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Contract No. W-7405 eng 26

Computer Sciences Division

CRITICALITY ANALYSES OF DISRUPTED CORE MODELS OF THREE MILE ISLAND UNIT 2

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December 1979

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UNION CARBIDE CORPORATION-NUCLEAR DIVISION
operating the
Oak Ridge Gaseous Diffusion Plant — Oak Ridge National Laboratory
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ACKNOWLEDGMENTS

This manuscript was prepared for publication by B. R. Ferguson and P. S. Young. The authors express their appreciation for the fine quality of the manuscript as well as their cheerful assistance in performing the many tasks associated with publication.

The brief duration and successful completion of this study were made possible by a high level of cooperation on the part of several individuals and organizations. Staff members of the Babcock and Wilcox Company supplied information on the as-built reactor core, the zero-power startup benchmark critical configuration and the core damage assessment.
G. T. Mays of the Nuclear Safety Information Center, ORNL, assisted in the acquisition of information from the Final Safety Analysis Report.
D. O. Campbell of the Chemical Technology Division, ORNL, supplied information on the soluble boron content of the damaged reactor. R. E. Pawel of the Metals and Ceramics Division, ORNL, discussed the zirconium oxidation reaction and its implications for potential core damage.
L. M. Petrie and N. F. Landers of the Computer Sciences Division, UCCND, developed the MAKARAY KENO-IV input-processing program on an urgent basis. Priority was given to the machine computations by the operations staff of the computing facilities at the Idaho National Engineering Laboratory and the Oak Ridge National Laboratory. Finally, the highly sophisticated analytical capabilities used in this study were developed under continuing programs supported by the Office of Nuclear Material Safety and Safeguards and the Office of Nuclear Regulatory Research, U. S. Nuclear Regulatory Commission.

CRITICALITY ANALYSES OF DISRUPTED CORE MODELS OF THREE MILE ISLAND UNIT 2

R. M. Westfall, J. T. West, G. E. Whitesides, and J. T. Thomas

ABSTRACT

Three hypothetical disrupted core models were analyzed for the President's Commission on the Accident at Three Mile Island. Soluble boron in the present configuration was assumed to be 3180 weight parts per million (wppm). Positive reactivity effects due to fuel swelling, fuel slumping, and coolant displacement by ZrO_2 increase the cold, shutdown system multiplication factor from approximately 0.74 to 0.86. The increase in reactivity for the three models can be roughly correlated with a decrease in the borated water-to-fuel volume ratio. Each of the 39,825 pin-lattice locations was modeled explicitly in the Monte Carlo analyses of the reactor core. Parametric studies were performed with one-dimensional discrete-ordinates analyses. The report includes a benchmark critical analysis of the system at hot, zero-power startup, a description of the analytical methods used, and a comprehensive compilation of the data upon which the analytical models were based.

I. INTRODUCTION

At the request of W. R. Stratton, staff member of the President's Commission on the Accident at Three Mile Island, a series of analyses were performed to determine the reactivity effects of various hypothetical modes in which the reactor core of Three Mile Island Unit 2 may have been disrupted. The results of these analyses were forwarded to Dr. Stratton for use in preparing his portion of the commission report. The purpose of this memorandum is to provide formal documentation of this effort in terms of the hypothetical models studied and the analytical methods applied. The scope of this study was restricted to the disrupted core analyses. No quantitative judgment was made as to the likelihood of

the occurrence of the particular accident modes. Also, no recommendations are made as to specific actions to be taken to avoid a criticality incident during plant recovery operations.

The sources of information used in constructing the disrupted core models are described in Section II. This information includes data on the reactor design, a benchmark critical configuration, possible core disruptive mechanisms, and the soluble boron content of the reactor coolant. The disrupted-core models are described in Section III. The analytical methods are described in Section IV. This section includes a brief description of the 27-group neutron cross-section library and the geometry modeling features of the Monte Carlo transport programs MORSE-SGC/S[1] and KENO-IV.[2] The capability of these programs to represent the disrupted core with a high level of geometric detail was the primary reason for performing this study at Oak Ridge.

The results of the study are presented in Section V. The results pertain to three categories:

1. Parametric studies of the effects of fuel pin geometry changes determined through infinite-lattice pin-cell calculations.
2. A benchmark analysis of the as-measured critical configuration at hot, zero-power reactor-startup conditions.
3. Analyses of the disrupted core models including variations to determine the reactivity worths of the soluble boron, the control rods and the burnable poison rods.

Conclusions drawn from these results are summarized in Section VI.

II. MODEL DESIGN DATA

Reactor Design--The primary source of data on the design of Three Mile Island Unit 2 was the Final Safety Analysis Report (FSAR).[3] Information was taken from this report on the following design features:

1. Fuel assembly design, compositions and dimensions including

   a. fuel pins,
   b. control rods,
   c. axial power shaping rods,
   d. lumped burnable poison rods,
   e. orifice rods, and
   f. instrumentation guide tubes.

2. Cycle one fuel-loading scheme.

3. Rod locations, 0-200 full power days.

4. Reactor vessel and internals.

Copies of the tables and figures from which this information was taken are included here as Appendix A. This information was supplemented with particular details supplied by the Babcock and Wilcox Company. These pertain to the various fuel enrichments, given in Table 1, the B_4C loadings of the lumped burnable poison rods, given in Table 2, and the density of the Ag-In-Cd control rods (10.17 g/cc). All analyses in this study include fuel and fixed-absorber compositions based upon the beginning-of-life value. That is, no variation due to the brief operating history of the reactor was taken into account.

Table 1. Cycle One Fuel Enrichments

Fuel Element[a] Designation	Fuel Enrichment, Weight % U-235
Fuel Type "A"	1.98
Fuel Type "B"	2.64
Fuel Type "C"	2.96

[a] UO_2 at 10.138 g/cc (0.925 of theoretical).

Table 2. Lumped Burnable Poison Rod[a] B_4C Loadings

Rod Designation	B_4C[b] Loading, Weight % B_4C
LBP-1	1.395
LPB-2	1.260
LPB-3	1.060

[a] Al_2O_3-B_4C mixture at 3.7 g/cc.

[b] Natural boron.

Benchmark Critical--Additional information supplied by the Babcock and Wilcox Company included a set of conditions under which Three Mile Island Unit 2 was critical.

1. Hot, zero-power startup (fuel and moderator at 551°K).
2. Coolant at 2200 psi (0.77 g/cc).
3. Soluble boron at 1490 wppm.
4. Control rods out.
5. Axial power shaping rods out.

Core Disruptive Mechanisms--Information concerning the possible modes in which the reactor core may have been disrupted was provided by staff members of the Babcock and Wilcox Company and by cognizant individuals at Oak Ridge National Laboratory. Three major phenomena have been postulated.

1. Zirconium Oxidation
    a. function of temperature and steam distributions.
    b. hydrogen release indicated approximately 35% of Zircaloy oxidized.
    c. ZrO_2 probably flaked off and crumbled.
    d. damage concentrated in upper axial center of core.
    e. damage likely on fuel rod clad, possible on LBP rod clad and control rod guide tubes.
2. Fuel Swelling
    a. rapid depressurization of core may have caused clad to "balloon out" and rupture.

b. thermal stresses may have caused UO_2 to crack and crumble.
c. UO_2 may convert to U_3O_8 at a lower density (10.96 vs 8.3 g/cc theoretical).

3. Fuel Slumping

a. may occur with loss of clad integrity and physical displacement of UO_2.
b. heat transfer analyses indicate that the melting point of UO_2 may have been exceeded in the top central portion of the core.
c. severe downward displacement of the fuel believed to be restricted to the area above the third axial spacer grid at the center of the core extending radially and upward to the first axial spacer grid at the third fuel assembly from the edge of the core.

Soluble Boron Content--Coolant samples dated June 7, 1979, and analyzed at Oak Ridge National Laboratory contained a boron content equivalent to 2400 wppm. Trace amounts of silver, indium, and cadmium were detected. The boron content was scheduled to be increased to 3180 wppm by July 1, 1979.

III. DISRUPTED CORE MODELS

Three disrupted core models were analyzed. For the intact portions of the reactor core, each of the three models included an explicit representation of the contents of the 39,825 pin lattice locations. That is, the fuel rods, control rods, axial power shaping rods, lumped burnable poison rods and the orifice rods were each treated with all available detail as to composition and geometry. No distinction was made between the 40 instrumentation tubes containing in-core detectors and the 137 remaining water-filled locations. Staff members of the Babcock and Wilcox Company have indicated that the in-core detectors are worth about 0.2% $\Delta k/k$ in negative reactivity. The major difference between the three disrupted core models was in the number of axial layers used to represent the disrupted portion of the core. The MORSE-SGC/S model includes seven

axial levels in the core while the KENO-IV models have a maximum of two axial core zones.

MORSE-SGC/S "Three Jump Slump" Model--This disrupted core model is shown in Fig. 1. The intent in designing this model was to incorporate all of the core disruptive mechanisms in an internally consistent manner. Thus, all of the fuel pins in the core are swollen by 30 percent with the fuel consisting of a UO_2-U_3O_8 mixture with effective densities calculated to fill the increased volume and conserve the original mass of uranium. The densities for the two components in this mixture were 6.521 g/cc for U_3O_8 and 1.534 g/cc for UO_2. Complete conversion from UO_2 to U_3O_8 (at a constant percentage of theoretical density) would result in a volume increase of 37 percent.

A second major feature of this model concerns the disposition of the ZrO_2 formed in the upper central portion of the core. Here it is assumed to be uniformly distributed in the coolant channels immediately below the slumped fuel. The ZrO_2 occupies 32.9 percent of the flow channel areas for an axial distance equal to the length of the slumped fuel. The fuel element spacer grids would be the primary mechanism for preventing the ZrO_2 from exiting the core.

The third major feature of this model concerns the nature of the slumped fuel. With the loss of the zircaloy clad, it is assumed that the UO_2 converts to U_3O_8 and is physically displaced downward to rest upon the spacer grids and non-disrupted fuel. The fuel is assumed to be a mixture of the types A and B fuel assemblies located in the disrupted region yielding an average enrichment of 2.3 wt % U-235. The slumped fuel has a 0.687 volume factor which is near the theoretical maximum

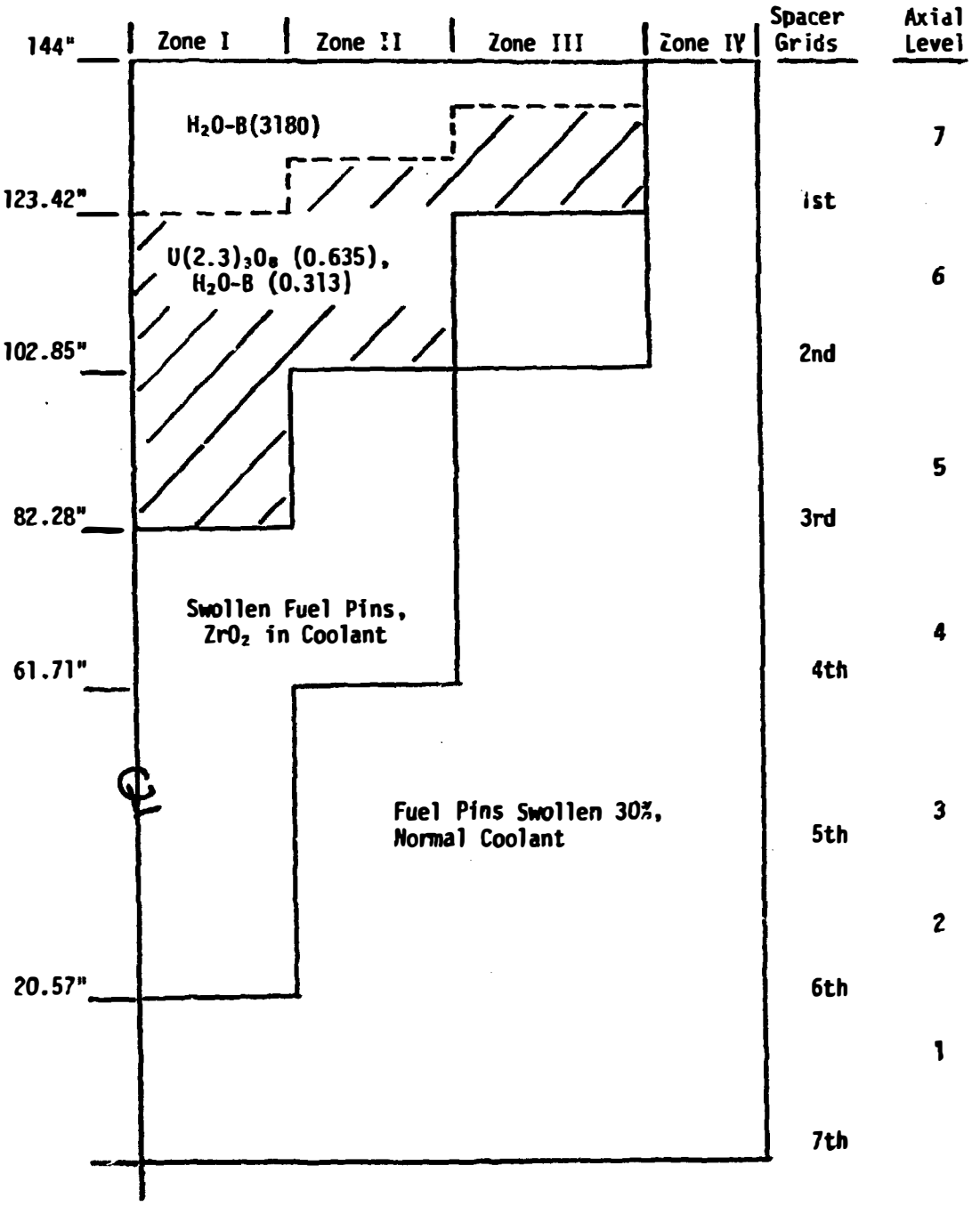

Fig. 1. MORSE-SGC/S Three Jump Slump Core Model*

*Control and Lumped Burnable Poison Rods from Disrupted Portion of Core Missing. Boron in Coolant in All Zones at 3180 wppm. Core Barrel, Radial, and Axial Reflector Regions in Model.

packing factor for spheres. The U_3O_8 and borated water are the only materials remaining in the disrupted region of the core. That is, portions of the control rods, lumped burnable poison rods and orifice rods that originally extended through this region have been removed from the model. This is a conservative assumption from the criticality safety point of view.

There are four radial zones in this model. A detailed layout of the contents of each radial zone is given in Appendix B. This appendix includes a description of how this model was mocked-up using the array of arrays feature of the MORSE-SGC/S geometry package. Of particular interest is the manner in which the overall pin lattice array was truncated axially and indented radially to accommodate the representation of the disrupted portion of the core.

KENO-IV "Displaced-Fuel Slump" Model--This disrupted core model is shown in Fig. 2. Here it is assumed that the complete upper half of the core has been disrupted. The fuel has converted to U_3O_8 and been displaced downward to form the same U_3O_8-H_2O + B mixture assumed in the MORSE-SGC/S model. However, the fuel enrichment used here was 2.57 wt % U-235, which corresponds to the core average. This model assumes that the fuel clad and the other non-fuel materials in the disrupted region have been removed from the core. The lower half of the core is the normal pin lattice configuration (39,825 lattice locations). Details of the geometry mock-up in KENO-IV are given in Appendix C.

KENO-IV "In-Place Fuel Slump" Model--This disrupted core model is shown in Fig. 3. Here it is assumed that the fuel pin expands radially at constant clad density and volume and that the UO_2 slumps axially at

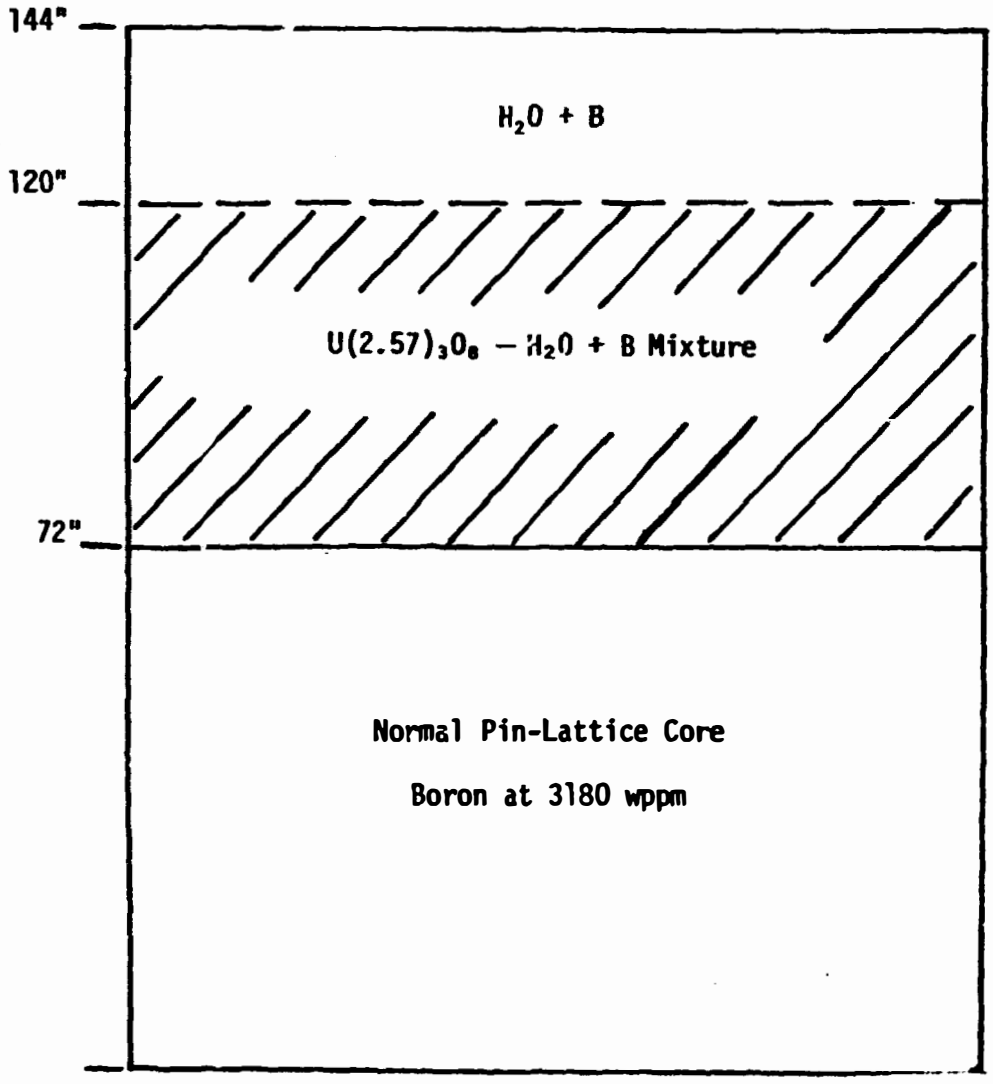

Fig. 2. KENO-IV Displaced Fuel Slump Model*

*Includes Radial and Axial Reflectors of H_2O + B

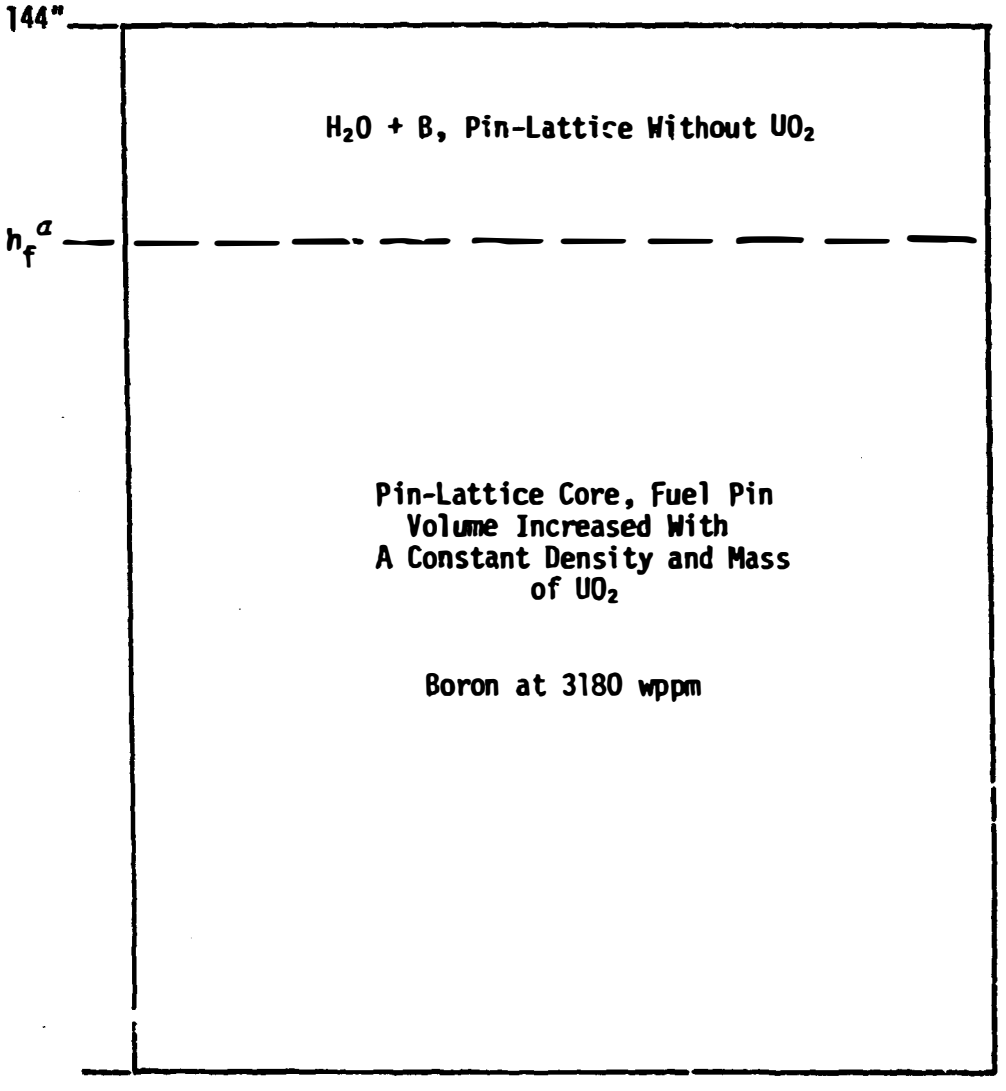

Fig. 3. KENO-IV In-Place Fuel Slump Model[b]

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[a] h_f values: 144", 114.2", 94.6", 80.8", 70.4"

[b] Includes Radial and Axial Reflectors of H_2O + B

constant density and volume. Including the as-built core, five fuel heights were analyzed. The minimum fuel height corresponds to the case in which the outer diameter of the fuel pins is equal to the lattice pitch (1.443 cm) and thus the fuel pins are touching. The three intermediate fuel heights correspond to 25, 50, and 75 percent of the total possible increase in the cross sectional area of the fuel. The fuel pin clad and the other nonfuel material above the active portion of the core are present in this model. Details of the geometry mock-up in KENO-IV are given in Appendix C.

