in the execution path of CSAS2.

i. BONAMI (Bondarenko AMPX Interpolator) is a module which accesses master data sets that contain Bondarenko factors. It is a new program which performs resonance cross-section processing by the shielding factor method most frequently associated with Bondarenko and produces problem-dependent master data sets. The initial application of BONAMI in SCALE is the automation of the use of the Hansen-Roach 16-group library in the criticality safety analytical sequence. Eventually, BONAMI will be used to perform problem-dependent unresolved resonance processing with the cross-section libraries based on ENDF/B.

ii. NITAWL (Nordheim's Integral Treatment And Working Library production) is an application of the Nordheim integral technique to perform neutron cross-section processing in the resonance energy range.

This technique involves a five-energy-group calculation of the slowing-down phase across each resonance with subsequent flux-weighting of the resonance cross-sections. This is the major function of NITAWL in its conversion of cross-section libraries from a problem-independent to a problem-dependent form. However, NITAWL also assembles group-to-group transfer arrays from the elastic and inelastic scattering components and performs other tasks in producing the problem-dependent library.

iii. KENO-IV is an improvement and extension of KENO - a Multigroup Monte-Carlo Criticality program written for the IBM 360 computers. It is flexibly dimensioned, utilizes free-form input, and offers more geometry options. The geometry input is quite simple to prepare, and complicated three-dimensional systems can often be described with a minimum of effort. The results calculated by KENO-IV include K-effective lifetime and generation time, energy-dependent leakages and absorptions, energy- and region-dependent fluxes and region-dependent fission densities.

4. The data base:

The SCALE system data base contains a standard composition library, various neutron and coupled neutron-photon libraries, and the ORIGEN-S libraries. The standard compositions library is used by the materials input processor in developing nuclide atom densities. Also the library contains data on each nuclide which is used in developing the input for the resonance processors and for the mesh spacing algorithms used with the determination codes. The library consists of a standard compositions directory, a standard compositions table, an isotope distribution directory, an isotope distribution table, and a nuclide information table. The library is configured as a permanent direct access data set. It contains 109 standard compositions, 78 nuclides, 3 elements with variable isotopic distributions and data for the specification of three aqueous fuel solutions. The physical data contained in the library is taken from standard references.

APPENDIX B

SCALE SYSTEM INPUT FOR THE FIRST AND SECOND SERIES OF EXPERIMENTS

To simplify the input and to eliminate the chance for human error, the SCALE system control module internally applies a standardized procedure to calculate the number density for each nuclide in the system. It also creates the necessary mixing tables for use in KENO.

In the input stream, the user describes all material mixtures found in the problem under study in terms of various "standard compositions" and other engineering type specifications such as their associated volume fraction or the percent theoretical density, temperature and isotopic distribution. For each "standard composition," subroutine DETUPB scans the standard composition library to determine the theoretical density (gm/cm), the number of elements in the standard composition, and whether the standard composition is a compound, alloy or solution.

The input is divided into three main parts. First, the problem parameters are read. This provides a general description of the system. Next, a description of each material composition is read. As many entries as needed may be used to fully describe any material mixture.

Finally, the geometry description for the problem is read. In the CSAS2 analytic sequence, several additional blocks of data are required to describe the three-dimensional KENO-IV geometry.