IV. ANALYTICAL METHODS

Neutron Cross Sections--The neutron cross sections used in these analyses were taken from a 27 energy-group library developed from ENDF/B-IV data for the U. S. Nuclear Regulatory Commission. The 27 energy-group structure was determined through an extensive series of model calculations.[4] The group structure includes the boundaries of the 16-group Hansen-Roach[5] cross-section library with two additional boundaries in the high-energy "fission-spectrum" range and nine additional boundaries in the low-energy "thermal-upscatter" range. The group structure is given in Table 3.

Resonance processing was performed using the NITAWL-S module of the SCALE system. This module applies the Nordheim[6] method to calculate resonance self-shielding for the absorber materials located in a pin-lattice cell. Resonance processing was performed for nine nuclides: U-238, U-235, Zircaloy, Ag-107, Ag-109, In-113, In-115, Cd, and Mn. Several parameters determined the number of lattice-cell resonance analyses.

Table 3. 27-Broad-Energy Group Structure

Group No.	Upper Boundary	Group No.	Upper Boundary
1	20 MeV	15	3.05 eV
2	6.434	16	1.77
3	3	17	1.3
4	1.85	18	1.13
5	1.4	19	1
6	900KeV	20	0.8
7	400	21	0.4
8	00	22	0.325
9	1'	23	0.225
10	3	24	0.1
11	55υ eV	25	0.05
12	100	26	0.03
13	30	27	0.01
14	10		0.00001

This group structure was found to be adequate through the broad-group-determination procedure for the nuclides: U-238, U-235, Pu-239, Pu-240, Pu-241, Pu-242, B-10, SS-304, (Ni, Fe, Cr), Cd, Al, Cu, H_2O, zircaloy-2.

1. Fuel enrichment
2. Fuel diameter and density
3. Fuel temperature
4. Temperature and density of the coolant
5. Boron content of coolant
6. Presence of ZrO_2 in coolant

Appropriate Dancoff factors for the various combinations of cell parameters were applied. The U_3O_8-H_2O + B mixtures were treated as infinite homogeneous media in the resonance processing for U-235 and U-238. Fuel enrichment was the only variable in these analyses.

Of particular interest to this study is the expected performance of this cross-section library in the analysis of systems similar to Three Mile Island Unit 2. The results of previous analyses[7] of pin-lattice critical experiments with ENDF/B-IV data are given in Table 4. The 27-group library is a subset of the 218-group library in the table. Also, the 19-group library is a subset of the 27-group library. Thus, the 27-group library would yield system multiplication factors consistent with the results from 218- and 19-group libraries. The results using point cross sections are in good agreement with the multigroup results. For comparison purposes, the lattice pitch for the Three Mile Island Unit 2 fuel assemblies is 0.57 inches and the effective water/fuel volume ratio is 1.27 for the hot, zero-power startup configuration. Thus, Cases 1, 2, and 5 correspond fairly well to the critical benchmark configuration for Three Mile Island Unit 2. From these results, the expected multiplication factor calculated with the 27-group library for the critical benchmark would be between 0.980 and 0.990.

MORSE-SGC/S--This is a new version of the MORSE[10] Monte Carlo transport codes. It combines the supergroup capabilities of MORSE-SGC[1]

Table 4. Calculated Results for Critical Uranium Oxide Lattices with Clean and Borated Water Moderators

Critical Experiment		Case	Water/Fuel Volume Ratio	Pitch (inches)	ENDF/B-IV Data					
					Point XSECS		218 Group		19 Group	
WCAP[6]	A water moderated 23 × 23 array of 2.72% enriched UO_2 rods	1	1.49	0.6	0.9869	0.0063	0.9848	0.0068	0.9867	0.0044
EPRI[5]	Clean water moderated lattice of 2.35% enriched UO_2 rods	2	1.20	0.615	0.9900	0.0060	0.9864	0.0042	0.9849	[illegible]
		3	2.41	0.750	---		0.9922	0.0050	0.9934	[illegible]
		4	3.68	0.87	0.9984	0.0061	0.9932	0.0047	0.9934	[illegible]
EPRI[3]	Borated water moderated lattice of 2.35% enriched UO_2 rods	5[a]	1.20	0.615	---		---		0.9837	0.0035
		6	2.41	0.75	---		---		0.9983	0.0036
		7	3.68	0.87	---		---		1.0007	0.0034

[a] 468 wppm soluble boron

with a new array of arrays nesting feature developed for the U. S. Nuclear Regulatory Commission. The array of arrays feature provides for a single description of each type of fuel pin, lumped burnable poison rod, etc., followed by array specifications to define the fuel assemblies and a subsequent array specification of the fuel assemblies in the reactor core. The power of this procedure is demonstrated by the minimal computer storage requirement for the geometry description of the MORSE-SGC/S "Three Jump Slump" disrupted core model. Less than 9,000 decimal words of computer storage were required to describe the three-dimensional array containing 241,200 pin locations--plus the various uniform media bodies corresponding to the U_3O_8-H_2O + B mixture and the water and steel reflector regions.

The MORSE-SGC/S analyses were performed on the Idaho National Engineering Laboratory CDC-7600 computer. Several initial neutron source distributions were specified for differing fuel regions. There was no discernable trend with source specification in the results. Standard variance reduction techniques such as Russian Roulette and splitting were applied. The analyses required about 1.2 minutes of CPU time per thousand histories calculated. Standard deviations of 0.003 were obtained with 60,000 histories, 0.006 with 30,000 histories, and 0.01 with 8,000 histories.

KENO-IV--This is the current production version of the KENO[11] series of multigroup Monte Carlo criticality programs. These programs feature an easily-specified geometry scheme which permits an extremely efficient particle tracking algorithm. The accuracy, efficiency, and ease-of-use of these programs has led to their being the most popular codes for

multidimensional criticality analyses. A high level of experience in this use has been accumulated in the last decade. Automated procedures in KENO-IV include source specifications, particle biasing, reflector weighting, and output edits.

The primary limitation in applying KENO-IV to this study stems from the very large number of pin-lattice locations that must be described. In KENO-IV, the entire mixed-box orientation array is stored in the computer memory. Thus, the primary application of KENO-IV has been to corroborate the MORSE-SGC/S results for those models requiring only one axial layer in the pin-lattice specifications.

Applying one-quarter core symmetry, the entire Three Mile Island Unit 2 reactor lattice was mocked-up in a 120 x 120 mixed box orientation array. A computer program, MAKARAY, was written to simplify the specification of this array. First the fuel assemblies were specified, then the combination of fuel assemblies corresponding to the first core loading was specified. From this information MAKARAY constructed the KENO-IV mixed-box orientation array for the one-quarter core. Note that the one-quarter core symmetry was achieved through the specification of hemicylinders for the pins lying on the X and Y core midplanes.

The KENO-IV analyses were performed on the Oak Ridge National Laboratory IBM-360/91 computer. The analyses required about 0.4 minutes of CPU time per thousand histories calculated. Standard deviations of 0.006 were obtained with 6,000 histories.

XSDRNPM-S--This is the SCALE[12] system version of the XSDRN[13] one-dimensional discrete-ordinates neutral particle transport programs. Its primary application in this study was in pin-lattice cell calculations

to determine the effects of various changes in fuel composition and geometry. The analyses were performed with the S_8 angular quadrature approximation and a P_3 scattering expansion order. ~~ISDRNPM~~-S was executed in a SCALE system analytical sequence (CSAS1) which performs the problem-dependent cross-section processing and sets up the input for the transport analysis. MITAWL[12] input parameters and nuclide atom densities from these analyses were also used in the three-dimensional Monte Carlo analyses.

V. ANALYTICAL RESULTS

Infinite Pin Lattice Analyses--These analyses were performed to provide qualitative estimates of the reactivity effects due to possible core disruptive mechanisms. Since they are one-dimensional analyses, the combined effects of fuel and neutron absorbing rods are not calculated. Also, the neutron leakage is not taken into account. However, the leakage for this core is only worth about 4 percent in reactivity.

Generally, the reactivity effects are due to postulated changes in the fuel pin geometry and associated variations in the water-to-fuel volume ratio in the reactor core. One limit to this variation is the case of an infinite medium of $U(2.96)O_2$. The multiplication factor for this dry fuel case is 0.663. Note that the fuel enrichment corresponds to the highest of the three values for the Three Mile Island Unit 2 reactor core. Thus, some content of water and its associated neutron moderation must be present for this system to become critical.

The effects of water content on reactivity are complicated by the high soluble boron content of the reactor coolant. Pressurized water reactor fuel is normally considered to be undermoderated, that is, at

less than an optimum water-to-fuel volume ratio for maximum reactivity. Such is the case for the "cold clean" (unborated water) results listed in Table 5 and shown in Fig. 4. Reducing the lattice pitch lowers the multiplication factor still further. However, for the "cold borated" situation, the opposite effect is observed. The most reactive lattice pitch is significantly less than the design value. Eventually, the negative reactivity due to the loss of water overtakes the positive reactivity due to the loss of boron and the system multiplication factor comes back down.

The results of fuel swelling listed in Table 6 and shown in Fig. 5 reflect a similar variation. Fuel swelling removes water and boron from the system and the multiplication factor rises. Here the water-to-fuel volume ratio ranges from 1.65 to 1.07 while the lattice pitch variation discussed above resulted in a much wider range in this ratio (2.97 to 0.57). This limited range accounts for the monotonic behavior of the curves in Fig. 5.

The effect of boron concentration upon the system multiplication factor is given in Table 7. From 0 to 2400 wppm the reactivity worth of the boron is 1.13% $\Delta k/k_1k_2$ per 100 wppm while from 2400 to 3180 wppm the worth is 1.08% $\Delta k/k_1k_2$ per 100 ppm. Thus the incremental worth of the boron decreases as saturation is approached. These values are slightly higher than the 1% $\Delta k/k$ per 100 ppm soluble boron worth determined by the Babcock and Wilcox Company. This value, given in Table 4.3-11 of Appendix A, pertains to the hot reactor core at rated power. Thus the soluble boron worth should be somewhat reduced due to the lower water density and the presence of fixed absorbers.

Table 5. TMI[a] Infinite Lattice Pitch Variation

Case	Lattice Pitch (cm)	Cold[b] Clean k_∞	Cold Borated[c] k_∞
1	1.154 (-20%)	1.142	1.025
2	1.227 (-15%)	1.229	1.047
3	1.299 (-10%)	1.284	1.040
4	1.371 (-5%)	1.319	1.016
5	1.443 (Design)	1.340	0.982
6	1.515 (+5%)	1.351	0.943
7	1.587 (+10%)	1.355	0.902
8	1.659 (+15%)	1.352	0.860
9	1.732 (+20%)	1.345	0.817

[a]2.57 wt % enriched UO_2 (92.5% theoretical density), 0.94 cm OD, Zircaloy clad 1.092 cm OD, 0.958 cm ID.

[b]All materials at 293°K, H_2O at full density.

[c]2400 wppm natural boron, June 7, 1979, ORNL analysis.

Table 6. TMI Infinite Lattice[a] Fuel Swelling

Case	Swelling Factor	(UO_2) (g/cc)	Fuel OD (cm)	Clad[b] OD (cm)	Cold Clean k_∞	Cold Borated k_∞
1	1.00(design)	10.14	0.940	1.092	1.340	0.982
2	1.05	9.66	0.963	1.097	1.338	0.984
3	1.10	9.22	0.985	1.116	1.335	0.989(3)[c]
4	1.15	9.10	1.008	1.137	1.329	1.001(7)
5	1.20	8.45	1.030	1.157	1.326	1.002(3)
6	1.30	7.80	1.071	1.193	1.316	1.012(5)

[a]Constant lattice pitch of 1.443 cm, 2400 wppm boron in H_2O.

[b]Clad expanded at constant volume.

[c]Next significant figure.

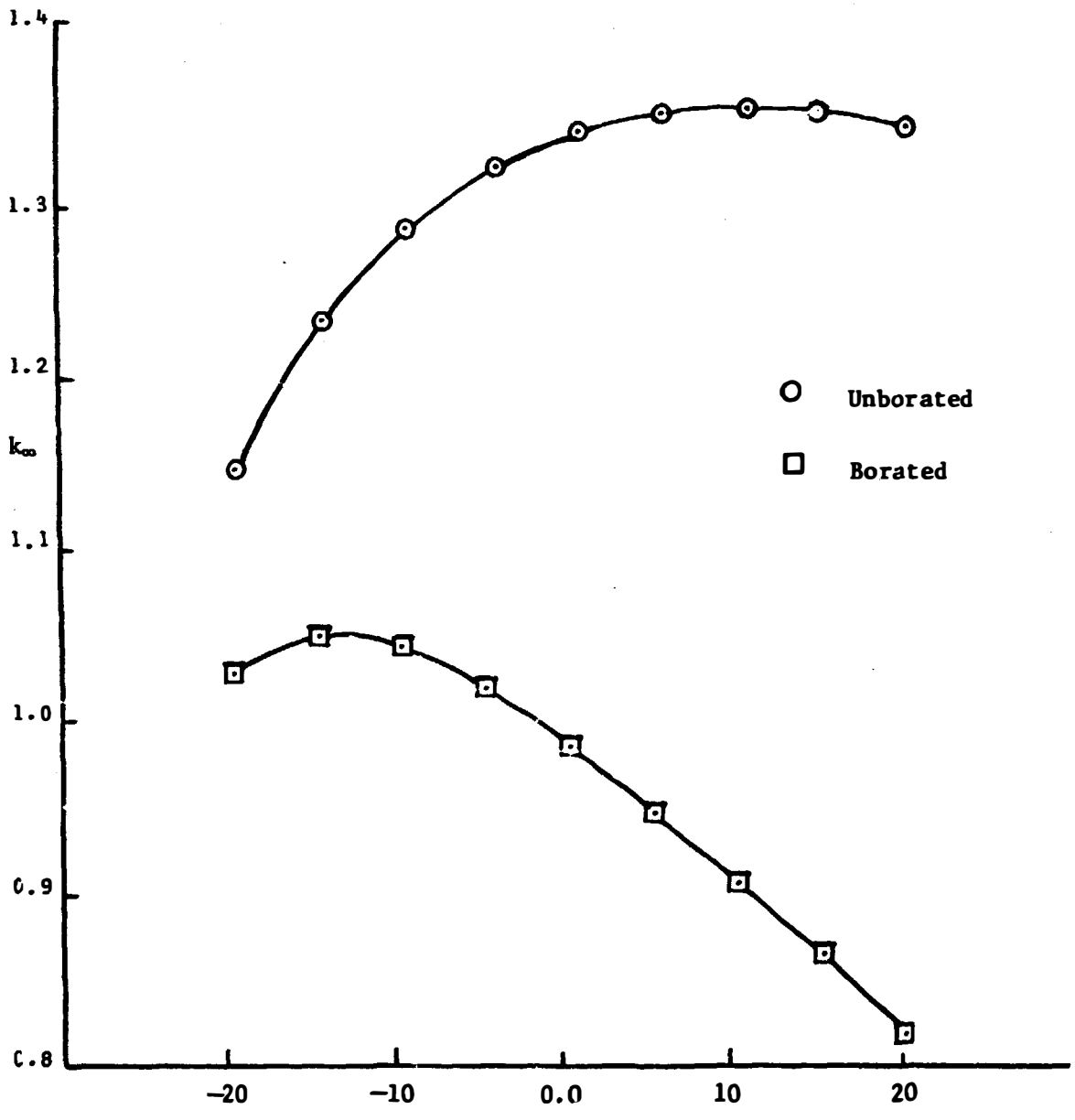
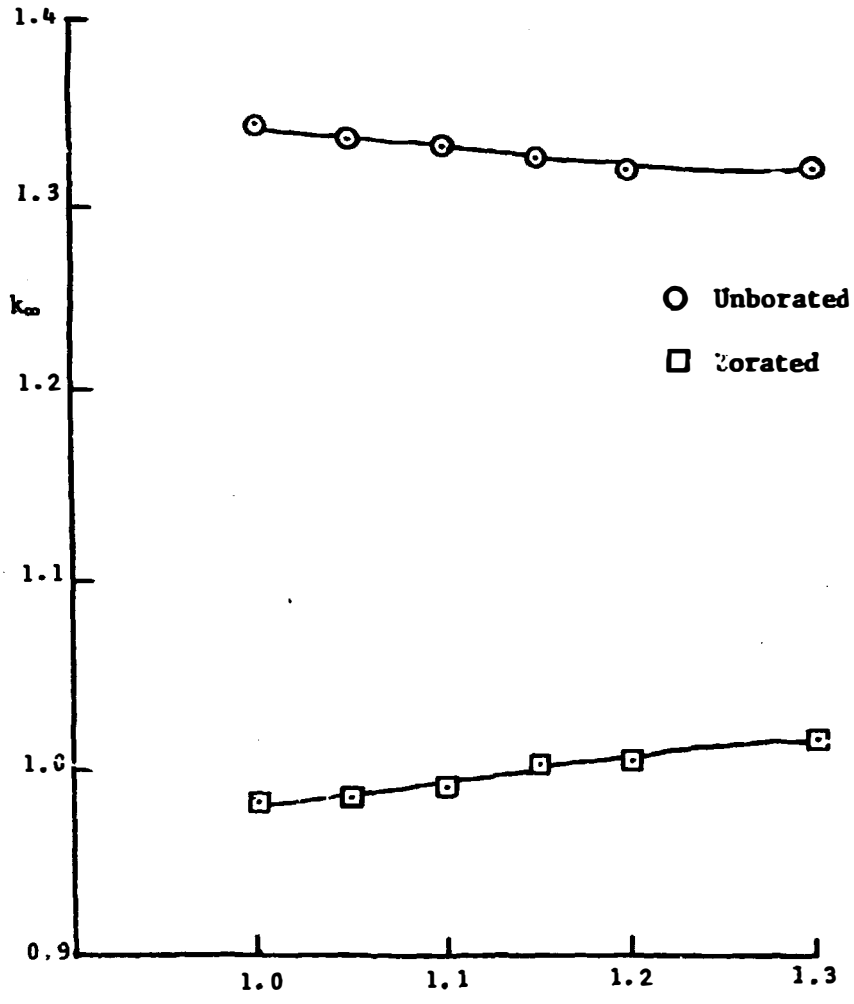


Fig. 4. TMI Infinite Lattice Pitch Variation



Volume Fraction Fuel Expansion

(Constant Lattice Pitch = 1.443 cm)

Fig. 5. TMI Infinite Lattice Fuel Swelling

Table 7. Multiplication Factor vs Boron Content and Enrichment

Fuel Enrichment	Boron Concentration, wppm 0	2400	3180
2.57 wt % (Core Average)	1.34	0.982	0.907
2.96 wt % (Type C)	-	1.032	0.957
2.64 wt % (Type B)	-	0.992	0.918
1.98 wt % (Type A)	-	-	0.811

Table 8. Combined Fuel Swelling, Interstitial ZrO_2

Case	2.96 Wt % Enriched Fuel, Cell Description	Multiplication Factor
A	Normal fuel, boron at 3180 ppm	0.959
B	30% swollen fuel,* boron at 3180 ppm	0.992
C	Case B, 33 vol % ZrO_2 in H_2O	1.012

*Fuel composed of U_3O_8 and UO_2 inside zircaloy clad.

The combined effect of fuel swelling and coolant displacement by ZrO_2 is given by the data in Table 8. The overall effect is worth 5.5% $\Delta k/k_1k_2$ while the swelling alone is worth 3.5% $\Delta k/k_1k_2$.

The results in Table 9 demonstrate the relative worths of the Ag-In-Cd control rods and the B_4C-Al_2O_3 lumped burnable poison rods. In these analyses, the cell lattice pitch was taken as the average spacing between control rod centers, and the intervening fuel rods were treated as a homogeneous fuel-clad-coolant medium. The primary purpose of the analyses was to determine the input parameters for treating resonance absorption in the control rods. The results indicate that the control rods are worth substantially more than the lumped burnable poison rods.

The results of infinite medium calculations for the U_3O_8-H_2O + B mixtures appearing in the MORSE-SGC/S "Three Jump Slump" model and the KENO-IV "Displaced-Fuel Slump" model are given in Table 10. Of particular interest is a comparison between the multiplication factor for the 2.57 wt % enriched fuel case with the corresponding pin cell result in Table 7. In going from the pin cell to the displaced fuel, the water-to-fuel volume ratio has gone from 1.65 to 0.46. The corresponding reactivity increase was 8.2% $\Delta k/k_1k_2$.

Benchmark Critical Analyses--The results of these analyses are given in Table 11. Good agreement is shown between the system multiplication factors calculated with MORSE-SGC/S and KENO-IV. Furthermore, these values are consistent with the 27 group results from the analyses of critical experiments having the same level of neutron moderation. Since the water density is 0.77 g/cc for this system, the effective water-to-fuel volume ratio drops from 1.65 to 1.27. Good agreement is shown between the results of Table 11 and the appropriate values in Table 4.

Table 9. Relative Rod Worth*--
Control Rod vs LBP1

Absorber Type	Multiplication Factor
Ag-In-Cd rod, SS304 clad	0.466
LBP1-B_4C-Al_2O_3 rod, Zr clad	0.680

*Pin-cell models include ZrO_2 and B(3180) in coolant, smeared $U(2.57)O_2$ fuel-clad-coolant.

Table 10. U_3O_8-H_2O[a] Worth vs Enrichment

Fuel Enrichment	Multiplication Factor
2.3 wt %, inner core	0.948
2.57 wt %, core average	0.980[b]

[a] U_3O_8 at 68.7 vol % (0.635 theoretical density), H_2O and B (3180 wppm) at 31.3 vol %.

[b] cf, $U(2.57)O_2$ K_∞ = 0.907 @ 3180 ppm boron, see Table 7.

Comparison of Cases A and B of Table 11 yields the lumped burnable poison rod worth in this configuration to be approximately 5% $\Delta k/k_1k_2$. This value is consistent with the 4.4% $\Delta k/k$ burnable poison rod assembly (BPRA) control worth listed in the (FSAR)[3] and reproduced in Table 4.3-9 of Appendix A.

Comparison of Cases A and C yields the control rod worth in this configuration to be approximately 12% $\Delta k/k$. This value is consistent with the 10.5% $\Delta k/k$ control rod worth at hot zero power listed in the FSAR[3] and given in Table 4.3-12 of Appendix A. The FSAR value does not include the worth of the axial power shaping rods shown in Bank 8 of Fig. 4.3-25 in Appendix A. Thus the FSAR value should be somewhat less than the value given by the present analysis.

Disrupted Core Analyses--The base case for these analyses is the normal core (nondisrupted) with the soluble boron level set at the 3180 wppm value corresponding to the current status. The results from analyses of this configuration are given in Table 12. Again, good agreement is seen between the MORSE-SGC/S and KENO-IV results. The control rods are worth approximately 9% $\Delta k/k_1k_2$ and the lumped burnable poison rods are worth approximately 4% $\Delta k/k_1k_2$. The high soluble boron level in the coolant tends to reduce the worth of the fixed absorbers.