The SCALE system input for a 20x21 lattice, 85.9 cm critical height, and 2.52 cm lattice pitch is shown in Fig. 4 as an example, which is one experiment in the first series. The input for one of the experiments in the second series is shown in Fig. 5.

```
      PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - JULY 6,1978)

MODULE CSAS2     WILL BE CALLED  TIME OF DAY 15.07.35  DATE 8,.126

  0.827 IN PITCH LATTICE CELL 4.75 WT% ENRICHED FUEL
  123GROUPMTH    4 4 4 LATTICECELL 6 9
  UO2    1 0.947 295 92235 4.75 92238 95.25 END UO2
  ARBMAGS    2.0 4 0 0 1 13827 98.85 12[illegible] 0.47 14026 0.43 [illegible] 0.23 2 1 295 END
  ARBMTLNAND3     1.1094 4 0 0 1 11.23 4.342 7014 2.643 [illegible] 3.328 8016 83.047 3 1
  295 END
  ARBMSS304   7.93 6 0 0 1 24000 18.56 25055 1.50 42000 0.26
  2P[illegible] 11.09 4 1 295 END SS304
  SQUARE PITCH    2.10 0.79 1 3 0.94 2 0.02 3 END GEOMETRY
  AND3 SOLUTION,    16*1e ARRAYS, 89.5 CM CRITICAL HEIGHT, 2.10 CM LATTICE PITCH
  20 100 300 4 12 18 13 3 0
  BOX TYPE    1
  CYLINDER    1 0.395 89.5 0.0 -0.5
  CYLINDER    0 0.41 89.5 0.0 -0.5
  CYLINDER    2 0.47 89.5 0.0 -0.5
  CUBOID    3 1.05 -1.05 1.05 -1.05 89.5 0 -0.5
  BOX TYPE    2
  CYLINDER    1 0.395 90 89.5 -0.5
  CYLINDER    0 0.41 90 89.5 -0.5
  CYLINDER    2 0.47 90 89.5 -0.5
  CUBOID    0 1.05 -1.05 1.05 -1.05 90 89.5 -0.5
  BOX TYPE    3
  CUBOID    3 -1.05 -21.05 21.05 1.05 0 -1.8 -0.5
  BOX TYPE    4
  CUBOID    3 1.05 -1.05 21.05 1.05 0 -1.8 -0.5
  BOX TYPE    5
  CUBOID    3 -1.05 -21.05 1.05 -1.05 0 -1.8 -0.5
  BOX TYPE    6
  CYLINDER    2 0.47 0 -1.8 -0.5
  CUBOID    3 1.05 -1.05 1.05 -1.05 0 -1.8 -0.5
  BOX TYPE    7
  CUBOID    3 -1.05 -21.05 21.05 1.05 89.5 0 -0.5
  BOX TYPE    8
  CUBOID    3 -1.05 -21.05 1.05 -1.05 89.5 0 -0.5
  BOX TYPE    9
  CUBOID    3 1.05 -1.05 21.05 1.05 89.5 0 -0.5
  BOX TYPE    10
  CUBOID    0 -1.05 -21.05 21.05 1.05 90 89.5 -0.5
```

Figure 4 SCALE system input for one of the cases in the first series of experiments

```
BOX TYPE     11
CUBOID     0 -1.05 -21.05 1.05 -1.05 90 89.5 -0.5
BOX TYPE     12
CUBOID     0 1.05 -1.05 21.05 1.05 90 89.5 -0.5
REFLECTOR     3 20 20 20 20 0 20 500
END GEOMETRY
3     1 18 17 1 18 17 1 1 1 0
4     2 17 1 1 16 17 1 1 1 0
5     1 18 17 2 17 1 1 1 1 0
6     2 17 1 2 17 1 1 1 1 0
1     2 17 1 2 17 1 2 2 1 0
7     1 18 17 1 18 17 2 2 1 0
8     1 18 17 2 17 1 2 2 1 0
9     2 17 1 1 16 17 2 2 1 0
2     2 17 1 2 17 1 3 3 1 0
10     1 18 17 1 18 17 3 3 1 0
11     1 18 17 2 17 1 3 3 1 0
12     2 17 1 1 18 17 3 3 1 1
END
```

Figure 4 (continued)

```
PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 06/13/80 - 10.37)

MODULE CSAS2     WILL BE CALLED  TIME OF DAY 17.59.50  DATE 80.177

  0.53 IN PITCH LATTICE CELL 4.75 WT% ENRICHED FUEL
  123GROUPMTH    4 4 4 LATTICECELL 0 0
  UO2    1 0.947 295 92235 4.75 92238 95.25 END UO2
  ARBMAGS    2.6 4 0 0 1 13027 96.65 12000 0.47 14028 0.43 26000 0.23 2 1 295 END
  H2O    3 1 END
  ARBMTLCM2    0.5680 2 0 0 0 6012 85.63 1001 14.37 4 1 295 END
  SQUARE PITCH 1.35 0.79 1 3 0.94 2 0.82 0 END GEOMETRY
  CM2 BOX.18418 ARRAYS. 10.CM SEPARATION. 49.94 CM CRITICAL HEIGHT.
  20 100 300 4 48 41 41 3 0
  BOX TYPE    1
  CYLINDER    1 0.395 49.94 0 -0.5
  CYLINDER    0 0.41 49.94 0.0 -0.5
  CYLINDER    2 0.47 49.94 0.0 -0.5
  CUBOID    3 0.675 -0.675 0.675 -0.675 49.94 0.0 -0.5
  BOX TYPE    2
  CYLINDER    1 0.395 90 49.94 -0.5
  CYLINDER    0 0.41 90 49.94 -0.5
  CYLINDER    2 0.47 98.2 49.94 -0.5
  CUBOID    0 0.675 -0.675 0.675 -0.675 98.2 49.94 -0.5
  BOX TYPE    3
  CUBOID    3 -0.675 -20.675 -0.675 -20.675 0 -1.8 -0.5
  BOX TYPE    4
  CUBOID    3 0.675 -0.675 -0.675 -20.675 0 -1.8 -0.5
  BOX TYPE    5
  CUBOID    3 -0.675 -20.675 0.675 -0.675 0 -1.8 -0.5
  BOX TYPE    6
  CYLINDER    2 0.47 0 -1.8 -0.5
  CUBOID    3 0.675 -0.675 0.675 -0.675 0 -1.8 -0.5
  BOX TYPE    7
  CUBOID    3 -0.675 -20.675 -0.675 -20.675 49.94 0 -0.5
  BOX TYPE    8
  CUBOID    3 -0.675 -20.675 0.675 -0.675 49.94 0 -0.5
  BOX TYPE    9
  CUBOID    3 0.675 -0.675 -0.675 -20.675 49.94 0 -0.5
```