The results from the analyses of the MORSE-SGC/S "Three Jump Slump" model are given in Table 13. Comparison of Case A with the as-built, cold shutdown case in Table 12 indicates that the overall positive reactivity worth of the disruptive core mechanisms is approximately 17% $\Delta k/k_1k_2$. The water-to-fuel volume ratio in this core varies from 0.47 in

Table 11. Hot,[a] Zero-Power Startup Configuration[b]

Case Description	Monte Carlo Code	Multiplication Factor
A. As measured critical[c]	MORSE-SGC/S	0.987 ± 0.003
	KENO-IV	0.983 ± 0.006
B. Case A with LBP rods removed	MORSE-SGC/S	1.042 ± 0.011
C. Case A with control rods inserted[d]	MORSE-SGC/S	0.864 ± 0.008
	KENO-IV	0.863 ± 0.009

[a] Coolant at 532°F, 2200 psi, ρ = 0.77, fuel at 532°F.

[b] Control rods out, soluble boron at 1490 wppm.

[c] H_2O/fuel-volume ratio = 1.27; multi-group ENDF/B-IV cross sections calculated K = 0.984 for other low-enriched uranium pin-lattice criticals at this H_2O/fuel-volume ratio.

[d] B&W calculates control rods to be worth 10.5% at hot, zero power.

Table 12. Normal Core Shutdown With Boron at 3180 wppm[a]

Case Description	Monte Carlo Code	Multiplication Factor
A. As-built, cold shutdown[b]	KENO-IV	0.737 ± 0.006
	MORSE-SGC/S	0.752 ± 0.007
B. Case A with control rods out	MORSE-SGC/S	0.805 ± 0.006
C. Case A with LBP rods removed	MORSE-SGC/S	0.778 ± 0.008
D. Case A with control rods out and LBP rods removed	MORSE-SGC/S	0.819 ± 0.007

[a] Value as of July 1, 1979.

[b] Coolant at 293°K, ρ = 1.0, fuel at 293°K.

the U_3O_8-H_2O + B mixture to 0.72 in the regions with ZrO_2 in the coolant to 1.07 in the remainder of the pin-lattice core. The average water-to-fuel volume ratio is 0.95.

The control rod worth for the borated core (Cases A and B) is less than 2% $\Delta k/k_1k_2$. However, the control rod worth for the unborated core (Cases D and F) is approximately 9% $\Delta k/k_1k_2$. Similarly, the lumped burnable poison rod worth for the borated core (Cases A and C) is less than 1% $\Delta k/k_1k_2$, while the unborated core worth (Cases E and F) is approximately 5% $\Delta k/k_1k_2$. Note that portions of the control and lumped burnable poison rods originally positioned in the disrupted region of the core are missing from this model.

The results from the analysis of the KENO-IV "Displaced-Fuel Slump" model are given in Table 14. Comparison of Case A with the as-built, cold shutdown case in Table 12 indicates that the positive reactivity worth of the fuel displacement is approximately 17% $\Delta k/k_1k_2$. The average water-to-fuel volume ratio is 1.06 for this configuration. Since this value is close to that of the "Three Jump Slump" model and the positive reactivity worths are the same, it appears that the reactivity can be grossly correlated with the water-to-fuel volume ratio.

However, the differential reactivity worths of the disruptive core mechanisms are highly dependent upon the particular features of the disrupted core models. For example, removal of the soluble boron from the pin-lattice portion of the core is worth 15% $\Delta k/k_1k_2$ for the "Three Jump Slump" model while it is worth more than 25% $\Delta k/k_1k_2$ for the "Displaced-Fuel Model." In the latter case, the coolant channels are at normal size and the boron is worth much more. Also, the control rods are worth more

Table 13. MORSE-SGC/S "Three Jump Slump" Disrupted Core

Case Description	Multiplication Factor
A. Base configuration[a]	0.862 ± 0.006
B. Case A with control rods out	0.875 ± 0.006
C. Case A with LBP rods removed	0.868 ± 0.006
D. Case A with controls rods and boron[b] out	1.079 ± 0.012
E. Case A with LBP rods and boron[b] out	1.043 ± 0.010
F. Case A with control rods inserted, boron out	0.988 ± 0.011

[a] 13.5% of upper middle core collapsed as U_3O_8-H_2O mixture; ZrO_2 distributed in coolant channels of lower core; intact portion of fuel pin swollen by 30%; boron in coolant at 3180 wppm.

[b] Boron remaining in U_3O_8-H_2O mixture.

Table 14. KENO-IV "Displaced-Fuel Slump" Disrupted Core[a]

Case Description	Multiplication Factor
A. Base configuration	0.845 ± 0.006
B. Case A with control rods out	0.870 ± 0.006
C. Case A with boron out[b]	1.080 ± 0.006

[a] Upper 50% of core collapsed as U_3O_8-H_2O mixture; corresponding portions of control and LBP rods missing; lower half of core in normal configuration; boron in coolant at 3180 wppm.

[b] Boron remaining in U_3O_8-H_2O mixture.

than 3% $\Delta k/k_1k_2$ which, although small, is substantially more than the corresponding value for the "Three Jump Slump" model (<2% $\Delta k/k_1k_2$). This difference is all the more remarkable because the "Three Jump Slump" model has 73 percent more intact control rod volume than does the "Displaced-Fuel Slump" model. Evidently, the neutron moderation level has a very strong effect upon the control rod worth.

The results from the analysis of the KENO-IV "In-Place Fuel Slump" model are given in Table 15. Here we have the variation of the system multiplication factor as the fuel is displaced downward in the pins and the clad expands to accommodate the increase in cross-sectional area. The water-to-fuel volume ratio varies from 1.65 for the as-built core to 0.31 for the case with the fuel pins touching. A new reactivity search technique[14] was used with these results to predict an optimum water-to-fuel volume ratio of 0.62. The maximum multiplication factor calculated in the study was 0.845 for the case in which the water-to-fuel volume ratio is 0.77. Both the system multiplication factor and the water-to-fuel volume ratio are in the range of the values calculated with the "Three Jump Slump" and the "Displaced-Fuel Models". The slightly lower water-to-fuel volume ratio corresponding to an equivalent multiplication factor with the "In-Place Fuel Slump" model is probably due to the presence of control and lumped burnable poison rods throughout this system. The fixed absorbers enhance the positive reactivity effect of spectral hardening. Indeed, the XSDRNPM lattice cell calculations do not include fixed absorbers and their results indicate a maximum system multiplication factor at a higher water-to-fuel volume ratio.

Table 15. KENO-IV "In-Place Fuel Slump" Disrupted Core[a]

Assumptions: Fuel stays at constant density (0.925 of theoretical);
Zr clad expands at constant volume;[b]
fuel height drops to conserve volume.

Swelling (% of Max)	Height (cm)	Fuel OD (cm)	Clad OD (cm)	Min. Gap between pins (cm)	KENO-IV k-eff[c]	XSDRNPM[d] Lattice k_∞
None	365.8	0.94	1.092	0.176	0.737±0.006	0.907
25%	290.0	1.056	1.179	0.132	0.807±0.006	0.980
50%	240.2	1.160	1.273	0.085	0.845±0.005	1.014
75%	205.2	1.255	1.360	0.042	0.840±0.006	1.005
100%	178.8	1.344	1.443	0.0	0.812±0.0073	0.950

[a] Boron at 3180 wppm, constant lattice pitch = 1.443 cm.

[b] Constant clad volume, interior radius increases.

[c] Clad, control rods & LBP rods above, core as normal.

[d] 2.57 wt % enriched UO_2 (core average).

VI. CONCLUSIONS

The significant results of the parametric studies, the benchmark critical analyses and the disrupted core analyses are summarized.

Parametric Studies--Infinite fuel-pin lattice and infinite fuel-coolant media analyses indicate that, while the fuel assemblies in unborated water are undermoderated, the high soluble boron content causes the shutdown configuration to be overmoderated. Therefore, core disruptive mechanisms which remove the coolant from the core introduce positive reactivity insertions. Core disruptive mechanisms introducing positive reactivity are:

1. Fuel pin lattice-pitch reduction,
2. Fuel pin swelling,
3. ZrO_2 in coolant channels, and
4. Fuel displacement into U_3O_8-H_2O + B mixtures.

At very low water-to-fuel volume ratios (<0.6 for 2400 wppm boron, <0.4 for 3180 wppm boron), the borated systems become undermoderated and any further ejection of the coolant reduces the system multiplication factor. As a limiting case, an infinite medium of dry $U(2.97)O_2$ has a multiplication factor of 0.66.

Benchmark Critical Analyses--The Three Mile Island Unit 2 reactor in a critical configuration at hot, zero-power startup was analyzed as a benchmark experiment. The results of this analysis validate the analytical methods used in this study for the following reasons:

1. The multiplication factor for the benchmark configuration agreed well with the expected value drawn from the analyses of similar critical experiments using the same transport programs and the multigroup, ENDF/B-IV based, neutron cross sections.

2. Good agreement was obtained between independent analyses of the benchmark configuration using the Monte Carlo transport programs MORSE-SGC/S and KENO-IV.

3. Good agreement was obtained between calculated control rod worths and those predicted by the Babcock and Wilcox Company.

4. Good agreement was obtained between calculated lumped burnable poison rod worths and those predicted by the Babcock and Wilcox Company.

Disrupted Core Analyses--The analysis of three disrupted core models and a cold shutdown, normal-core base case yielded several important considerations.

1. Positive reactivity insertions due to the various core disruptive mechanisms increased the system multiplication factor from approximately 0.74 to 0.86.

2. To a first order approximation, the increase in reactivity for the three models can be correlated with a decrease in the borated water-to-fuel volume ratio.

3. The reactivity worths of the control rods and the lumped burnable poison rods are significantly reduced by the high soluble boron content in the reactor.

4. The presence of fixed absorbers in the disrupted portions of the core significantly reduces the reactivity worth of the soluble boron.

5. The water-to-fuel volume ratio corresponding to the maximum system multiplication factor is influenced by neutron absorption due to either fixed absorbers or the soluble boron.

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APPENDIX A

Core Design Data

In order to provide a complete set of the information upon which this study was based, certain tables and figures were excerpted from the Final Safety Analysis Report for inclusion in this appendix.

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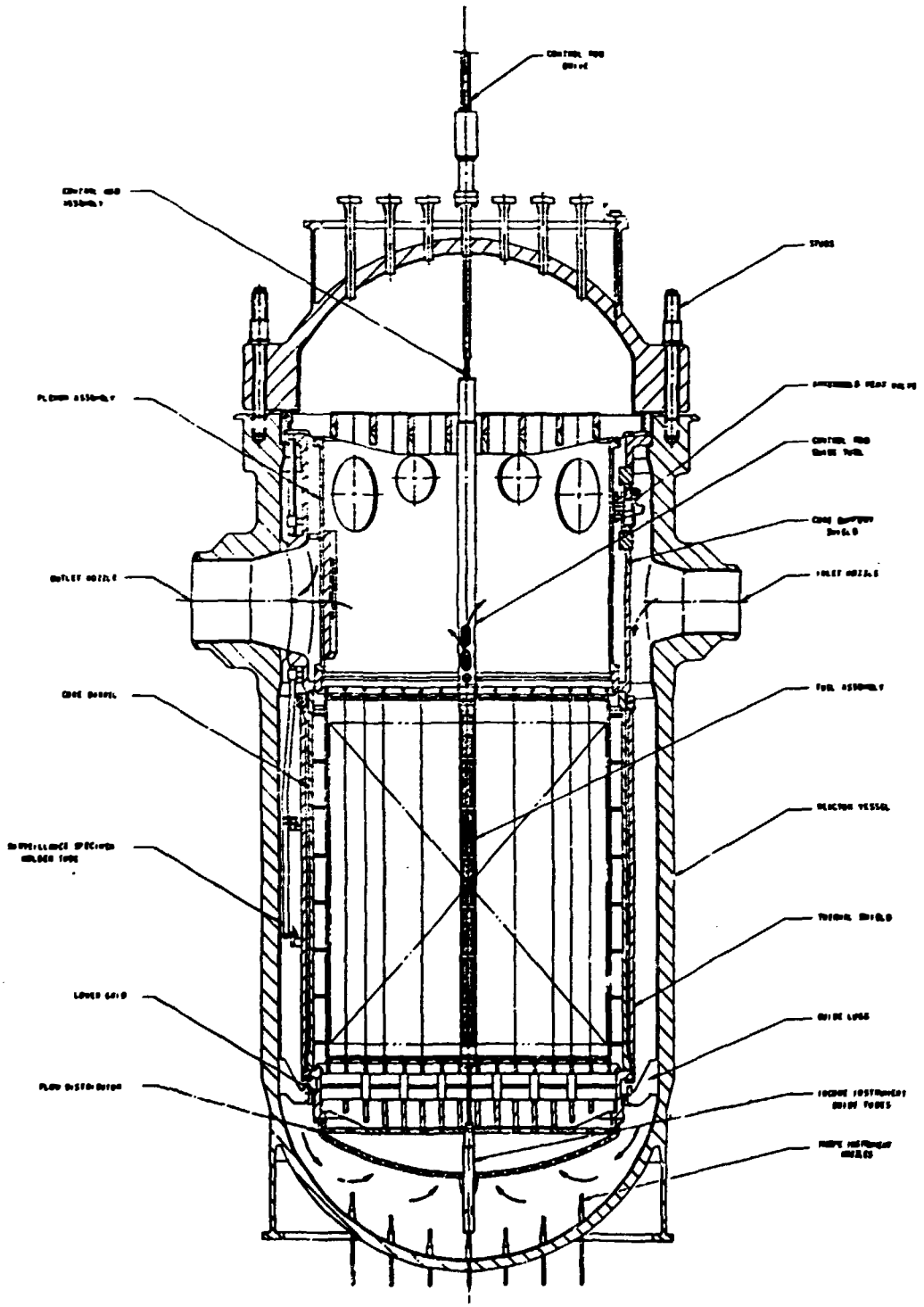


Fig. 4.2-3. Reactor Vessel and Internals — General Arrangement
Three Mile Island Nuclear Station Unit 2

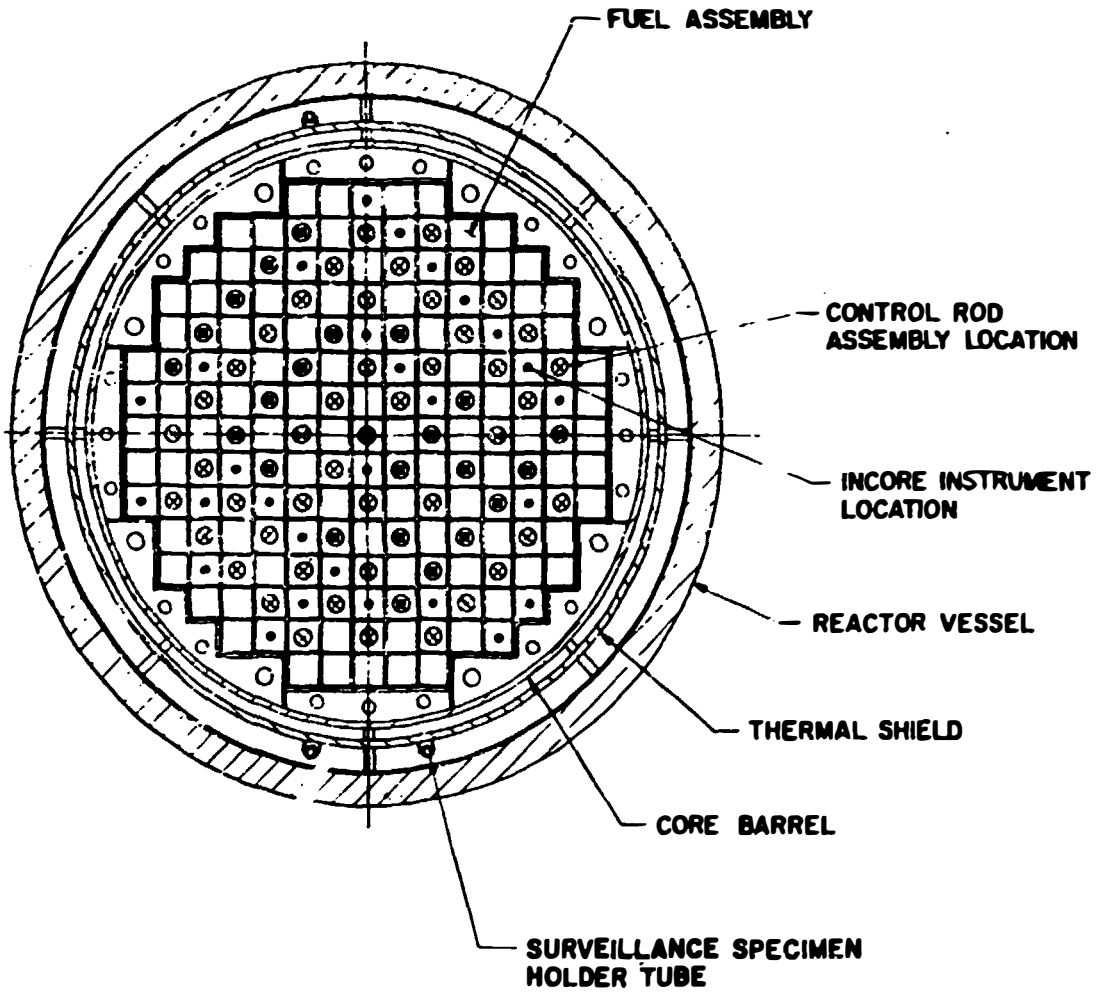
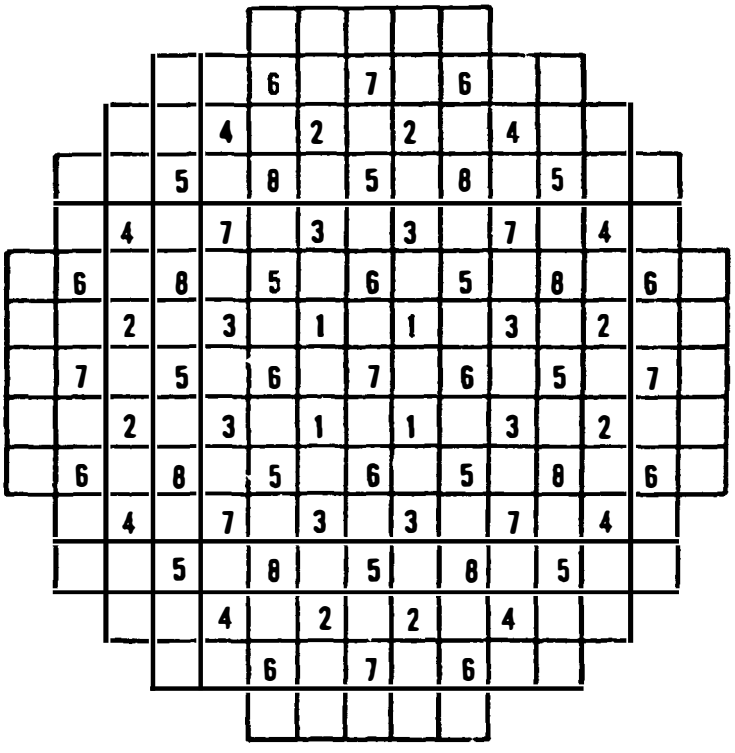


Fig. 4.2-4 Reactor Vessel and Internals Cross Section
Three Mile Island Nuclear Station Unit 2



Bank	No. Rods	Purpose
1	4	Safety
2	8	Safety
3	8	Safety
4	8	Safety
5	12	Regulating
6	12	Regulating
7	9	Regulating
8	8	APSR

Fig. 4.3-25. Rod Locations, 0-200 FPD Three Mile Island Nuclear Station Unit 2

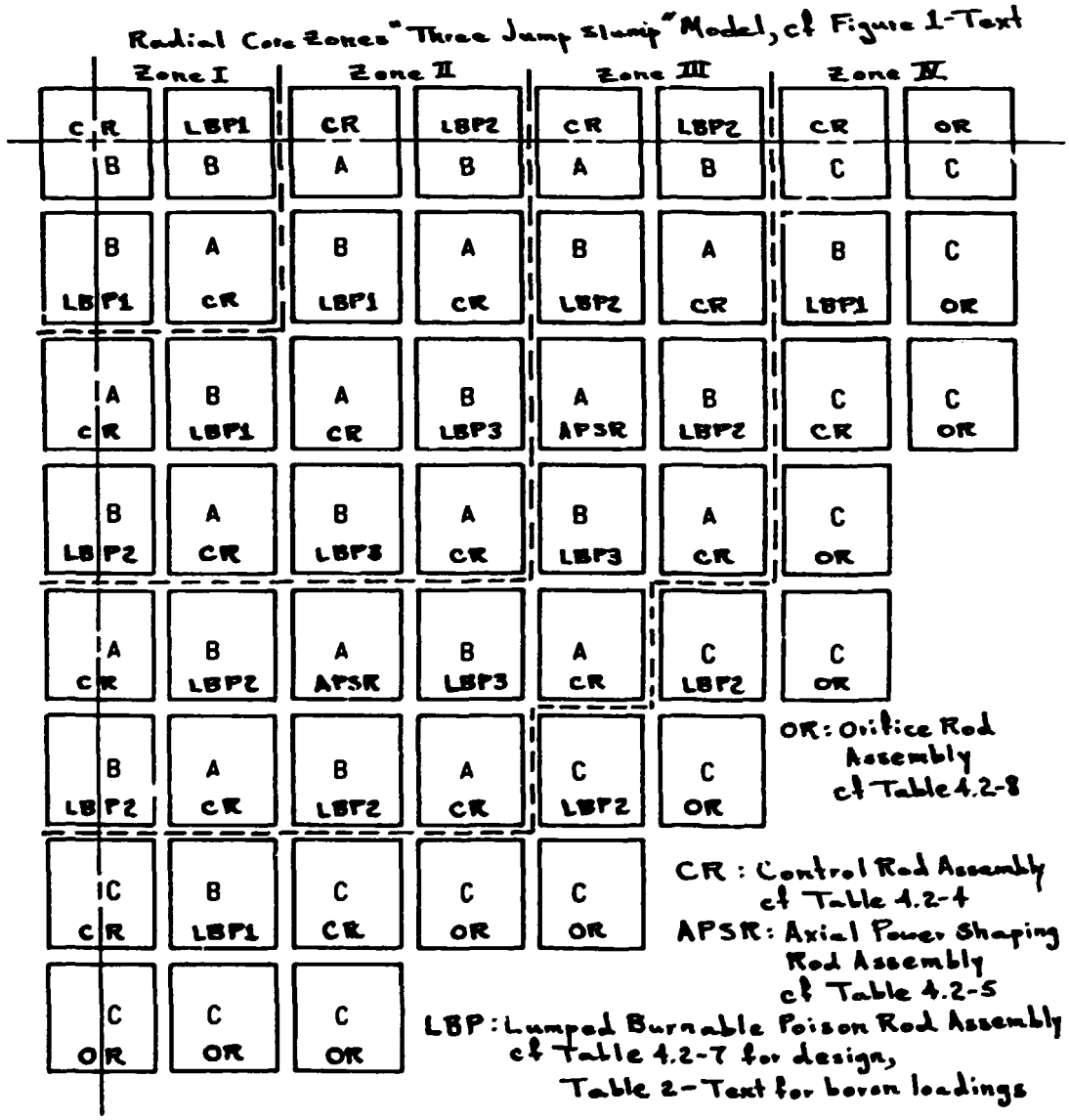


Fig. 4.3-1. Cycle One Fuel Loading Scheme
Three Mile Island Nuclear Station Unit 2

Table 4.3-1. Core Design Data

A.	Reactor	
1.	Design heat output, MWt	2772
2.	Vessel coolant inlet temperature, F	557
3.	Vessel coolant outlet temperature, F	607.7
4.	Core coolant outlet temperature, F	610.6
5.	Core operating pressure, psig	2185
B.	Core and Fuel Assemblies	
1.	Total No. of fuel assemblies in core	177
2.	No. of fuel rods per fuel assembly	208
3.	No. of control rod guide tubes per assembly	16
4.	No. of in-core instr. positions per fuel assembly	1
5.	Fuel rod outside diameter, in.	0.430
6.	Cladding thickness, in.	0.0265
7.	Fuel rod pitch, in.	0.568
8.	Fuel assembly pitch spacing, in.	8.587
9.	Unit cell metal/water ratio (volume basis)	0.82
10.	Cladding material	Zircaloy-4 (cold worked)
C.	Fuel	
1.	Material	UO_2
2.	Form	Dish-end, cylindrical pellets
3.	Pellet diameter, in.	0.370
4.	Active length, in.	144
5.	Density, % of theoretical	92.5

Table 4.3-2. Nuclear Design Data

Fuel Assembly Volume Fractions	
Fuel	0.303
Moderator	0.580
Zircaloy	0.102
Stainless steel	0.003
Void	0.012
	1.000
Total UO_2 (BOL)	
First core, $mtUO_2$	93.1
Core Dimensions	
Equivalent diameter, in.	128.9
Active height, in.	144.0
Unit Cell H_2O/U Atomic Ratio, Fuel Assembly	
Cold/hot	2.88/2.06
Full-Power Lifetime	
First cycle, days	421
Each succeeding cycle, days	284
Fuel Irradiation	
First cycle avg, MWd/mtU	14,220
Each succeeding cycle, MWd/mtU	9,600
Fuel Loading	
Core avg first cycle, wt% ^{235}U	2.57
Control Data	
Control rod material	Ag-In-Cd
No. of full-length CRAs	61
No. of APSRAs	8
Worth of 61 full-length CRAs, $(\Delta k/k)\%$	11.1
Control rod cladding material	SS304
No. of BPRAs	68 (first cycle only)
BPRA cladding material	Zircaloy-4, cold-worked
BPR poison material	B_4C in Al_2O_3

Table 4.2-1. Fuel Assembly Components, Materials and Dimensions

Item	Material	Dimensions, in.
Fuel Rod (208)		
Fuel	UO_2 sintered pellets (92.5% TD)	0.370 diameter
Cladding	Zircaloy-4	0.430 OD × 0.377 ID × 153.125 long
Fuel rod pitch	--	0.568
Active fuel length	--	144
Nom. fuel-cladding gap (BOL)	--	0.007
Ceramic spacer	ZrO_2	0.366 OD
Fuel Assembly		
FA pitch	--	8.587
Overall length	--	165.625
CR guide tube (16)	Zircaloy-4	0.530 OD × 0.016 wall
Instr tube (1)	Zircaloy-4	0.493 OD × 0.441 ID
End fittings (2)	SS (castings)	--
Spacer grid strips (8)	Inconel-718	--
Spacer sleeve (7)	Zircaloy-4	0.554 OD × 0.502 ID

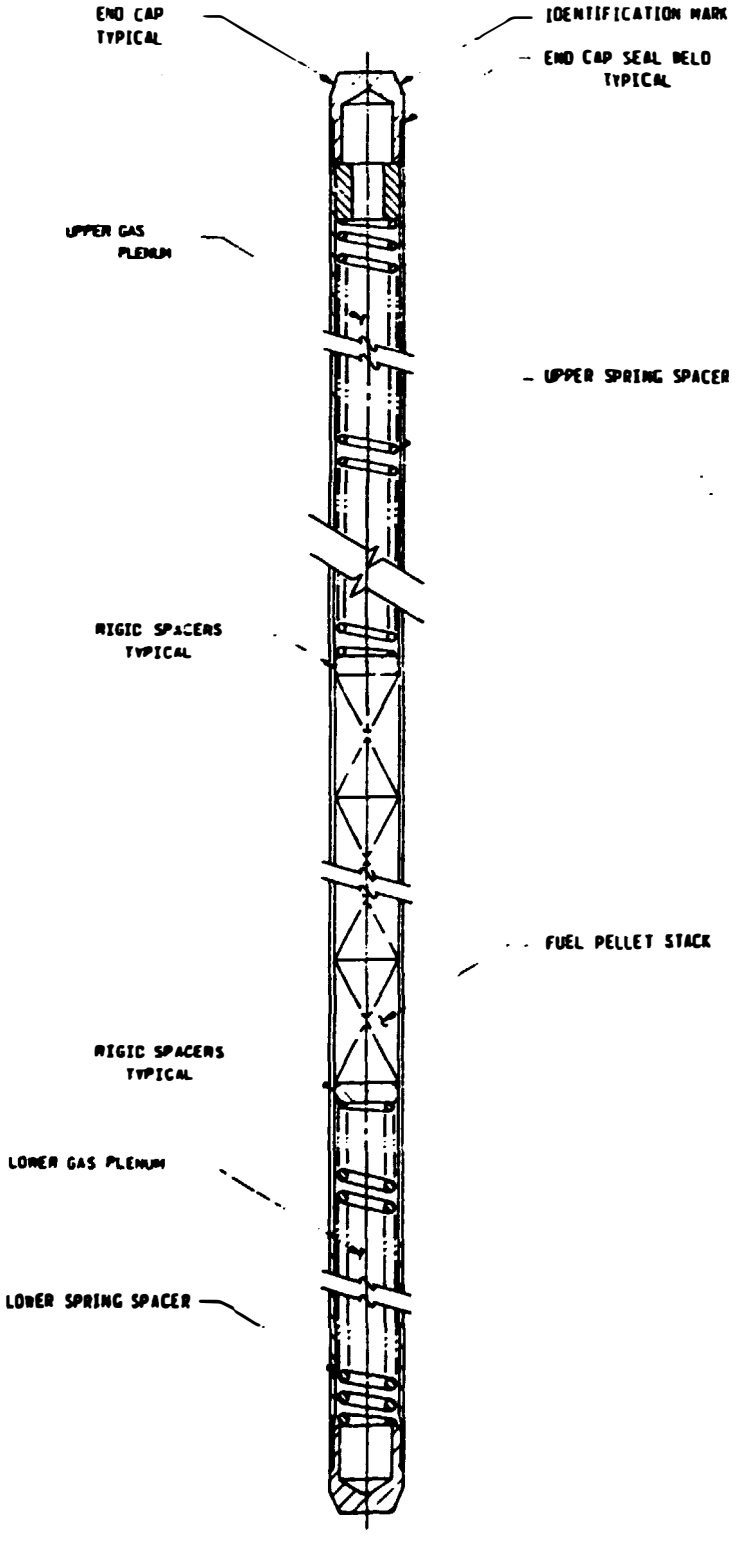


Fig. 4.2-2. Prepressurized Fuel Rod
Three Mile Island Nuclear Station Unit 2

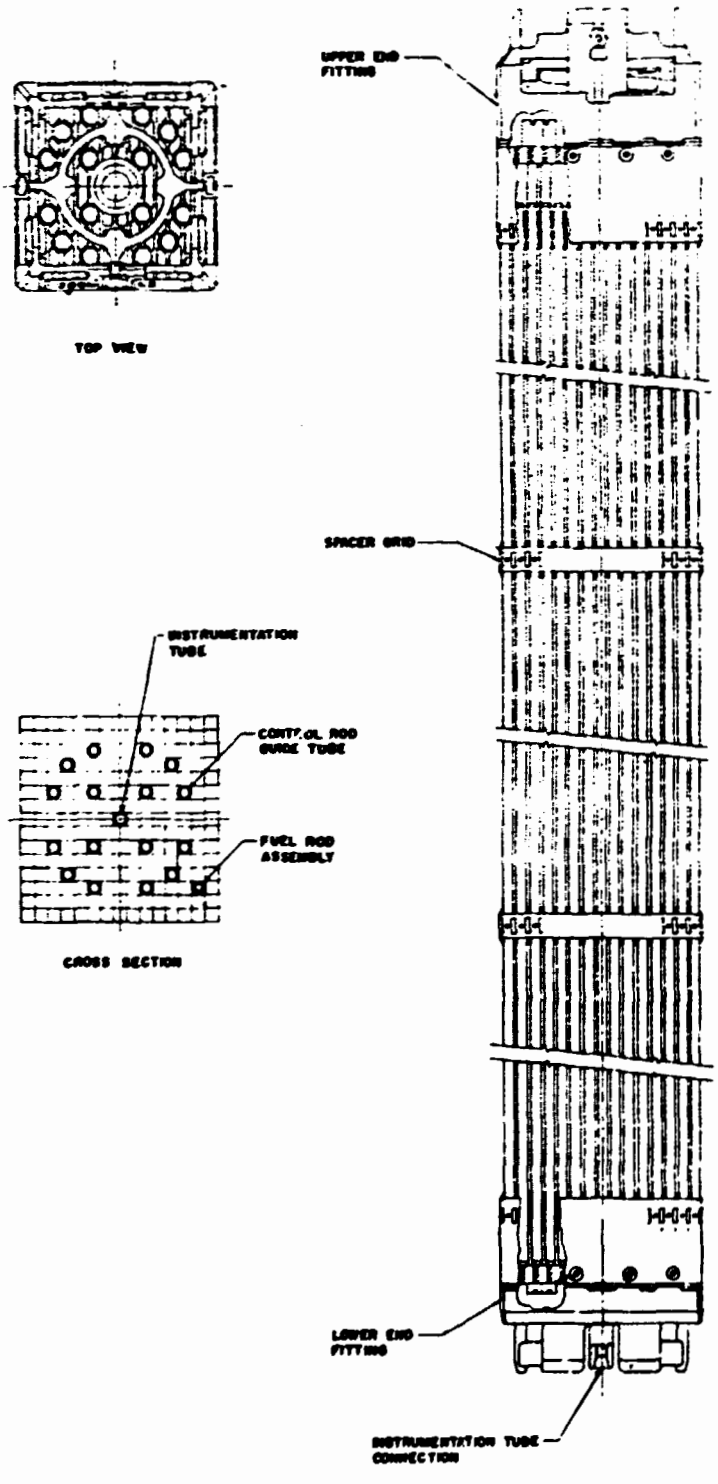


Fig. 4.2-1. Fuel Assembly
Three Mile Island Nuclear Station Unit 2

Table 4.2-4. Control Rod Assembly Data

Item	Data
Number of CRAs	61
Number of control rods per assembly	16
Outside diameter of control rod, in.	0.440
Cladding thickness, in.	0.021
Cladding material	304 SS, cold-worked
End plug material	304 SS, annealed
Spider material	SS grade CF3M
Poison material	80% Ag, 15% In, 5% Cd
Female coupling material	304 SS, annealed
Length of poison section, in.	134
Stroke of control rod, in.	139

Table 4.2-5. Axial Power Shaping Rod Assembly Data

Item	Data
Number of APSRAs	8
Number of APSR/assy	16
OD of APSR, in.	0.440
Cladding thickness, in.	0.021
Cladding material	304 SS, cold-worked
Plug material	304 SS, annealed
Poison material	80% Ag, 15% In, 5% Cd
Spider material	SS, grade CF3M
Female coupling material	304 SS, annealed
Length of poison section, in.	36
Stroke of APSR, in.	139

Table 4.2-6. Control Rod Drive Data

Item	Control	Axial power shaping
Number of drives	61	8
Type	Roller nut	Roller nut
Location	Top-mounted	Top-mounted
Direction of trip	Down	Does not trip
Maximum travel time for trip at full flow		
2/3 insertion, s	1.40	Does not trip
3/4 insertion, s	1.54	Does not trip
Length of stroke, in.	139	139
Design pressure, psig	2500	2500
Design temperature, F	450/650(a)	450/650(a)
Weight of mechanism, (approx), lb	940	940

(a) See 4.2.3.3.1.1

Table 4.2-7. Burnable Poison Rod Assembly Data

Item	Data
Number BPRA's	
First cycle	68
Equilibrium cycle	None
Number of burnable poison rods per assembly	16
Outside diameter of burnable poison rod, in.	0.430
Cladding thickness, in.	0.035
Cladding material	Zircaloy-4, cold-worked
End cap material	Zircaloy-4, annealed
Poison material	Al_2O_3-B_4C
Length of poison section, in.	126
Spider material	SS, grade CF3M
Coupling mechanism material	Type 304 SS, annealed and 17-4PH, condition H1100

Table 4.2-8. Orifice Rod Assembly Data

Item	Data
Number of ORA	97
First cycle	40
Equilibrium cycle	108
Number of OR/assy	16
OD of OR, in.	0.480
Orifice rod material	304 SS, annealed
Spider material	SS, grade CF3M
Coupling mechanism material	304 SS, annealed, and 17-4 PH, condition H1100

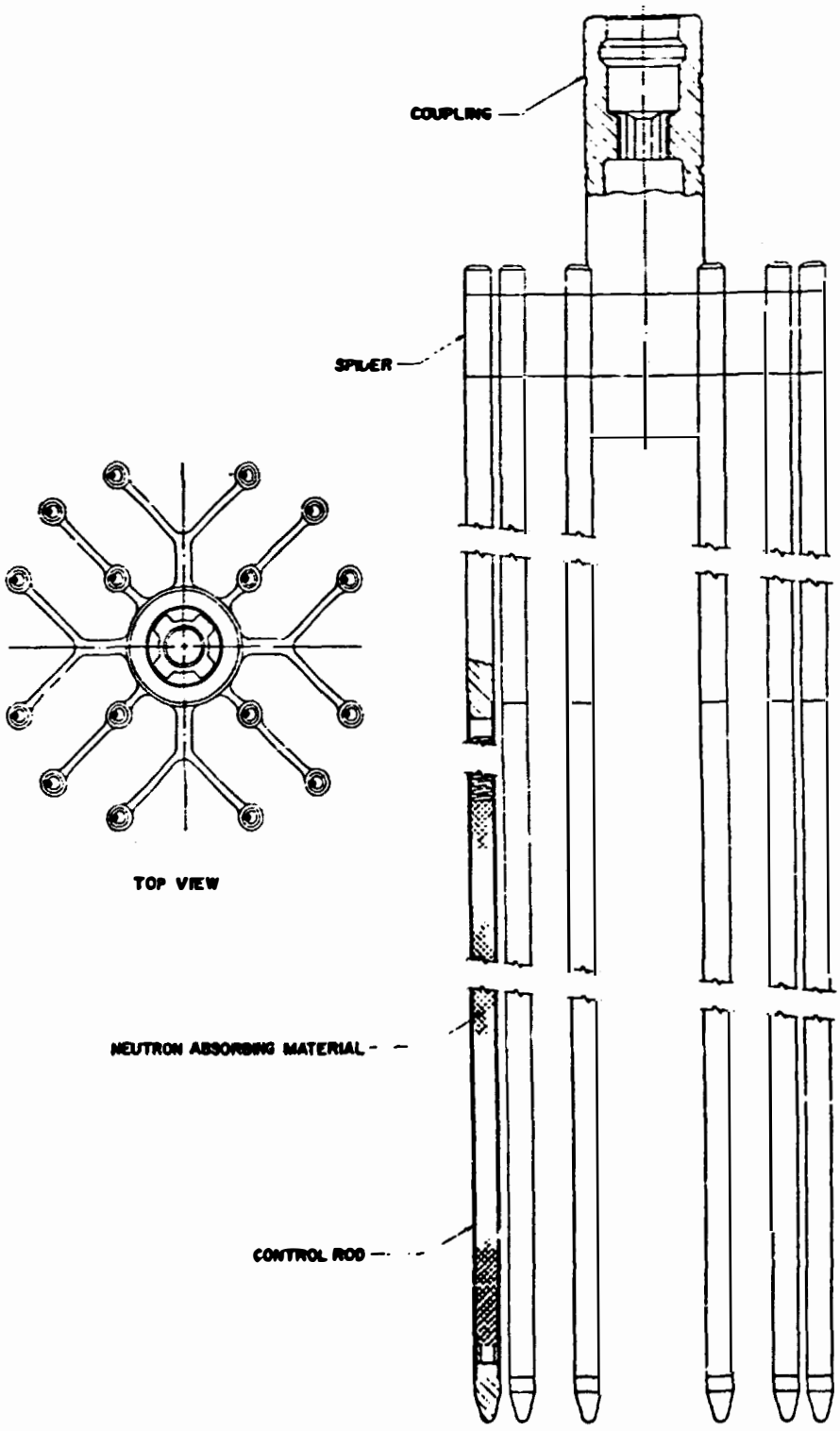


Fig. 4.2-8 Control Rod Assembly
Three Mile Island Nuclear Station Unit 2

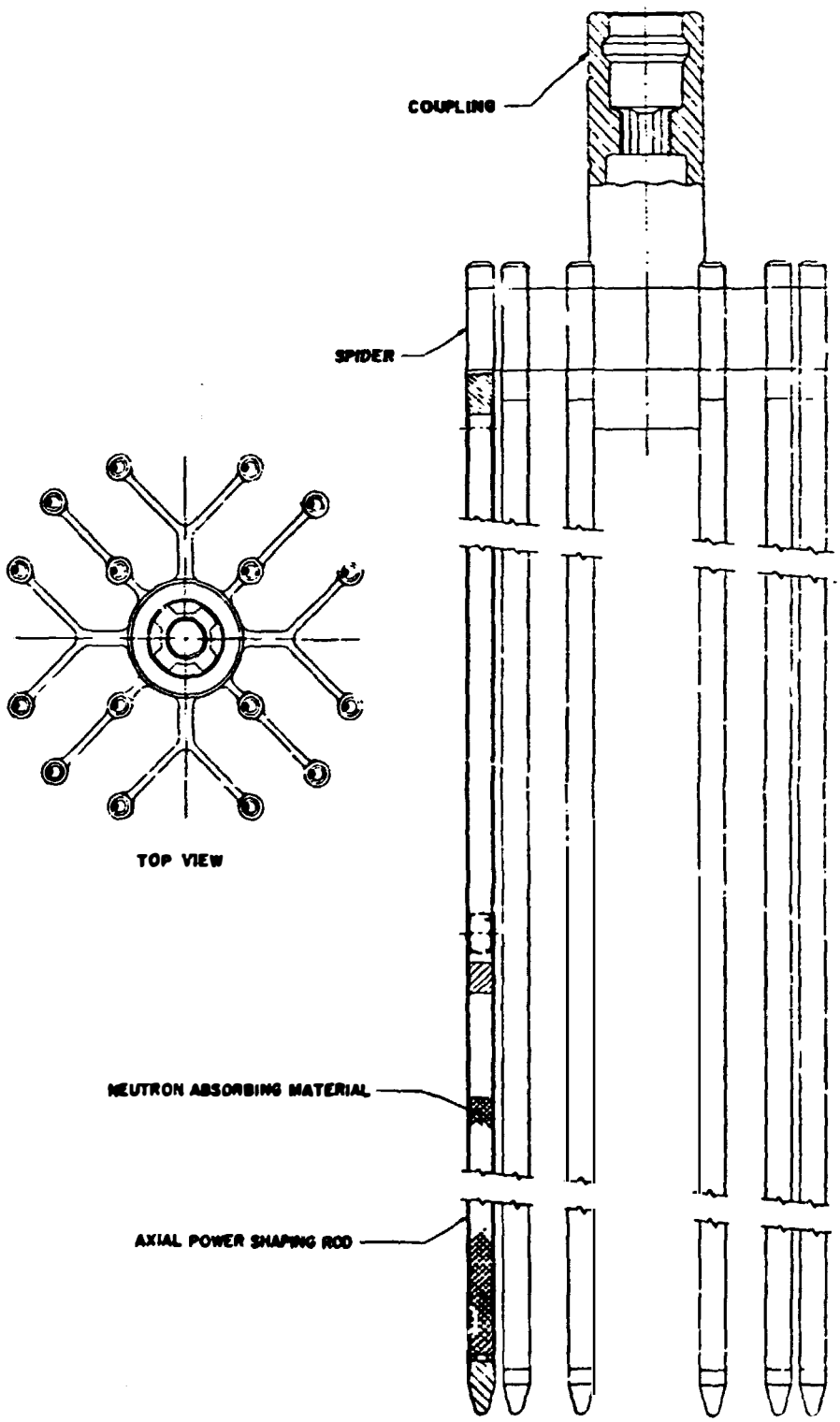


Fig. 4.2-9. Axial Power Shaping Rod Assembly
Three Mile Island Nuclear Station Unit 2