Figure 5. SCALE system input for some of the cases in the second series of experiments

```
BOX TYPE     47
CUBOID     2 23.925 23.625 -0.675 -0.975 49.94 0 -0.5
CUBOID     3 23.925 23.625 -0.675 -20.675 49.94 0 -0.5
BOX TYPE     48
CUBOID     2 23.925 23.625 -0.675 -0.975 98.2 49.94 -0.5
CUBOID     0 23.925 23.625 -0.675 -20.675 98.2 49.94 -0.5
REFLECTOR    3 20 20 20 20 0 20 500
END GEOMETRY
3     1 41 40 1 41 40 1 1 1 0
4     2 40 1 1 41 40 1 1 1 0
5     1 41 40 2 40 1 1 1 1 0
6     2 40 1 2 40 1 1 1 1 0
13     2 40 1 20 22 2 1 1 1 0
14     20 22 1 2 40 1 1 1 1 0
15     2 40 1 21 21 1 1 1 1 0
16     21 21 1 2 40 1 1 1 1 0
17     1 41 40 20 22 1 1 1 1 0
20     20 22 1 20 22 1 1 1 1 0
21     21 21 1 21 21 1 1 1 1 0
22     21 21 1 20 22 2 1 1 1 0
23     1 41 40 21 21 1 1 1 1 0
46     20 22 1 1 41 40 1 1 1 0
26     21 21 1 1 41 40 1 1 1 0
29     20 22 2 21 21 1 1 1 1 0
7     1 41 40 1 41 40 2 2 1 0
9     2 40 1 1 41 40 2 2 1 0
8     1 41 40 2 40 1 2 2 1 0
1     2 40 1 2 40 1 2 2 1 0
30     2 40 1 20 22 2 2 2 1 0
32     20 22 1 2 40 1 2 2 1 0
34     2 40 1 21 21 1 2 2 1 0
36     21 21 1 2 40 1 2 2 1 0
18     1 41 40 20 22 1 2 2 1 0
38     20 22 1 20 22 1 2 2 1 0
40     21 21 1 21 21 1 2 2 1 0
42     21 21 1 20 22 2 2 2 1 0
24     1 41 40 21 21 1 2 2 1 0
47     20 22 1 1 41 40 2 2 1 0
27     21 21 1 1 41 40 2 2 1 0
44     20 22 2 21 21 1 2 2 1 0
```

Figure 5 (continued)

```
BOX TYPE    28
CUBOID    2 33.325 23.925 -0.675 -0.975 98.2 49.94 -0.5
CUBOID    0 33.325 23.925 -0.675 -20.675 98.2 49.94 -0.5
BOX TYPE    29
CUBOID    4 23.925 23.625 33.325 23.925 0 -1.6 -0.5
BOX TYPE    30
CUBOID    2 0.675 -0.675 23.925 23.625 49.94 0 -0.5
BOX TYPE    31
CUBOID    2 0.675 -0.675 23.925 23.625 98.2 49.94 -0.5
BOX TYPE    32
CUBOID    2 23.925 23.625 0.675 -0.675 49.94 0 -0.5
BOX TYPE    33
CUBOID    2 23.925 23.625 0.675 -0.675 98.2 49.94 -0.5
BOX TYPE    34
CUBOID    4 0.675 -0.675 33.325 23.925 49.94 0 -0.5
BOX TYPE    35
CUBOID    4 0.675 -0.675 33.325 23.925 98.2 49.94 -0.5
BOX TYPE    36
CUBOID    4 33.325 23.925 0.675 -0.675 49.94 0 -0.5
BOX TYPE    37
CUBOID    4 33.325 23.925 0.675 -0.675 98.2 49.94 -0.5
BOX TYPE    38
CUBOID    2 23.925 23.625 23.925 23.625 49.94 0 -0.5
BOX TYPE    39
CUBOID    2 23.925 23.625 23.925 23.625 98.2 49.94 -0.5
BOX TYPE    40
CUBOID    4 33.325 23.925 33.325 23.925 49.94 0 -0.5
BOX TYPE    41
CUBOID    4 33.325 23.925 33.325 23.925 98.2 49.94 -0.5
BOX TYPE    42
CUBOID    4 33.325 23.925 23.925 23.625 49.94 0 -0.5
BOX TYPE    43
CUBOID    4 33.325 23.925 23.925 23.625 98.2 49.94 -0.5
BOX TYPE    44
CUBOID    4 23.925 23.625 33.325 23.925 49.94 0 -0.5
BOX TYPE    45
CUBOID    4 23.925 23.625 33.325 23.925 98.2 49.94 -0.5
BOX TYPE    46
CUBOID    2 23.925 23.625 -0.675 -0.975 0 -1.6 -0.5
CUBOID    3 23.925 23.625 -0.675 -20.675 0 -1.6 -0.5
```

Figure 5 (continued)

```
BOX TYPE    10
CUBOID    0 -0.675 -20.675 -0.675 -20.675 98.2 49.94 -0.5
BOX TYPE    11
CUBOID    0 -0.675 -20.675 0.675 -0.675 98.2 49.94 -0.5
BOX TYPE    12
CUBOID    0 0.675 -0.675 -0.675 -20.675 98.2 49.94 -0.5
BOX TYPE    13
CUBOID    2 0.675 -0.675 23.925 23.625 0 -1.8 -0.5
BOX TYPE    14
CUBOID    2 23.925 23.625 0.675 -0.675 0 -1.8 -0.5
BOX TYPE    15
CUBOID    4 0.675 -0.675 33.325 23.925 0 -1.8 -0.5
BOX TYPE    16
CUBOID    4 33.325 23.925 0.675 -0.675 0 -1.8 -0.5
BOX TYPE    17
CUBOID    2 -0.675 -0.975 23.925 23.625 0 -1.8 -0.5
CUBOID    3 -0.675 -20.675 23.925 23.625 0 -1.8 -0.5
BOX TYPE    18
CUBOID    2 -0.675 -0.975 23.925 23.625 49.94 0 -0.5
CUBOID    3 -0.675 -20.675 23.925 23.625 49.94 0 -0.5
BOX TYPE    19
CUBOID    2 -0.675 -0.975 23.925 23.625 98.2 49.94 -0.5
CUBOID    0 -0.675 -20.675 23.925 23.625 98.2 49.94 -0.5
BOX TYPE    20
CUBOID    2 23.925 23.625 23.925 23.625 0 -1.8 -0.5
BOX TYPE    21
CUBOID    4 33.325 23.925 33.325 23.925 0 -1.8 -0.5
BOX TYPE    22
CUBOID    4 33.325 23.925 23.925 23.625 0 -1.8 -0.5
BOX TYPE    23
CUBOID    2 -0.675 -0.975 33.325 23.925 0 -1.8 -0.5
CUBOID    3 -0.675 -20.675 33.325 23.925 0 -1.8 -0.5
BOX TYPE    24
CUBOID    2 -0.675 -0.975 33.325 23.925 49.94 0 -0.5
CUBOID    3 -0.675 -20.675 33.325 23.925 49.94 0 -0.5
BOX TYPE    25
CUBOID    2 -0.675 -0.975 33.325 23.925 98.2 49.94 -0.5
CUBOID    0 -0.675 -20.675 33.325 23.925 98.2 49.94 -0.5
BOX TYPE    26
CUBOID    2 33.325 23.925 -0.675 -0.975 0 -1.8 -0.5
CUBOID    3 33.325 23.925 -0.675 -20.675 0 -1.8 -0.5
BOX TYPE    27
CUBOID    2 33.325 23.925 -0.675 -0.975 49.94 0 -0.5
CUBOID    3 33.325 23.925 -0.675 -20.675 49.94 0 -0.5
```

Figure 5 (continued)

```
10    1  41  40  1  41  40  3  3  1  0
12    2  40  1  1  41  40  3  3  1  0
11    1  41  40  2  40  1  3  3  1  0
2    2  40  1  2  40  1  3  3  1  0
31    2  40  1  20  22  2  3  3  1  0
33    20  22  1  2  40  1  3  3  1  0
35    2  40  1  21  21  1  3  3  1  0
37    21  21  1  2  40  1  3  3  1  0
19    1  41  40  20  22  1  3  3  1  0
39    20  22  1  20  22  1  3  3  1  0
41    21  21  1  21  21  1  3  3  1  0
43    21  21  1  20  22  2  3  3  1  0
25    1  41  40  21  21  1  3  3  1  0
48    20  22  1  1  41  40  3  3  1  0
26    21  21  1  1  41  40  3  3  1  0
45    20  22  2  21  21  1  3  3  1  1
END
```

Figure 5 (continued)

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