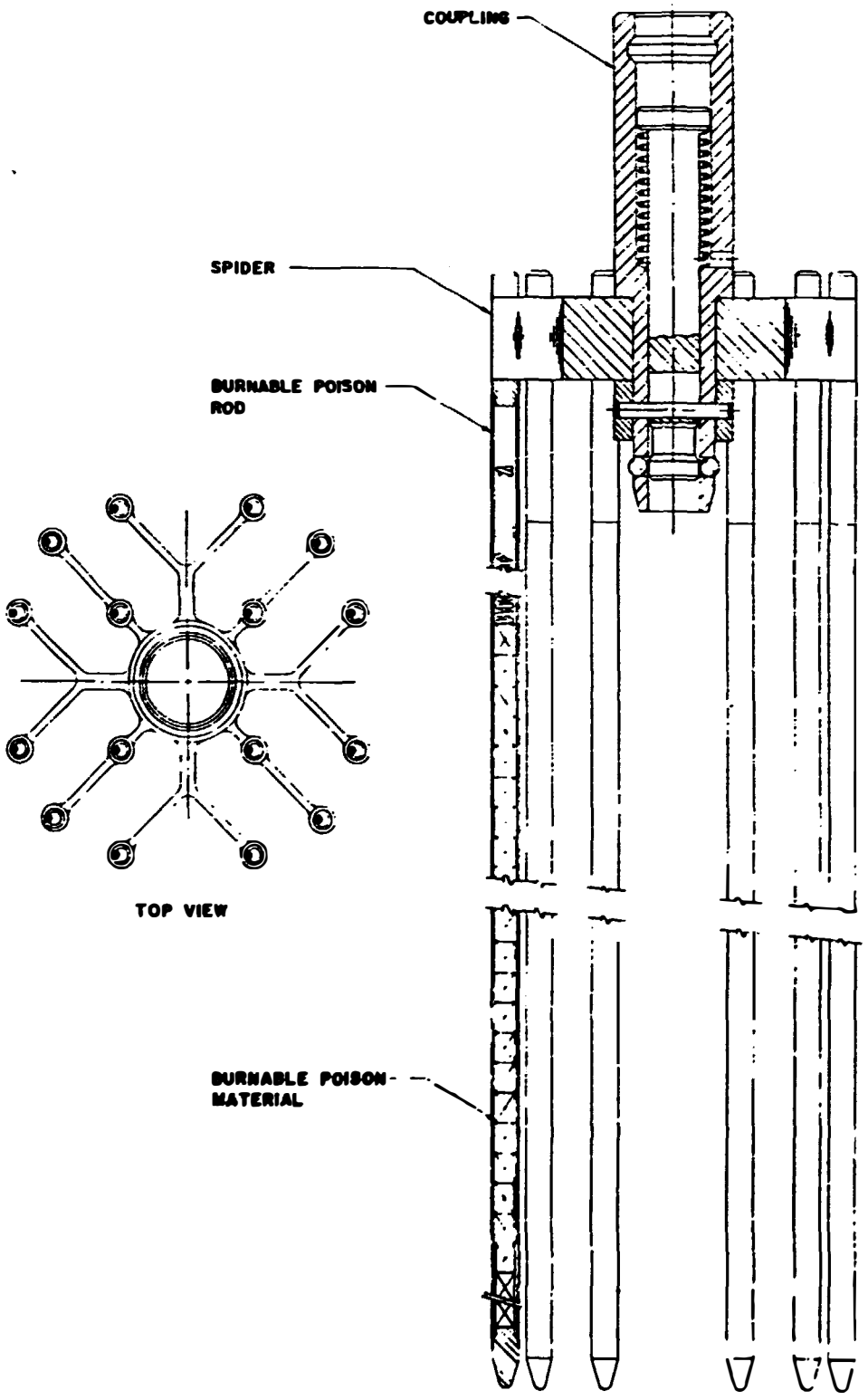


Fig. 4.2-12. Burnable Poison Rod Assembly
Three Mile Island Nuclear Station Unit 2

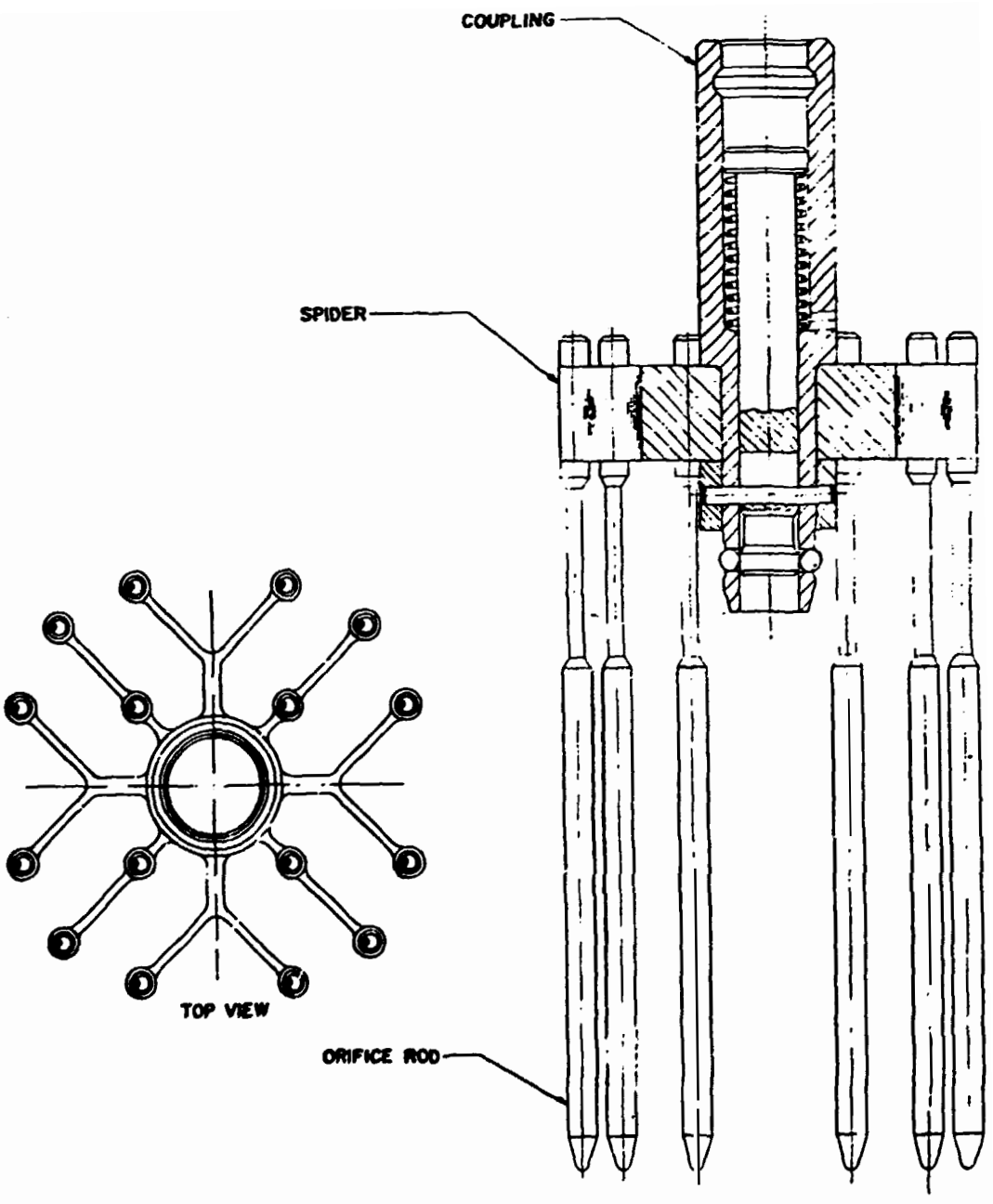


Fig. 4.2—13. Orifice Rod Assembly
Three Mile Island Nuclear Station Unit 2

Table 4.3-8. Excess Reactivity Conditions

Reactor core condtion[a]	k_{eff}
Cold, 70F, clean	1.252
Hot, 532F, clean, zero power	1.205
Hot, 584F, clean, full power	1.182
Hot, 584F, full power, equilibrium xenon and samarium	1.133
Single fuel assembly[b] (wet)	0.70
Two fuel assemblies[b] (wet)	1.014
Single fuel assembly[b] (dry)	0.03
Two fuel assemblies[b] (dry)	0.04
Cold array[c]	0.90

[a] First cycle at BOL, 68 BPRAs in core.

[b] Based on highest probable enrichment of 3.5 wt%.

[c] A center-to-center assembly pitch of 21 inches is required for this k_{eff} in cold, unborated water with no xenon or samarium.

Table 4.3-9. BOL First Cycle Reactivity Control Distribution

	Reactivity, %Δk/k
Controlled by Soluble Boron	
Moderator temp deficit (70 to 532F)	3.4
Equil Xe and Sm	3.5
Fuel burnup and fission product buildup	10.5
Transient Xe	1.0
Controlled by BPRAs	
Fuel burnup and fission product buildup	4.4
Controlled by Movable CRAs	
Doppler deficit (0 to 2772 MWt)	1.2
Moderator temp deficit (532 to 584F)	0.0
Dilution control	0.2
Shutdown margin	1.0
Xenon undershoot	0.4

Table 4.3-11. Soluble Boron Levels and Worth — First Cycle

Core Conditions	BOL Boron Level, ppm
70F, k_{eff} = 0.99	
No CRAs in	1582
All CRAs in	1057
One stuck CRA (full out)	1327
532F, 0 power, k_{eff} = 0.99	
No CRAs in	1710
All CRAs in	741
One stuck CRA (Full out)	1083
584F, rated power, k_{eff} = 1.00	
No CRAs in	1540
584F, rated power, equil Xe and Sm, k_{eff} = 1.00	
No CRAs in	1175
Boron worth, (%Δk/k)/ppm	
584F, rated power	1/100
70F, zero power	1/75

Table 4.3-12. Control Rod Worths

Group number	Purpose	No CRA's	Sequential worth, %Δk/k BOL	Sequential worth, %Δk/k EOL
Worth at Full Power				
1	Safety	4	0.5	0.3
2	Safety	8	2.2	1.9
3	Safety	8	1.5	1.4
4	Safety	8	1.2	2.1
5	Reg.	12	2.4	1.8
6	Reg.	12	1.8	1.6
7	Reg.	9	1.5	1.0
	Totals	61	11.1	10.1
Maximum stuck rod worth			3.6	2.0
Maximum ejected rod worth			0.31	0.19
Worth at Hot Zero Power				
1	Safety	4	0.5	0.3
2	Safety	8	2.1	1.8
3	Safety	8	1.4	1.3
4	Safety	8	1.1	2.0
5	Reg.	12	2.3	1.7
6	Reg.	12	1.7	1.5
7	Reg.	9	1.4	1.0
	Totals	61	10.5	9.6
Maximum ejected rod worth			0.58	0.47
Worth at Cold Conditions, 70F				
1	Safety	4	0.3	0.2
2	Safety	8	1.4	1.2
3	Safety	8	1.0	0.9
4	Safety	8	0.8	1.4
5	Reg.	12	1.5	1.2
6	Reg.	12	1.2	1.0
7	Reg.	9	1.0	0.7
	Totals	61	7.2	6.6

APPENDIX B

MORSE-SGC/S Input Procedures

Copies of the card image input and certain input edits for the MORSE-SGC/S "Three Jump Slump" disrupted core model analysis are presented here. The primary purpose of this appendix is to provide an example of how arrays are nested using the MARS (Multiple Array System) in MORSE-SGC/S. Similar sets of input were prepared for the MORSE-SGC/S analyses of the benchmark critical configuration and the cold shutdown configuration. Of particular interest in this input procedure is the creation of fuel assemblies from combinatorial geometry input zones followed by the combination of fuel assemblies to form the reactor core. Through the MARS universe specifications, the base level or "null universe" consists of the entire system. This includes the U_3O_8-H_2O + B mixture as an input zone and the reactor core as a truncated array. In turn, this truncated array contains the fuel assembly arrays defined as universes with negative identification numbers. The various items in this procedure are indicated in the following list:

Item	Cards	Page
MORSE-SGC/S Control Parameters	1-6	B3
Combinatorial Geometry Bodies	9-48	B3
Combinatorial Geometry Input Zones (Note U_3O_8-cards 143, 144; RPP's 16-18, 37-40)	50-146	B4
MARS Universe Specifications	149	B5
Media Numbers	150-153	B5

Item	Cards	Page
Array Size Specifications (Note 15 x 15 x 7 for array 14, reactor core)	154-155	B5
13 Fuel Assembly Arrays (15 x 15 x 1)	156-187	B5
Seven 15 x 15 Arrays for Axial Levels in Core	188-279	B6
MORSE-SGC/S Starting Parameters	280	B7
Splitting and Russian Roulette Parameters	281	B7
Mixing Table for Macroscopic Constants	282-295	B7
Fission Neutron Energy Distribution	296-300	B7
MORSE-SGC/S Edit of Control Parameters		B7
Printer Plots of 13 Fuel Assembly Arrays (Each symbol denotes a pin type)		B8-B14
Printer Plots of 7 Axial Levels in Core (Each negative symbol denotes a fuel assembly array, note disrupted region in levels 5, 6, and 7)		B15-B18

```
                                THE FOLLOWING IS A LIST OF CARD IMAGE INPUT
CARD NO.                                    C O L U M N
         1111111112222222223333333333444444444455555555556666666667777777778
123456789012345678901234567890123456789012345678901234567890123456789012345678
    1    TPI CRITICAL SILDIES, JIM WEST, ORAL
    2        0144230400132
    3    1R1 0 300 350-163 1-0-0 1 1 0-0 0-4 1
    4    2R1 13 48 0 1 1
    5    3R1 27 6R0 4 2 27 0 1 4P0 14 0 0 11
    6    4R1 0 27 0 1 5R5 0 0 0 0 0 0 0 4 4R1 16R0    T
    7    TP1 DISPLACED CORE POCEL, JIM WEST, ORAL
    8    200 TGO
    9    RCC    500.0 52.251428575  0.5385
   10    RCC    500.0 52.251428575  0.5367
   11    RCC    500.0 52.251428575  0.5065
   12    RPP    -0.72703 0.72703 -0.72703 0.72703 0.0 52.251428575
   13    RPP    -1.0E+10 1.0E+10 -1.0E+10 1.0E+10 -1.0E+10 1.0E+10
   14    RCC    500.0 52.251428575  0.45720
   15    RCC    500.0 52.251428575  0.50812
   16    RCC    500.0 52.251428575  0.55900
   17    RCC    500.0 52.251428575  0.61214
   18    RCC    500.0 52.251428575  0.63244
   19    RCC    500.0 52.251428575  0.67316
   20    RCC    500.0 52.251428575  0.56007
   21    RCC    500.0 52.251428575  0.62611
   22    RCC    500.0 52.251428575  0.60960
   23    RPP    -10.905469 10.905469 -10.905469 10.905469 0.0 52.251403
   24    RPP    -76.338150 76.338150 -119.559695 119.559695 313.5085714 400.0
   25    RPP    -119.559695 119.559695 -76.338150 76.338150 313.5085714 400.0
   26    RPP    -98.149050 98.149050 -98.149050 98.149050 313.5085714 400.0
   27    RPP    -163.581175 -163.581175 -163.581175 -163.581175 0.0 365.76
   28    RPP    -165.48735 165.48735 -165.48735 165.48735 0.0 365.76
   29    RPP    -163.581175 163.581175 -54.52725 54.52725 -100.0 400.0
   30    RPP    -165.48735 165.48735 -56.43245 56.43245 0.0 365.76
   31    RPP    -141.77685 141.77685 -98.149505 98.149505 -100.0 400.0
   32    RPP    -143.67637 143.67637 -100.05441 100.05441 0.0 365.76
   33    RPP    -119.559695 119.559695 -119.559695 119.559695 -100.0 400.0
   34    RPP    -121.86539 121.86539 -121.86539 121.86539 0.0 365.76
   35    RPP    -98.149505 98.149505 -141.77685 141.77685 -100.0 400.0
   36    RPP    -100.05441 100.05441 -143.6763 143.6763 0.0 365.76
   37    RPP    -54.52725 54.52725 -163.58175 163.58175 -100.0 400.0
   38    RPP    -56.43245 56.43245 -165.48735 165.48735 0.0 365.76
   39    RCC    0.0 0.0 -100.0 0.0 0.0 600.0 179.07
   40    RCC    0.0 0.0 -100.0 0.0 0.0 600.0 184.15
   41    RCC    0.0 0.0 -100.0 0.0 0.0 600.0 189.69
   42    RCC    0.0 0.0 -100.0 0.0 0.0 600.0 191.77
   43    RCC    0.0 0.0 -100.0 0.0 0.0 600.0 217.17
   44    RCC    0.0 0.0 -100.0 0.0 0.0 600.0 239.17
   45    RPP    -500.0 500.0 -500.0 500.0 330.9257 400.0
   46    RPP    -500.0 500.0 -500.0 500.0 349.3028 400.0
   47    RPP    -32.716350 32.716350 -32.716350 32.716350 205.0067143 400.0
   48    RPP    -76.338150 76.338150 -76.338150 76.338150 281.257142  400.0
   49      END
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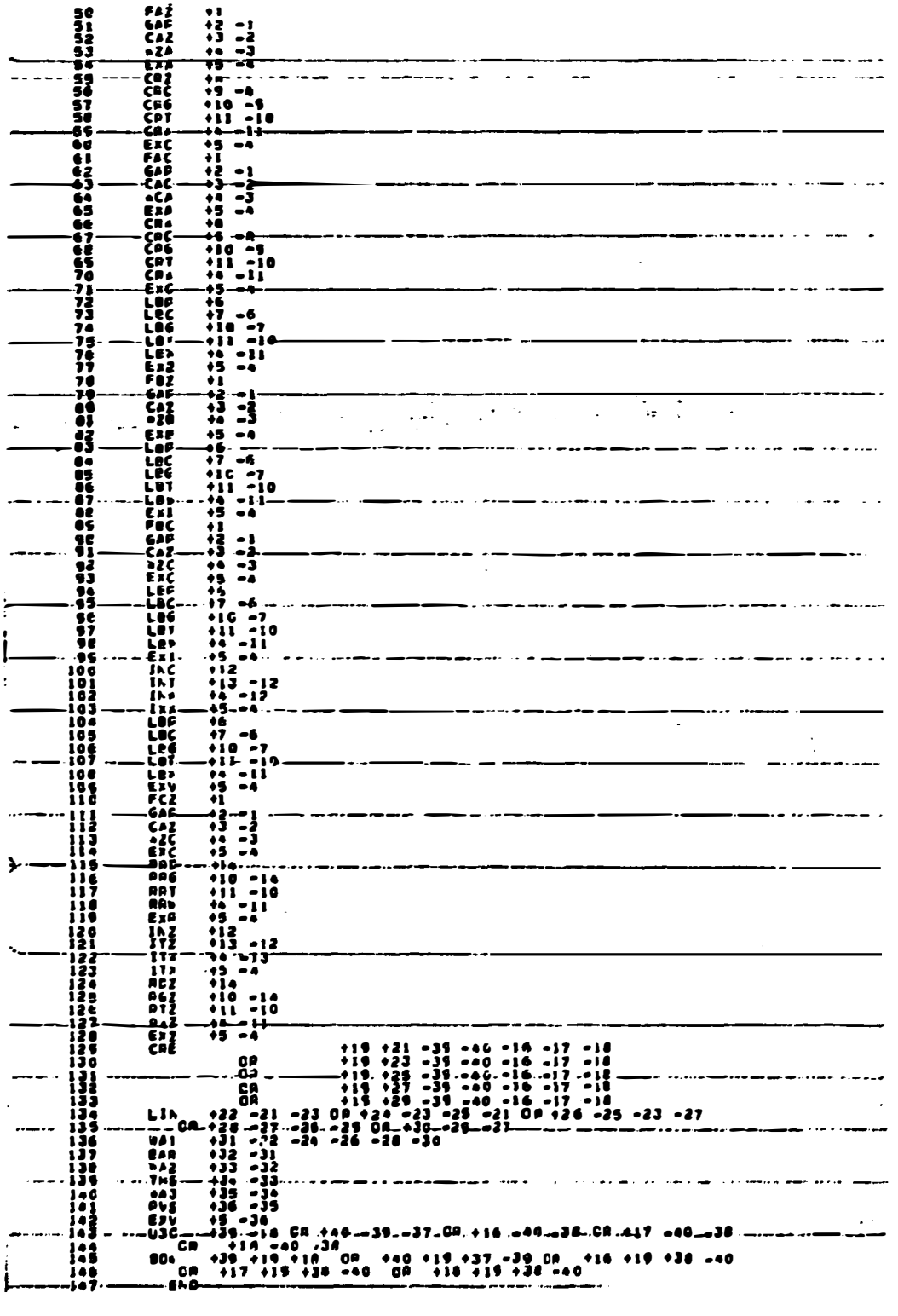
MORSE-SGC/S Control Parameters

and

Combinatorial Geometry Bodies



Combinatorial Geometry Input Zones

```
148     9601
149     601 602 603 604 605 606 607 608 609 6010 6011 6012 6013 6014 6015 1100
150     12 6 4 6 -1000 5 10 6 4 6 -1000 3 5 4 5 -1000 9 16 5 4 5 -1000
151     7 4 6 4 4 -1000 13 6 4 6 -1000 8 4 4 4 6 -1000 2 5 4 5 -1000
152     8 4 5 4 5 -1000 5 4 5 -1000 7 4 6 4 5 -1000 1 5 4 5 -1000
153     10 5 4 5 -1000 6 4 6 -1000 10 6 4 6 -1000 -14 16 5 10 5 10 5 10 6 11 5
154     15 15 1 15 15 1 15 15 1 15 15 1 15 15 1 15 15 1 15 15 1 15 15 1 15 15 1
155     15 15 1 15 15 1 15 15 1 15 15 1 15 15 7 6 6
156     3501 2 301 2 801 2 701 2 2001 2 201 2 301 2 201 2 2001 10 2001 2 201 2
157     301 2 201 2 2001 2 701 2 801 2 301 2 3501
158     3503 4 303 4 803 4 703 4 2003 4 203 4 303 4 203 4 2003 10 2003 4 203 4
159     303 4 203 4 2003 4 703 4 803 4 303 4 3503
160     3503 13 303 13 803 13 703 13 2003 13 203 13 303 13 203 13 2003 10 2003
161     13 203 13
162     303 13 203 13 2003 13 703 13 803 13 303 13 3503
163     3506 7 306 7 806 7 706 7 2006 7 206 7 306 7 206 7 2006 14 2006 7 206 7
164     306 7 206 7 2006 7 706 7 806 7 306 7 3506
165     3508 9 308 9 808 9 708 9 2008 9 208 9 308 9 208 9 2008 10 2008 9 208 9
166     308 9 208 9 2008 9 708 9 808 9 308 9 3508
167     3506 5 306 5 806 5 706 5 2006 5 206 5 306 5 206 5 2006 14 2006 5 206 5
168     306 5 206 5 2006 5 706 5 806 5 306 5 3506
169     3508 11 308 11 808 11 708 11 2008 11 208 11 308 11 208 11 2008 10 2008
170     11 208 11
171     308 11 208 11 2008 11 708 11 808 11 308 11 3508
172     3508 4 308 4 808 4 708 4 2008 4 208 4 308 4 208 4 2008 10 2008 4 208 4
173     308 4 208 4 2008 4 708 4 808 4 308 4 3508
174     3506 2 306 2 806 2 706 2 2006 2 206 2 306 2 206 2 2006 14 2006 2 206 2
175     306 2 206 2 2006 2 706 2 806 2 306 2 3506
176     30012 13 3012 13 8012 13 7012 13 20012 13 2012 13 3012 13 2012 13
177     20012 10 20012 13 2012 13
178     3012 13 2012 13 20012 13 7012 13 8012 13 3012 13 35012
179     35012 4 3012 4 8012 4 7012 4 20012 4 2012 4 3012 4 2012 4 20012
180     10 20012 4 2012 4
181     3012 4 2012 4 20012 4 7012 4 8012 4 3012 4 35012
182     35012 11 3012 11 8012 11 7012 11 20012 11 2012 11 3012 11 2012 11
183     20012 10 20012 11 2012 11
184     3012 11 2012 11 20012 11 7012 11 8012 11 3012 11 35012
185     3501 15 301 15 801 15 701 15 2001 15 201 15 301 15 201 15 2001 14 2001
186     15 201 15
187     301 15 201 15 2001 15 701 15 801 15 301 15 3501
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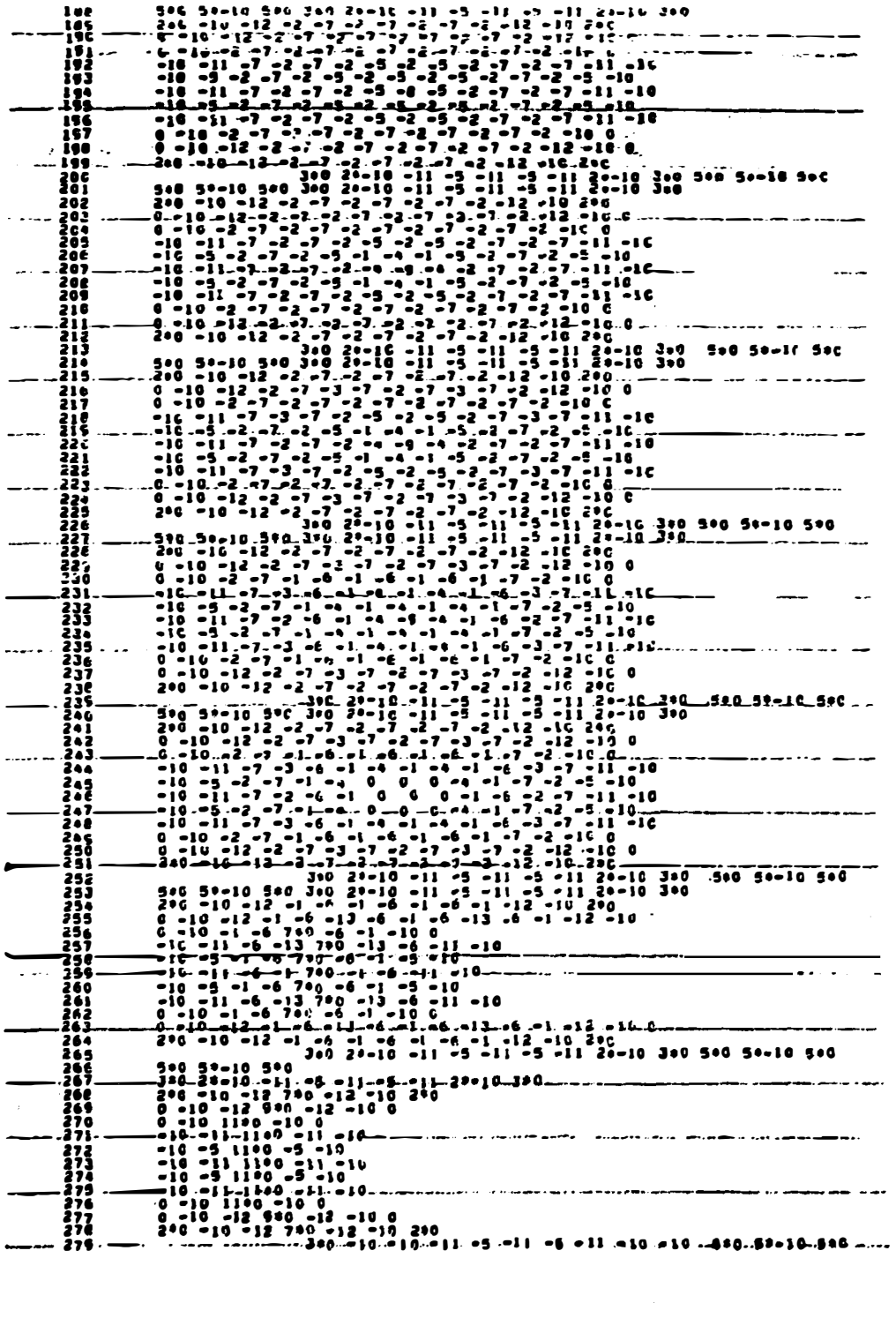
Cards

149	MARS Universe Specifications
150-153	Media Numbers
154-155	Array Size Specifications
156-187	13 Fuel Assembly Arrays (15x15x1)



Axial Levels in Core

```
280      600  0.0 0.0 1.0 0.0 -170.0 170.0 -170.0 170.0 0.0 370.0
281      800 27R1.5 27RC.167 27RC.50 27R0.0
282      1255
283      1 2 3 11 1 2 3 11 . 2 3 5 6 7 8 11 5 6 7 8 11 5 6 11.7 .
284      8 7 8 CR6 4R10 13 12 13 12
285      1355
286      92235 2 2 4 3699238 8 8R801E 403G2 403021 585G1C 585G11 361001
287      2R8012 8E13627 471.7 47109 486.6 49113 49115 50360 25655 26360 283C0
288      21 31 9223M1 9223P1
289      1400
290      5.220-4 4.656-4 3.452-4 2.633-4 1.656-2 1.695-2 1.707-2 1.108-2 4.817-2
291      4.817-2 4.817-2 3.338-2 4.134-2 6.478-2 6.48R-2 4.CRC-2 4.252-2
292      9.472-3 3.638-5 2.37C-5 3.EAU-4 3.163-4 1.167-5 1.418-4 5.510-5
293      1.456-3 1.375-3 4.428-5 5.R7C-2 4.450-2 2.C5C-2 5.167-4 4.233-4 4.317-2
294      4.326-2 2.374-2 2.165-2 2.725-3 3.472-4 7.655-3 1.742-2 1.736-3
295      5.636-2 7.721-3  4.65C-4 3.492-4 1.665-2 1.767-2
296      1700 2.1073PE-02 1.R830E-01 2.1485?E-VI 1.2453?E-01 1.6E156E-01
297       1.8VA7?E-01 R.9651?E-02 1.3R+65E-02 1.0?555E-03 7.AL5P5E-05 5.R70?8E-06
298       4.12M43E-07 R.5555?E-08 1.295?1?E-08 1.?6?1EE-09 4.311C5E-10 1.3?E37E-10
299      9.6M033E-11 1.A?9395E-10 2.2?9?5E-10 3.3?0EEE-11 3.R80E0E-11 3.71G47E-11
300       1.G0995E-11 2.65R?5E-12 2.C733?E-12 4.94C27E-13
301        T
302        TITLE AA
303      TITLE BB
304      TITLE CC
305      1500   T
```

END OF CARD INPUT LIST

Cards

280	MORSE-SGC/S Starting Parameters
281	Splitting and Russian Roulette Parameters
282-295	Mixing Table for Macroscopic Constants
296-300	Fission Neutron Energy Distribution

TPI CRITICAL STUDIES, JIM WEST, CRAL — CB/

1 S ARRAY

IADJM	ADJOINT INDICATOR	0	NSPLT	SPLITTING INDICATOR	
NSTAT	NUMBER OF PARTICLES PER BATCH	300	NRULL	RUSSIAN ROULETTE INDICATOR	
NPCST	MAX NUMBER OF PARTICLES ALLOWED	350	NEAST	EXPONENTIAL TRANSFORM INDICATOR	
NITS	NUMBER OF BATCHES	103	NOLEAK	NON-LEAKAGE INDICATOR	
NSLIT	NUMBER OF SETS OF BATCHES	1	IEBIAS	ENERGY BIAS INDICATOR	
NCOLTP	COLLISION TAPE INDICATOR	0	NRCALC	BATCH USED IN RECALCULATION	
ISTAT	INDICATOR TO STORE LEGENDRE COEFF	0	NORMF	NORMALIZATION INDICATOR	

2 S ARRAY

NECIA	NUMBER OF CROSS SECTION MEDIA	13	NXREG	NUMBER OF REGIONS	
NMIX	NUMBER OF MIXING OPERATIONS	48	NFISTG	FISSION INDICATOR	
NECALB	ALBEDO INDICATOR	0			

3 S ARRAY

NNGA	NUMBER OF N-GRPS TO ANALYZE	27	ISTR	PRINT CROSS SECTIONS AS STORED	
NGGA	NUMBER OF G-GRPS TO ANALYZE	0	IPPU	PRINT RESULTS OF MU CALC	
NNGTP	COMPLETELY COUPLED INDICATOR	0	INCM	PRINT MOMENTS	
NDSN	NUMBER OF N DOWNSCATTERS	0	IPRIN	PRINT ANGLES AND PROB	
NDSG	NUMBER OF G DOWNSCATTERS	0	IPUN	PRINT BAD COEF RESULTS	
NCOEF	NUMBER OF COEFFICIENTS	4	IXTAPE	INPUT LOGICAL TAPE UNIT	
NSCT	NUMBER OF DISCRETE ANGLES	2	JXTAPE	OUTPUT LOGICAL TAPE UNIT	
NANGP	LAST GP FOR NO SPLITTING OR XMOM	27	IGGR	CCR LOGICAL TAPE UNIT	
IPCSG	PRINT CROSS SECTIONS AS GRAY	0	IGGPT	LAST CCR GROUP	
NGCRT	EXTRA NEUTRON GROUP CRITER	0	IGGGP1	EXTRA GAMMA GROUP CRITER	

MORSE-SGC/S Edit of Control Parameters

OPTION 0 WAS USED IN CALCULATING VOLUMES FOR 1 REGIONS
0-SET VOLUMES = 1, 1-CONCENTRIC SPHERES, 2-SLABS, 3-INFINICYLINDERS.

VOLUMES (CC) USED IN COLLISION DENSITY AND TRACK LENGTH ESTIMATORS.

REG	1
VOLUME	1.0000E+00

ARRAY NO. 1 ARRAY SIZE IS 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 1

Y \ X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	2	1	1	1	2	1	1	1	1	1
12	1	1	1	3	1	1	1	1	1	1	1	2	1	3	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	2	1	1	2	1	1	1	2	1	1	2	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	10	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	2	1	1	2	1	1	1	2	1	1	2	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
3	1	1	1	1	1	2	1	1	1	2	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fuel Assembly Arrays

ARRAY NO. 2 ARRAY SIZE IS 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 2

Y \ X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
14	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
13	3	3	3	3	3	4	3	3	3	4	3	3	3	3	3
12	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3
11	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
10	3	3	4	3	3	4	3	3	3	4	3	3	4	3	3
9	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
8	3	3	3	3	3	3	3	10	3	3	3	3	3	3	3
7	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
6	3	3	4	3	3	4	3	3	3	4	3	3	4	3	3
5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3
3	3	3	3	3	3	4	3	3	3	4	3	3	3	3	3
2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

ARRAY NO. 3 ARRAY SIZE IS 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 3

Y \ X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
14	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
13	3	3	3	3	3	13	3	3	3	13	3	3	3	3	3
12	3	3	3	13	3	3	3	3	3	3	13	3	3	3	3
11	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
10	3	3	13	3	3	13	3	3	3	13	3	3	13	3	3
9	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
8	3	3	3	3	3	3	3	10	3	3	3	3	3	3	3
7	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
6	3	3	13	3	3	13	3	3	3	13	3	3	13	3	3
5	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	3	3	3	13	3	3	3	3	3	3	3	13	3	3	3
3	3	3	3	3	3	13	3	3	3	13	3	3	3	3	3
2	3	3	3	3	3	3	3	3	3	3	3	3	1	3	3
1	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

Fuel Assembly Arrays

ARRAY NO. 8 ARRAY SIZE IS 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 8

Y \ X =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
14	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
13	6	6	6	6	6	7	6	6	6	7	6	6	6	6	6
12	6	6	6	7	6	6	6	6	6	6	6	7	6	6	6
11	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
10	6	6	7	6	6	7	6	6	6	7	6	6	7	6	6
9	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
8	6	6	6	6	6	6	6	10	6	6	6	6	6	6	6
7	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
6	6	6	7	6	6	7	6	6	6	7	6	6	7	6	6
5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
4	6	6	6	7	6	6	6	6	6	6	6	7	6	6	6
3	6	6	6	6	6	7	6	6	6	7	6	6	6	6	6
2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
1	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

ARRAY NO. 9 ARRAY SIZE IS 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 9

Y \ X =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
14	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
13	8	8	8	8	8	9	8	8	8	9	8	8	8	8	8
12	8	8	8	8	8	8	8	8	8	8	8	9	8	8	8
11	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
10	8	8	8	8	8	9	8	8	8	8	8	8	9	8	8
9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
8	8	8	8	8	8	8	8	10	8	8	8	8	8	8	8
7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
6	8	8	8	8	8	9	8	8	8	8	8	8	8	8	8
5	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
4	8	8	8	9	8	8	8	8	8	8	8	8	8	8	8
3	8	8	8	8	8	9	8	8	8	9	8	8	8	8	8
2	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

Fuel Assembly Arrays

ARRAY NO. 6 ARRAY SIZE IS 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 6

Y \ X IS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
14	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
13	6	6	6	6	6	5	6	6	6	5	6	6	6	6	6
12	6	6	6	5	6	6	6	6	6	6	6	6	6	6	6
11	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
10	6	6	6	6	6	6	6	6	6	6	6	6	5	6	6
9	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
8	6	6	6	6	6	6	6	10	6	6	6	6	6	6	6
7	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
6	6	6	5	6	6	5	6	6	6	6	6	6	5	6	6
5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
4	6	6	6	5	6	6	6	6	6	6	6	6	6	6	6
3	6	6	6	6	6	5	6	6	6	5	6	6	6	6	6
2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
1	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

ARRAY NO. 7 ARRAY SIZE IS 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 7

Y \ X IS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
14	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
13	8	8	8	8	8	11	8	8	8	11	8	8	8	8	8
12	8	8	8	11	8	8	8	8	8	8	8	11	8	8	8
11	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
10	8	8	11	8	8	11	8	8	8	11	8	8	11	8	8
9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
8	8	8	8	8	8	8	8	10	8	8	8	8	8	8	8
7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
6	8	8	11	8	8	11	8	8	8	11	8	8	11	8	8
5	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
4	8	8	8	11	8	8	8	8	8	8	8	11	8	8	8
3	8	8	8	8	8	11	8	8	8	11	8	8	8	8	8
2	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

Fuel Assembly Arrays

ARRAY NO. 8 ARRAY SIZE IS 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 8

Y \ X =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
14	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
13	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
12	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
11	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
10	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
9	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
8	8	8	8	8	8	8	8	10	8	8	8	8	8	8	8
7	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
5	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
4	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
3	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
2	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
1	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8

ARRAY NO. 9 ARRAY SIZE IS 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 9

Y \ X =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
14	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
13	6	6	6	6	6	2	6	6	6	2	6	6	6	6	6
12	6	6	6	2	6	6	6	6	6	6	6	2	6	6	6
11	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
10	6	6	2	6	6	2	6	6	6	2	6	6	2	6	6
9	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
8	6	6	6	6	6	6	6	10	6	6	6	6	6	6	6
7	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
6	6	6	2	6	6	2	6	6	6	2	6	6	2	6	6
5	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
4	6	6	6	2	6	6	6	6	6	6	6	2	6	6	6
3	6	6	6	6	6	2	6	6	6	2	6	6	6	6	6
2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
1	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

Fuel Assembly Arrays

ARRAY NO. 10 ARRAY SIZE IS 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 10

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

ARRAY NO. 11 ARRAY SIZE IS 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 11

Y \ X =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
14	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
13	12	12	12	12	12	4	12	12	13	4	12	12	12	12	12
12	12	12	12	4	12	12	13	12	12	12	12	4	12	12	12
11	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
10	12	12	4	12	12	4	12	12	12	4	12	12	4	12	12
9	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
8	12	12	12	12	12	12	12	10	12	12	12	12	12	12	12
7	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
6	12	12	4	12	12	4	12	12	12	4	12	12	4	12	12
5	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
4	12	12	12	4	12	12	12	12	12	12	12	4	12	12	12
3	12	12	12	12	12	4	12	12	12	4	12	12	12	12	12
2	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
1	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12

Fuel Assembly Arrays

ARRAY I.D. 12 ARRAY SIZE 15 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 12

Y \ X =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
14	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
13	12	12	12	12	12	11	12	12	12	11	12	12	12	12	12
12	12	12	12	11	12	12	12	12	12	12	12	11	12	12	12
11	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
10	12	12	11	12	12	11	12	12	12	11	12	12	11	12	12
9	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
8	12	12	12	12	12	12	12	10	12	12	12	12	12	12	12
7	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
6	12	12	11	12	12	11	12	12	12	11	12	12	11	12	12
5	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
4	12	12	12	11	12	12	12	12	12	12	12	11	12	12	12
3	12	12	12	12	12	11	12	12	12	11	12	12	12	12	12
2	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
1	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12

ARRAY NO. 13 ARRAY SIZE 15 15 BY 15 BY 1

LEVEL 1 OF ARRAY NO. 13

Y \ X =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	15	1	1	1	15	1	1	1	1	1
12	1	1	1	15	1	1	1	1	1	1	1	15	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	15	1	1	15	1	1	1	15	1	1	15	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	10	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	15	1	1	15	1	1	1	15	1	1	15	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	15	1	1	1	1	1	1	1	15	1	1	1
3	1	1	1	1	1	15	1	1	1	15	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Fuel Assembly Arrays

ARRAY NO. 14 ARRAY SIZE IS 15 BY 15 BY 7

LEVEL 1 OF ARRAY NO. 14

Y \ X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	0	0	0	0	0	-10	-10	-10	-10	-10	0	0	0	0	0
14	0	0	0	-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0
13	0	0	-10	-12	-2	-7	-2	-7	-2	-7	-2	-12	-10	0	0
12	0	-10	-12	-2	-7	-2	-7	-2	-7	-2	-7	-2	-12	-10	0
11	0	-10	-2	-7	-2	-7	-2	-7	-2	-7	-2	-7	-2	-10	0
10	-10	-11	-7	-2	-7	-2	-5	-2	-5	-2	-7	-2	-7	-11	-10
9	-10	-5	-2	-7	-2	-5	-2	-5	-2	-5	-2	-7	-2	-5	-10
8	-10	-11	-7	-2	-7	-2	-5	-2	-5	-2	-7	-2	-7	-11	-10
7	-10	-5	-2	-7	-2	-5	-2	-5	-2	-5	-2	-7	-2	-5	-10
6	-10	-11	-7	-2	-7	-2	-5	-2	-5	-2	-7	-2	-7	-11	-10
5	0	-10	-2	-7	-2	-7	-2	-7	-2	-7	-2	-7	-2	-10	0
4	0	-10	-12	-2	-7	-2	-7	-2	-7	-2	-7	-2	-12	-10	0
3	0	0	-10	-12	-2	-7	-2	-7	-2	-7	-2	-12	-10	0	0
2	0	0	0	-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0
1	0	0	0	0	0	-10	-10	-10	-10	-10	0	0	0	0	0

LEVEL 2 OF ARRAY NO. 14

Y \ X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	0	0	0	0	0	-10	-10	-10	-10	-10	0	0	0	0	0
14	0	0	0	-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0
13	0	0	-10	-12	-2	-7	-2	-7	-2	-7	-2	-12	-10	0	0
12	0	-10	-12	-2	-7	-2	-7	-2	-7	-2	-7	-2	-12	-10	0
11	0	-10	-2	-7	-2	-7	-2	-7	-2	-7	-2	-7	-2	-10	0
10	-10	-11	-7	-2	-7	-2	-5	-2	-5	-2	-7	-2	-7	-11	-10
9	-10	-5	-2	-7	-2	-5	-1	-4	-1	-5	-2	-7	-2	-5	-10
8	-10	-11	-7	-2	-7	-2	-4	-2	-4	-2	-7	-2	-7	-11	-10
7	-10	-5	-2	-7	-2	-5	-1	-4	-1	-5	-2	-7	-2	-5	-10
6	-10	-11	-7	-2	-7	-2	-6	-2	-6	-2	-7	-2	-7	-11	-10
5	0	-10	-2	-7	-2	-7	-2	-7	-2	-7	-2	-7	-2	-10	0
4	0	-10	-12	-2	-7	-2	-7	-2	-7	-2	-7	-2	-12	-10	0
3	0	0	-10	-12	-2	-7	-2	-7	-2	-7	-2	-12	-10	0	0
2	0	0	0	-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0
1	0	0	0	0	0	-10	-10	-10	-10	-10	0	0	0	0	0

Axial Levels in Core

LEVEL 3 OF ARRAY NO. 14

Y \ X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	0	0	0	0	0-10	-16	-10	-10	-10	0	0	0	0	0	
14	0	0	0-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0	
13	0	0-10	-12	-2	-7	-2	-7	-2	-7	-2	-12	-10	0	0	
12	0-10	-12	-2	-7	-3	-7	-2	-7	-3	-7	-2	-12	-10	0	
11	0-10	-2	-7	-2	-7	-2	-7	-2	-7	-2	-7	-2	-10	0	
10	-10	-11	-7	-3	-2	-2	-5	-2	-5	-2	-7	-3	-7	-11	-10
9	-10	-5	-2	-7	-2	-5	-1	-4	-1	-5	-2	-7	-2	-5	-10
8	-10	-11	-7	-2	-7	-3	-4	-6	-4	-2	-7	-2	-7	-11	-10
7	-10	-5	-2	-7	-2	-5	-1	-4	-1	-5	-2	-7	-2	-5	-10
6	-10	-11	-7	-3	-7	-2	-5	-2	-5	-2	-7	-3	-7	-11	-10
5	0-10	-2	-7	-2	-7	-2	-7	-2	-7	-2	-7	-2	-10	0	
4	0-10	-12	-2	-7	-3	-7	-2	-7	-3	-7	-2	-12	-10	0	
3	0	0-10	-12	-2	-7	-2	-7	-2	-7	-2	-12	-10	0	0	
2	0	0	0-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0	
1	0	0	0	0	0-10	-10	-10	-10	-10	0	0	0	0	0	

LEVEL 4 OF ARRAY NO. 14

Y \ X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	0	0	0	0	0-10	-10	-10	-10	-10	0	0	0	0	0	
14	0	0	0-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0	
13	0	0-10	-12	-2	-7	-2	-7	-2	-7	-2	-12	-10	0	0	
12	0-10	-12	-2	-7	-3	-7	-2	-7	-3	-7	-2	-12	-10	0	
11	0-10	-2	-7	-1	-6	-1	-6	-1	-6	-1	-7	-2	-10	0	
10	-10	-11	-7	-2	-6	-1	-4	-1	-4	-1	-6	-3	-7	-11	-10
9	-10	-5	-2	-7	-1	-4	-1	-4	-1	-4	-1	-7	-2	-5	-10
8	-10	-11	-7	-2	-6	-1	-4	-6	-4	-1	-6	-2	-7	-11	-10
7	-10	-5	-2	-7	-1	-4	-1	-4	-1	-4	-1	-7	-2	-5	-10
6	-10	-11	-7	-3	-6	-1	-4	-1	-4	-1	-6	-3	-7	-11	-10
5	0-10	-2	-7	-1	-6	-1	-6	-1	-6	-1	-7	-2	-10	0	
4	0-10	-12	-2	-7	-3	-7	-2	-1	-3	-7	-2	-12	-10	0	
3	0	0-10	-12	-2	-7	-2	-7	-2	-7	-2	-12	-10	0	0	
2	0	0	0-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0	
1	0	0	0	0	0-10	-10	-10	-10	-10	0	0	0	0	0	

Axial Levels in Core

LEVEL 5 OF ARRAY NO. 14

Y \ X =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	0	0	0	0	0-10	-10	-10	-10	-10	0	0	0	0	0	
14	0	0	0-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0	
13	0	0-10	-12	-2	-7	-2	-7	-2	-7	-2	-12	-10	0	0	
12	0-10	-12	-2	-7	-3	-2	-2	-7	-3	-7	-2	-12	-10	0	
11	0-10	-2	-7	-1	-6	-1	-6	-1	-6	-1	-7	-2	-10	0	
10	-10	-11	-7	-3	-6	-1	-4	-1	-4	-1	-6	-3	-7	-11	-10
9	-10	-5	-2	-7	-1	-4	0	0	0	-4	-1	-7	-2	-5	-10
8	-10	-11	-7	-3	-6	-1	-4	0	0	-4	-1	-6	-3	-7	-11	-10
7	-10	-5	-2	-7	-1	-4	0	0	0	-4	-1	-7	-2	-5	-10
6	-10	-11	-7	-3	-6	-1	-4	-1	-4	-1	-6	-3	-7	-11	-10
5	0-10	-2	-7	-1	-6	-1	-6	-1	-6	-1	-7	-2	-10	0	
4	0-10	-12	-2	-7	-3	-7	-2	-7	-3	-7	-2	-12	-10	0	
3	0	0-10	-12	-2	-7	-2	-7	-2	-7	-2	-12	-10	0	0	
2	0	0	0-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0	
1	0	0	0	0	0-10	-10	-10	-10	-10	0	0	0	0	0	

LEVEL 6 OF ARRAY NO. 14

Y \ X =	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	0	0	0	0	0-10	-10	-10	-10	-10	0	0	0	0	0	
14	0	0	0-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0	
13	0	0-10	-12	-1	-6	-1	-6	-1	-6	-1	-12	-10	0	0	
12	0-10	-12	-1	-6	-13	-6	-1	-6	-13	-6	-1	-12	-10	0	
11	0-10	-1	-6	0	0	0	0	0	0	0	-6	-1	-10	0	
10	-10	-11	-6	-13	0	0	0	0	0	0	-13	-6	-11	-10	
9	-10	-5	-1	-6	0	0	0	0	0	0	-6	-1	-5	-10	
8	-10	-11	-6	-1	0	0	0	0	0	0	-1	-6	-11	-10	
7	-10	-5	-1	-6	0	0	0	0	0	0	-6	-1	-5	-10	
6	-10	-11	-6	-13	0	0	0	0	0	0	-13	-6	-11	-10	
5	0-10	-1	-6	0	0	0	0	0	0	0	-6	-1	-10	0	
4	0-10	-12	-1	-6	-13	-6	-1	-6	-13	-6	-1	-12	-10	0	
3	0	0-10	-12	-1	-6	-1	-6	-1	-6	-1	-12	-10	0	0	
2	0	0	0-10	-10	-11	-5	-11	-5	-11	-10	-10	0	0	0	
1	0	0	0	0	0-10	-10	-10	-10	-10	0	0	0	0	0	

Axial Levels in Core

LEVEL 7 OF ARRAY NO. 14

Y \ X	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Axial Levels in Core

APPENDIX C

KENO-IV Input Procedures

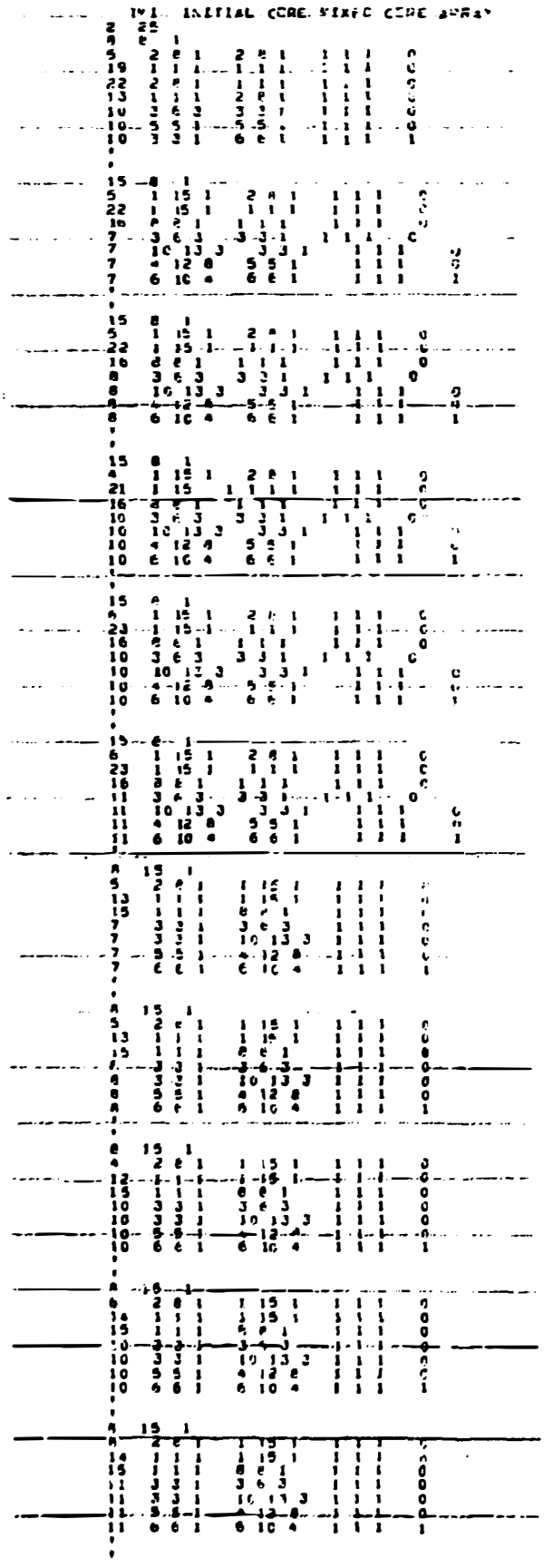
Copies of the card image input and certain input edits for the KENO-IV "Displaced-Fuel Slump" and "In-Place Fuel Slump" disrupted core model analyses are presented here. The primary purpose of this appendix is to demonstrate the use of the MAKARAY module in preparing the mixed-box orientation array for KENO-IV. MAKARAY is a program developed to simplify the specification of KENO-IV input data for large arrays. The approach taken is to first specify subarrays, in this case fuel assemblies, and then combine the subarrays to form the mixed-box orientation array. The one-quarter core geometry shown in Fig. 4.3-1 of Appendix A is the core geometry specified here. It consists of a 120 x 120 array of pin lattice locations, water gaps between assemblies, and water peripheral to the core. It includes seven unique combinations of fuel types and fixed absorbers defining 15 x 15 unit subarrays interior to the core. Additionally, along the horizontal core midplanes there are five unique 15 x 8 subarrays, five unique 8 x 15 subarrays, and a central 8 x 8 subarray. Hemicylinders are used to specify the fuel and absorber rods located on the core midplanes. The various items appearing in the input are indicated in the following list:

Item	Page
NITAWL Input for Cross Section Processing	C3
MAKARAY Input for Core Midplane Arrays	C4
MAKARAY Input for 6 Full Assemblies (15 x 15)	C5
MAKARAY Input for Peripheral Water (15 x 15) and Water Gaps (1 x 8, 8 x 1, 1 x 15, 15 x 1, 1 x 1)	C5

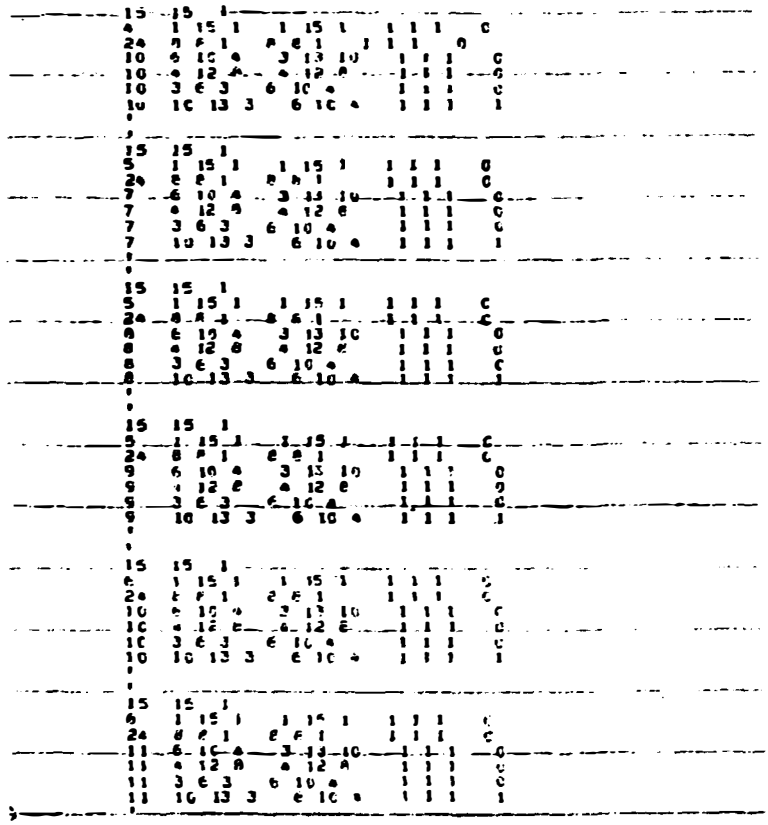
Item	Page
MAKARAY Input for 7th Full Assembly (Fuel C-Box 6, LBP2-Box 8, 24th subarray specified)	C5
MAKARAY Input for Combining Subarrays	C6
KENO-IV Control Parameters Edit	C6
KENO-IV Mixing Table for Macroscopic Constants	C7
KENO-IV Box Type Specifications (Note Box 6 for Fuel C-Material 3, Box 8 for LBP2-Material 5, each with Zr Clad-Material 9)	C8-C9
NITAWL Table of Contents	C10
Printer Plots of MAKARAY Subarrays Core Midplane Arrays	C10-15
Full Assembly Arrays (15 x 15)	C16-C18
Peripheral Water (15 x 15)	C19
Water Gap (Subarrays 20, 21, 22, 23 omitted)	C19
24th Subarray for Fuel C-LBP2 (Note Box Type 6 and Box Type 8)	C20
Subarray Combination for Mixed-Box Orientation Array (Center of core is subarray 1, Note subarray 24)	C20
Portion of Mixed-Box Orientation Array (Note Fuel-C, LBP2 Assembly)	C21
KENO-IV Mixing Table for "Displaced-Fuel Slump" Model Analysis	C22
Input Stream for "In-Place Fuel Slump" Model Analysis (Note differences between this and previous case for NITAWL resonance processing data, KENO-IV mixing table, KENO-IV specifications for the fuel radius and height. The MAKARAY specifications are the same for both cases.	C24-C30

```
        PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - JULY 6,1975)

    MODULE NITAWL   WILL BE CALLED  TIME OF DAY  9.39.47  DATE 75.201

        0$$   BZ    E   1$$ A2 22 A8 12 A11 1 1   1T
        25$ 92235 -2 -3 -4 92239 -8 8016 5010 6011 6012 13027 47107
        47109 48000 49113 49115 10001 40302 24350 25055 25350 28350
        3&&
        25055 253 1 0.05 0.093 6266.7 1.73E-3 1 55.85 385.6 1 58.85 77.0 1 1
        47107 253 2 0.56 0.0233 193 2.37E-2 1 107.9 56.5 1 110.9 2.53 1 1
        47109 253 2 0.56 0.0233 157 2.16E-2 1 106.9 6 1 110.9 2.78 1 1
        49113 253-2 0.56 0.0633 9726.6 3.47-3 1 108.9 6611.1 106.9 374.6 1 1
        49115 253 2 0.56 0.0633 444 7.65-3 1 106.9 300 1 106.9 17 1 1
        40302 253 1 0.067 0.329 191.7 4.25-2 1 620 1
        92235 253 2 0.47 0.226 3.1E+3 4.53-4 1 15.996 37A 1 238.125 406 1 1
        2 253 2 0.47 0.226 2350 6.64-4 1 15.996 221 1 238.125 302 1 1
        3 253 2 0.47 0.226 2095 6.67-7 1 15.996 250 1 238.125 265 1 1
        4 253 300 2268 7.54-4 1 1.00A 1444 1 15.996 517 1 1
        92238 253 2 0.47 0.226 64.18 0.0221 1 15.996 7.65 1 235 0.215 1 1
        8 253 300 60.65 3.411 1-1.008 38.6 1 15.996 13.78 1 1
        &&&   FE93.0   2T
        END
```

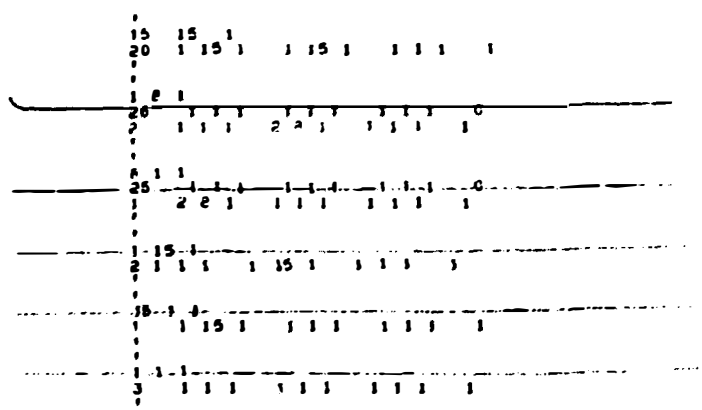
NITAWL Input for Cross Section Processing



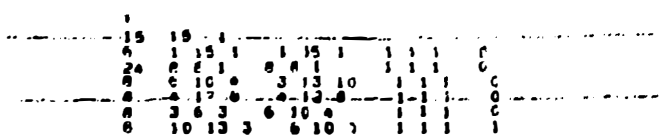
MAKARAY Input for Core Midplane Arrays



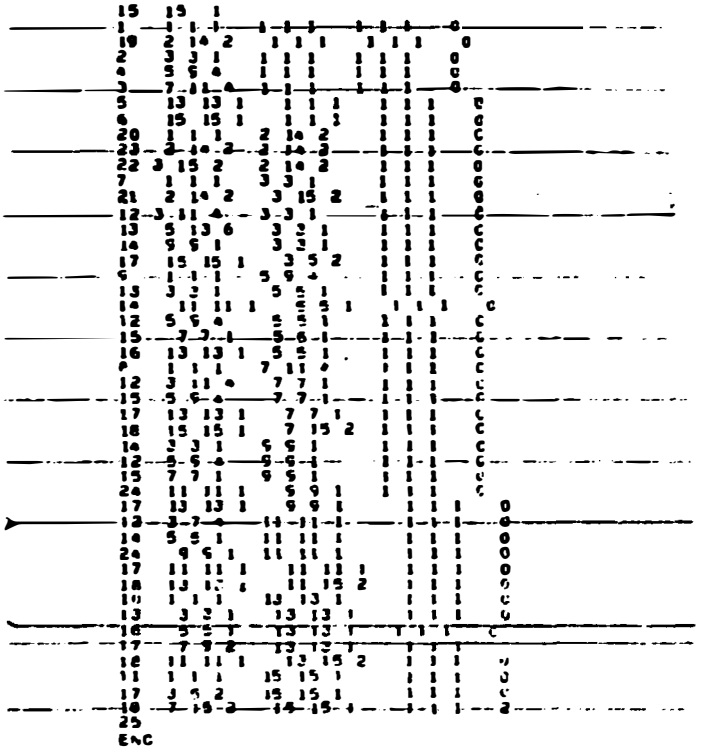
MAKARAY Input for Six Full Assemblies



MAKARAY Input for Peripheral Water and Water Gaps



MAKARAY Input for 7th Full Assembly

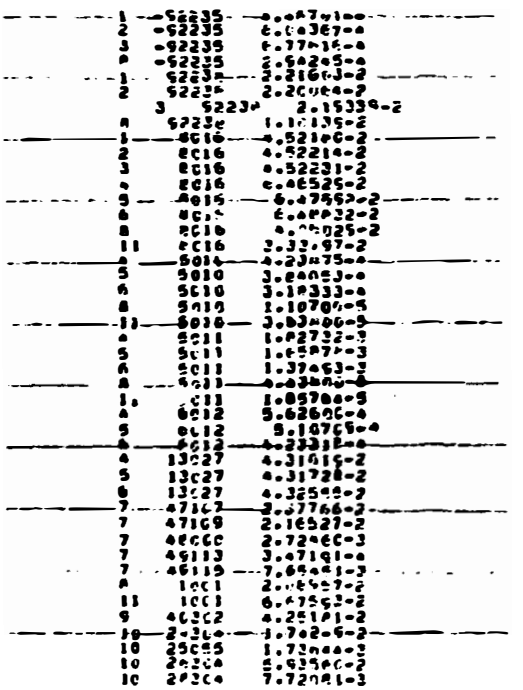


```
15  15  1
1   1 1 1   1 1 1   1 1 1   0
19  2 14 2    1 1 1    1 1 1    0
2   3 3 1    1 1 1    1 1 1    0
4   5 5 4    1 1 1    1 1 1    0
3   7 11 4   1 1 1    1 1 1    0
5   13 13 1    1 1 1    1 1 1    0
6   15 15 1    1 1 1    1 1 1    0
20  1 1 1    2 14 2    1 1 1    0
23  2 10 2   2 14 2    1 1 1    0
22  3 15 2   2 14 2    1 1 1    0
7   1 1 1    3 3 1     1 1 1    0
21  2 14 2   3 15 2    1 1 1    0
12  3 11 4   3 3 1     1 1 1    0
13  5 13 6   3 5 1     1 1 1    0
14  5 5 1    3 5 1     1 1 1    0
17  15 15 1    3 5 2    1 1 1    0
9   1 1 1    5 5 4     1 1 1    0
13  3 5 1    5 5 1     1 1 1    0
14  11 11 1    5 5 1    1 1 1    0
12  5 5 4    5 5 1     1 1 1    0
15  7 7 1    5 5 1     1 1 1    0
16  13 13 1    5 5 1    1 1 1    0
8   1 1 1    7 11 4    1 1 1    0
12  3 11 4    7 7 1    1 1 1    0
15  5 5 4    7 7 1     1 1 1    0
17  13 13 1    7 7 1    1 1 1    0
18  15 15 1    7 15 2   1 1 1    0
14  3 3 1    9 9 1     1 1 1    0
12  5 5 4    9 9 1     1 1 1    0
15  7 7 1    9 9 1     1 1 1    0
24  11 11 1    9 9 1    1 1 1    0
17  13 13 1    9 9 1    1 1 1    0
12  3 7 4    11 11 1    1 1 1    0
14  5 5 1    11 11 1    1 1 1    0
24  9 9 1    11 11 1    1 1 1    0
17  11 11 1    11 11 1   1 1 1    0
18  13 15 4    11 15 2   1 1 1    0
10  1 1 1    13 13 1    1 1 1    0
13  3 3 1    13 13 1    1 1 1    0
16  5 5 1    13 13 1    1 1 1    0
17  7 9 2    13 13 1    1 1 1
18  11 11 1    13 15 2   1 1 1    0
11  1 1 1    15 15 1    1 1 1    0
17  3 5 2    15 15 1    1 1 1    0
18  7 15 2   14 15 1    1 1 1    2
25
END
```

MAKARAY Input for Combining Subarrays

```
 TWT HALF CORE HALF CHIDE
2.15 100  300  3  27  27  20  11  44  81  24 12C 12C 1 -20 1
0  1GCC  0  C  1  72
0  -1.C  0  -1.C  0  0
```

KENO-IV Control Parameters

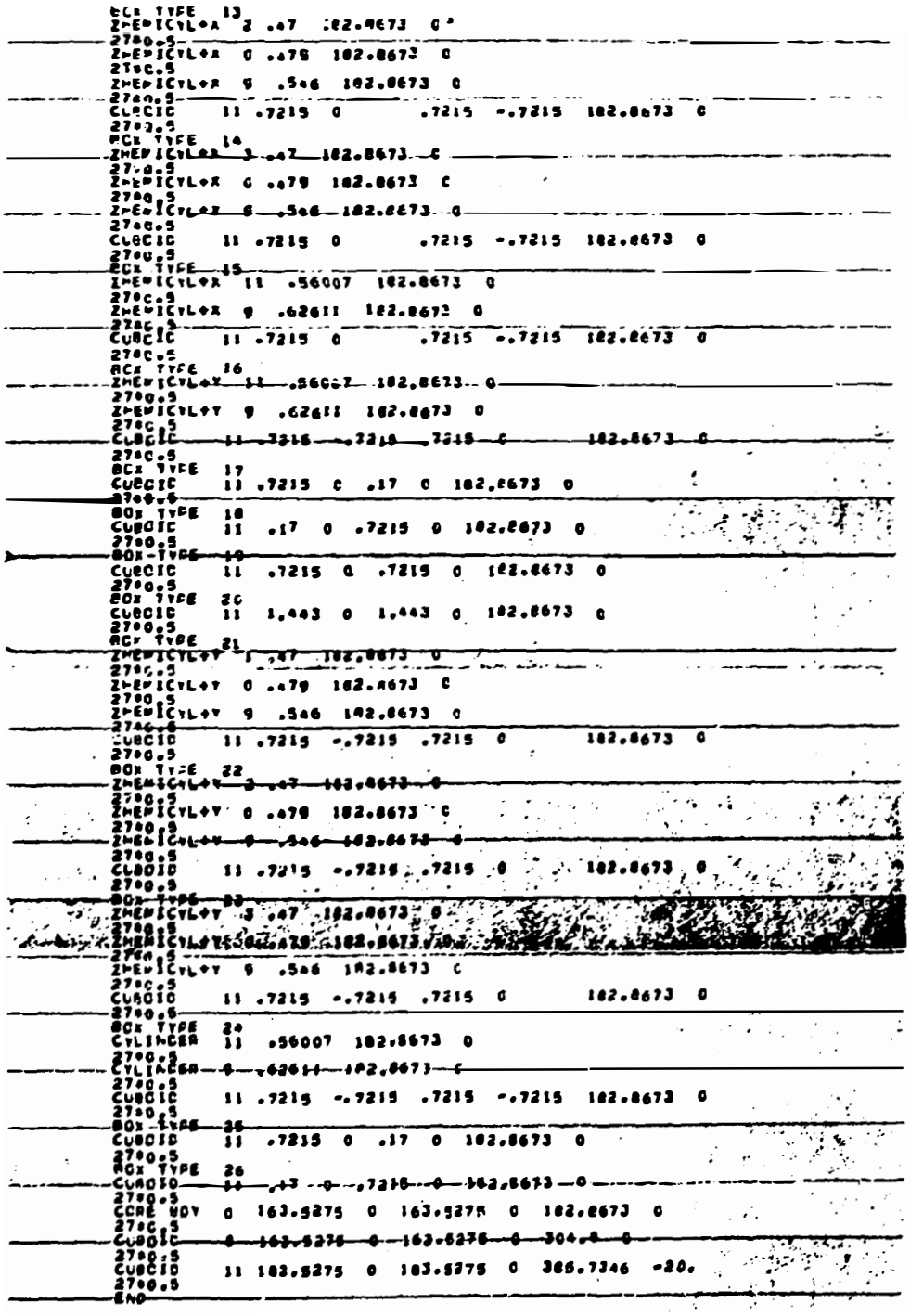


KENO-IV Mixing Table for Macroscopic Constants

```
BOX TYPE  1
CUBOID    11 1.443  0  .17  0  182.8673  0
2700.5
BOX TYPE  2
CUBOID    11  .17  0  1.443  0 182.8673  0
2700.5
BOX TYPE  3
CUBOID    11 .17  0  .17  0  182.8673  0
2700.5
BOX TYPE  4
CYLINDER  1 .47  182.8673  0
2700.5
CYLINDER  0 .479  182.8673  0
2700.5
CYLINDER  9  .546  182.8673  0
2700.5
CUBOID    11 .7215  -.7215  .7215  -.7215  182.8673  0
2700.5
BOX TYPE  5
CYLINDER  2 .47  182.8673  0
2700.5
CYLINDER  0 .479  182.8673  0
2700.5
CYLINDER  9  .546  182.8673  0
2700.5
CUBOID    11 .7215  -.7215  .7215  -.7215  182.8673  0
2700.5
BOX TYPE  6
CYLINDER  3 .47  182.8673  0
2700.5
CYLINDER  0 .479  182.8673  0
2700.5
CYLINDER  9  .546  182.8673  0
2700.5
CUBOID    11 .7215  -.7215  .7215  -.7215  182.8673  0
2700.5
BOX TYPE  7
CYLINDER  4  .4572  182.8673  0
2700.5
CYLINDER  9  .546  182.8673  0
2700.5
CYLINDER  11  .632a6  182.8673  0
2700.5
CYLINDER  9  .67310  182.8673  0
2700.5
CUBOID    11 .7215  -.7215  .7215  -.7215  182.8673  0
2700.5
BOX TYPE  8
CYLINDER  5  .4572  182.8673  0
2700.5
CYLINDER  9  .546  182.8673  0
2700.5
CYLINDER  11  .632a6  182.8673  0
2700.5
CYLINDER  9  .67310  182.8673  0
2700.5
CUBOID    11 .7215  -.7215  .7215  -.7215  182.8673  0
2700.5
BOX TYPE  9
CYLINDER  6  .4572  182.8673  0
2700.5
CYLINDER  9  .546  182.8673  0
2700.5
CYLINDER  11  .632a6  182.8673  0
2700.5
CYLINDER  9  .67310  182.8673  0
2700.5
CUBOID    11 .7215  -.7215  .7215  -.7215  182.8673  0
2700.5
BOX TYPE  10
CYLINDER  11 .56  182.8673  0
2700.5
CYLINDER  10  .61  182.8673  0
2700.5
CYLINDER  11  .632a6  182.8673  0
2700.5
CYLINDER  9  .67310  182.8673  0
2700.5
CUBOID    11 .7215  -.7215  .7215  -.7215  182.8673  0
2700.5
BOX TYPE  11
CYLINDER  10  .6096  182.8673  0
2700.5
CYLINDER  11  .632a6  182.8673  0
2700.5
CYLINDER  9  .67310  182.8673  0
2700.5
CUBOID    11 .7215  -.7215  .7215  -.7215  182.8673  0
2700.5
BOX TYPE  12
ZHEXICYL+X  1 .47  182.8673  0
2700.5
ZHEXICYL+X  0 .479  182.8673  0
2700.5
ZHEXICYL+X  9  .546  182.8673  0
2700.5
CUBOID    11 .7215  0  .7215  -.7215  182.8673  0
2700.5
```

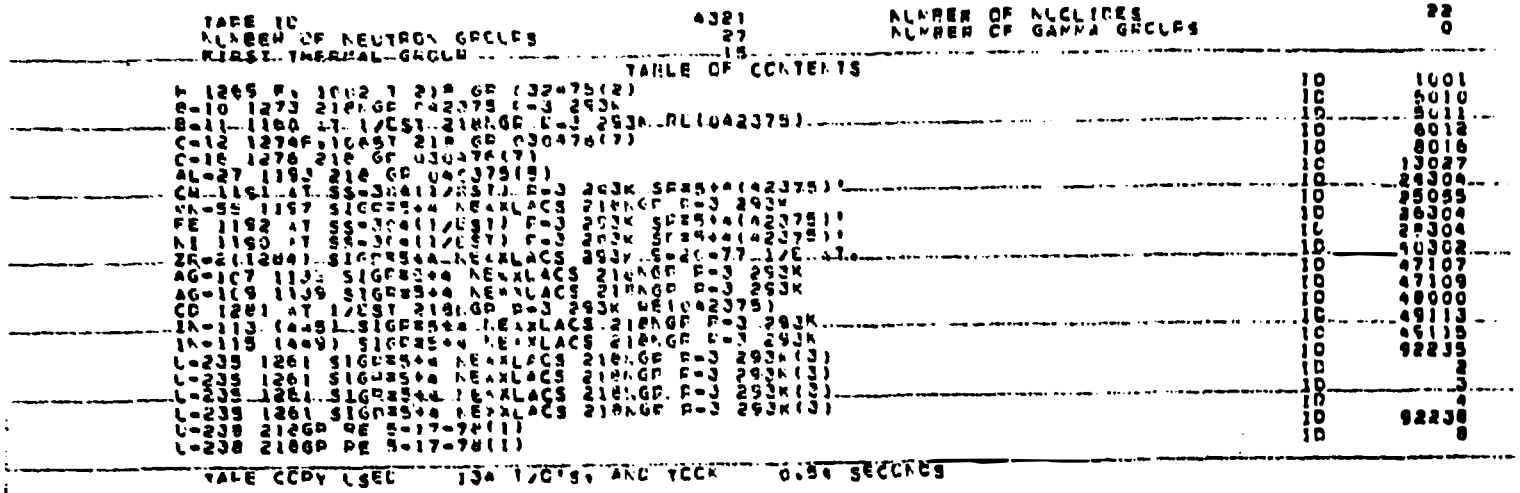
KENO-IV Box Type Specifications

(continued)



```
BOX TYPE  13
ZHEPICYL+A   2  .47   182.8673  0
2700.5
ZHEPICYL+A   0  .479  182.8673  0
2700.5
ZHEPICYL+A   9  .546  182.8673  0
2700.5
CU8CIC      11 .7215  0         .7215  -.7215  182.8673  0
2700.5
BOX TYPE  14
ZHEPICYL+X   2  .47   182.8673  0
2700.5
ZHEPICYL+X   0  .479  182.8673  0
2700.5
ZHEPICYL+X   9  .546  182.8673  0
2700.5
CU8CIC      11 .7215  0         .7215  -.7215  182.8673  0
2700.5
BOX TYPE  15
ZHEPICYL+X  11  .56007  182.8673  0
2700.5
ZHEPICYL+X   9  .62611  182.8673  0
2700.5
CU8CIC      11 .7215  0         .7215  -.7215  182.8673  0
2700.5
BOX TYPE  16
ZHEPICYL+Y  11  .56007  182.8673  0
2700.5
ZHEPICYL+Y   9  .62611  182.8673  0
2700.5
CU8CIC      11 .7215  0         .7215  -.7215  182.8673  0
2700.5
BOX TYPE  17
CU8CIC      11 .7215  0  .17  0  182.8673  0
2700.5
BOX TYPE  18
CU8CIC      11  .17  0  .7215  0  182.8673  0
2700.5
BOX TYPE  19
CU8CIC      11  .7215  0  .7215  0  182.8673  0
2700.5
BOX TYPE  20
CU8CIC      11  1.443  0  1.443  0  182.8673  0
2700.5
BOX TYPE  21
ZHEPICYL+Y   1  .47   182.8673  0
2700.5
ZHEPICYL+Y   0  .479  182.8673  0
2700.5
ZHEPICYL+Y   9  .546  182.8673  0
2700.5
CU8CIC      11 .7215  -.7215  .7215  0        182.8673  0
2700.5
BOX TYPE  22
ZHEPICYL+Y   3  .47   182.8673  0
2700.5
ZHEPICYL+Y   0  .479  182.8673  0
2700.5
ZHEPICYL+Y   9  .546  182.8673  0
2700.5
CU8CIC      11 .7215  -.7215  .7215  0        182.8673  0
2700.5
BOX TYPE  23
ZHEPICYL+Y   3  .47   182.8673  0
2700.5
ZHEPICYL+Y   0  .479  182.8673  0
2700.5
ZHEPICYL+Y   9  .546  182.8673  0
2700.5
CU8CIC      11 .7215  -.7215  .7215  0        182.8673  0
2700.5
BOX TYPE  24
CYLINDER    11  .56007  182.8673  0
2700.5
CYLINDER     0  .62611  182.8673  0
2700.5
CU8CIC      11 .7215  -.7215  .7215  -.7215  182.8673  0
2700.5
BOX TYPE  25
CU8CID      11  .7215  0  .17  0  182.8673  0
2700.5
BOX TYPE  26
CU8CID      11  .17  0  .7215  0  182.8673  0
2700.5
CORE HDY    0  163.5275  0  163.5275  0  182.8673  0
2700.5
CU8CID      0  163.5275  0  163.5275  0  304.8  0
2700.5
CU8CID      11 163.5275  0  163.5275  0  365.7346  -20.
2700.5
END
```

KENO-IV Box Type Specifications



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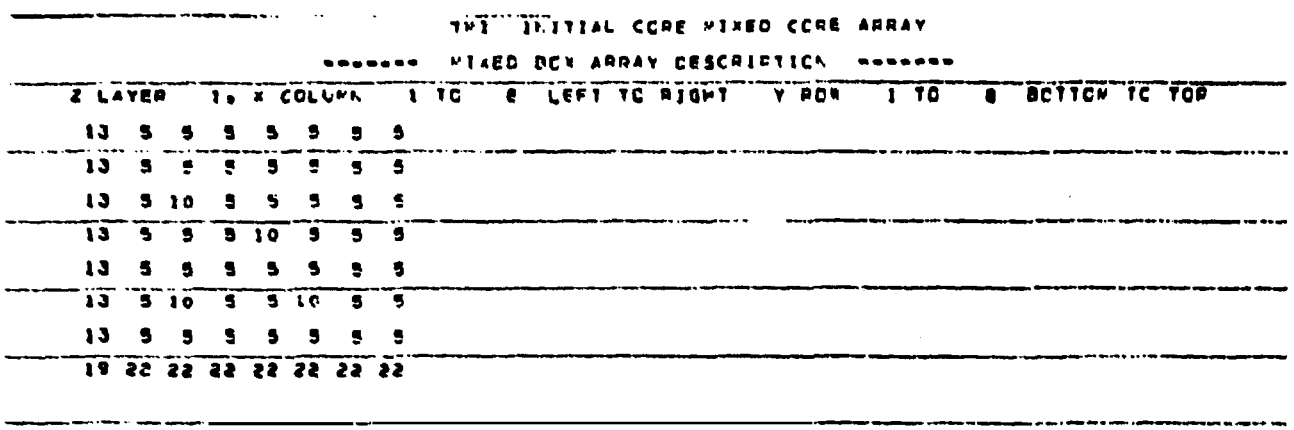


MAKARAY Subarrays Core Midplane Arrays

INI INITIAL CORE MIXED CORE ARRAY

-------- MIXED BCN ARRAY DESCRIPTION --------

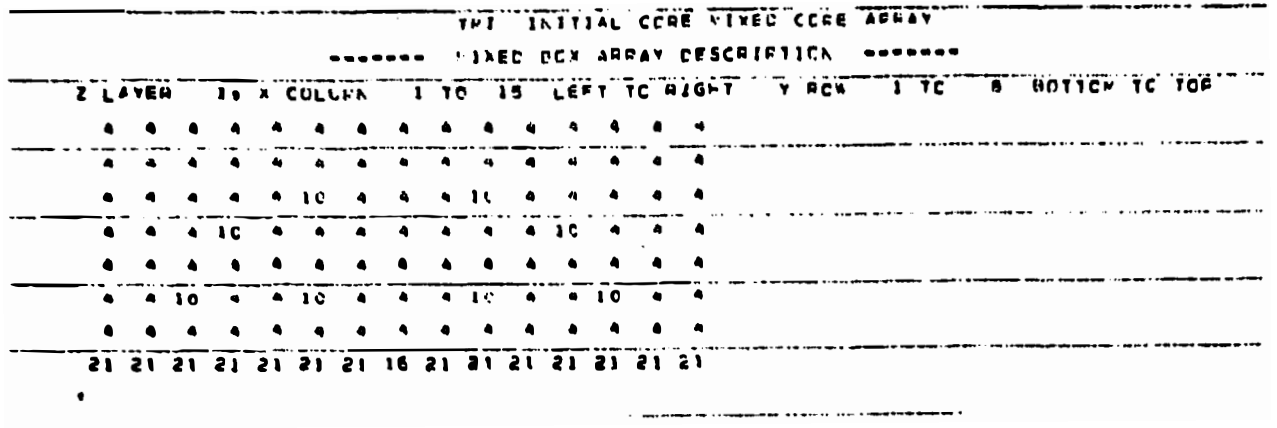
Z LAYER	I, X COLUMN	I TO 19	LEFT TC RIGHT	Y ROW	J TC	0 BOTTOM TC TOP
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 7 5 5 5 7 5 5 5 5 5						
5 5 5 7 5 5 5 5 5 5 5 7 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 7 5 5 7 5 5 5 7 5 5 7 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
22 22 22 22 22 22 22 16 22 22 22 22 22 22 22						

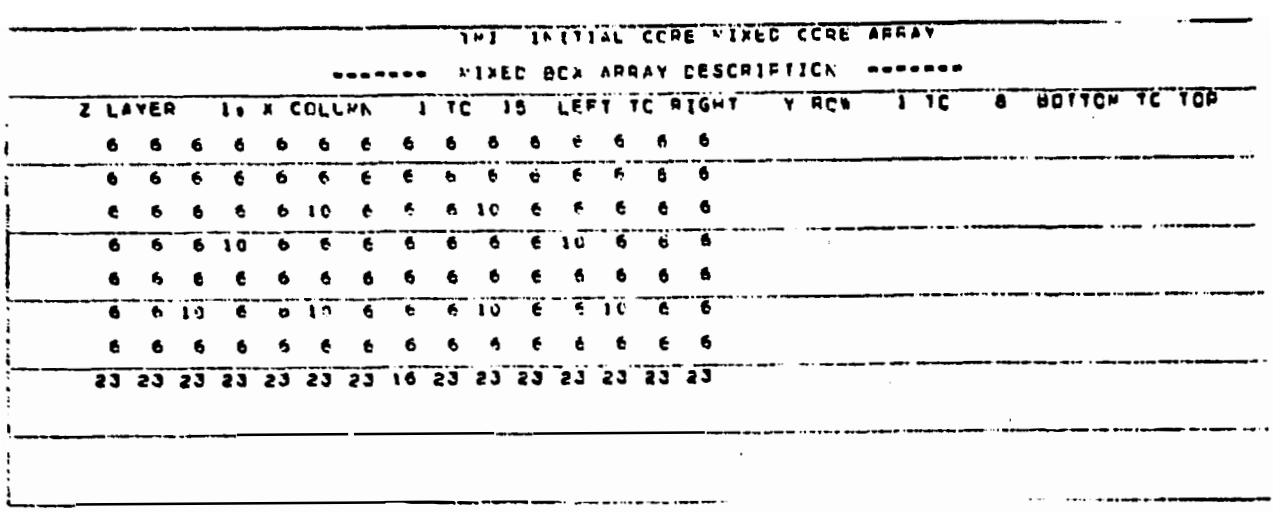
INI INITIAL CORE MIXED CORE ARRAY

-------- MIXED BCN ARRAY DESCRIPTION --------

Z LAYER	I, X COLUMN	I TO 19	LEFT TC RIGHT	Y ROW	J TC	0 BOTTOM TC TOP
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
22 22 22 22 22 22 22 16 22 22 22 22 22 22 22 22						

MAKARAY Subarrays Core Midplane Arrays





MAKARAY Subarrays Core Midplane Arrays

TMI INITIAL CORE MIXED CORE ARRAY

******* MIXED BOX ARRAY DESCRIPTION *******

Z LAYER	1 TO 15 X COLUMN	1 TO 15 LEFT TO RIGHT	Y ROW 1 TO 15 BOTTOM TO TOP
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6			
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6			
6 6 6 6 6 11 6 6 6 11 6 6 6 6 6			
6 6 6 11 6 6 6 6 6 6 6 11 6 6 6			
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6			
6 6 11 6 6 11 6 6 6 11 6 6 11 6 6			
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6			
23 23 23 23 23 23 23 16 23 23 23 23 23 23 23			

TMI INITIAL CORE MIXED CORE ARRAY

******* MIXED BOX ARRAY DESCRIPTION *******

Z LAYER	1 TO 15 X COLUMN	1 TO 15 LEFT TO RIGHT	Y ROW 1 TO 15 BOTTOM TO TOP
13 5 5 5 5 5 5 5			
13 5 5 5 5 5 5 5			
13 5 7 5 5 5 5 5			
13 5 5 5 7 5 5 5			
13 5 5 5 5 5 5 5			
13 5 7 5 5 7 5 5			
13 5 5 5 5 5 5 5			
13 5 5 5 5 5 5 5			
13 5 7 5 5 7 5 5			
13 5 5 5 5 5 5 5			
13 5 5 5 7 5 5 5			
13 5 7 5 5 5 5 5			
13 5 5 5 5 5 5 5			
13 5 5 5 5 5 5 5			

MAKARAY Subarrays Core Midplane Arrays

TYPE INITIAL CORE MIXED CORE ARRAY

******* MIXED PCM ARRAY DESCRIPTION *******

Z LAYER	1	2	3	4	5	6	7	8
13	5	5	5	5	5	5	5	5
13	5	5	5	5	5	5	5	5
13	5	6	5	5	5	5	5	5
13	5	5	5	6	5	5	5	5
13	5	5	5	5	5	5	5	5
13	5	6	5	5	6	5	5	5
13	5	5	5	5	5	5	5	5
15	5	5	5	5	5	5	5	5
13	5	5	5	5	5	5	5	5
13	5	6	5	5	6	5	5	5
13	5	5	5	5	5	5	5	5
13	5	5	5	6	5	5	5	5
13	5	6	5	5	5	5	5	5
13	5	5	5	5	5	5	5	5
13	5	5	5	5	5	5	5	5

TYPE INITIAL CORE MIXED CORE ARRAY

******* MIXED PCM ARRAY DESCRIPTION *******

Z LAYER	1	2	3	4	5	6	7	8
12	4	4	4	4	4	4	4	4
12	4	4	4	4	4	4	4	4
12	4	10	4	4	4	4	4	4
12	4	4	4	4	10	4	4	4
12	4	4	4	4	4	4	4	4
12	4	10	4	4	4	10	4	4
12	4	4	4	4	4	4	4	4
15	4	4	4	4	4	4	4	4
12	4	4	4	4	4	4	4	4
12	4	10	4	4	4	10	4	4
12	4	4	4	4	4	4	4	4
12	4	4	4	4	10	4	4	4
12	4	10	4	4	4	4	4	4
12	4	4	4	4	4	4	4	4
12	4	4	4	4	4	4	4	4

MAKARAY Subarrays Core Midplane Arrays

INT INITIAL CORE MIXED CORE ARRAY

------- MIXED BCX ARRAY DESCRIPTION -------

Z LAYER	I, X COLUMN	J TC @ LEFT TC RIGHT	Y ROW	J TC IS BOTTOM TC TOP
14 6 6 6 6 6 6 6				
14 6 6 6 6 6 6 6				
14 6 10 6 6 6 6 6				
14 6 6 6 10 6 6 6				
14 6 6 6 6 6 6 6				
14 6 10 6 6 10 6 6				
14 6 6 6 6 6 6 6				
15 6 6 6 6 6 6 6				
14 6 6 6 6 6 6 6				
14 6 10 6 6 10 6 6				
14 6 6 6 6 6 6 6				
14 6 6 6 10 6 6 6				
14 6 10 6 6 6 6 6				
14 6 6 6 6 6 6 6				
14 6 6 6 6 6 6 6				

INT INITIAL CORE MIXED CORE ARRAY

------- MIXED BCX ARRAY DESCRIPTION -------

Z LAYER	I, X COLUMN	J TC @ LEFT TC RIGHT	Y ROW	J TC IS BOTTOM TC TOP
14 6 6 6 6 6 6 6				
14 6 6 6 6 6 6 6				
14 6 11 6 6 6 6 6				
14 6 6 6 11 6 6 6				
14 6 6 6 6 6 6 6				
14 6 11 6 6 11 6 6				
14 6 6 6 6 6 6 6				
15 6 6 6 6 6 6 6				
14 6 6 6 6 6 6 6				
14 6 11 6 6 11 6 6				
14 6 6 6 6 6 6 6				
14 6 6 6 11 6 6 6				
14 6 11 6 6 6 6 6				
14 6 6 6 6 6 6 6				
14 6 6 6 6 6 6 6				

MAKARAY Subarrays Core Midplane Arrays

THI INITIAL CORE MIXED CORE ARRAY

-------- MIXED BCK ARRAY DESCRIPTION --------

Z LAYER	I, X COLUMN	J TC IS	LEFT TC RIGHT	Y BCK	I TC IS	BOTTOM TC TOP
4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4						
4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4						
4 4 4 4 4 10 4 4 4 10 4 4 4 4 4						
4 4 4 10 4 4 4 4 4 4 4 10 4 4 4						
4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4						
4 4 10 4 4 10 4 4 4 10 4 4 10 4 4						
4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4						
4 4 4 10 4 4 4 4 4 4 4 10 4 4 4						
4 4 4 4 4 10 4 4 4 10 4 4 4 4 4						
4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4						
4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4						

THI INITIAL CORE MIXED CORE ARRAY

-------- MIXED BCK ARRAY DESCRIPTION --------

Z LAYER	I, X COLUMN	J TC IS	LEFT TC RIGHT	Y BCK	I TC IS	BOTTOM TC TOP
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 7 5 5 5 7 5 5 5 5 5						
5 5 5 7 5 5 5 5 5 5 5 7 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 7 5 5 7 5 5 5 7 5 5 7 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 5 5 24 5 5 5 5 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 7 5 5 7 5 5 5 7 5 5 7 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 7 5 5 5 5 5 5 5 7 5 5 5						
5 5 5 5 5 7 5 5 5 7 5 5 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5						

Full Assembly Arrays

THI INITIAL CORE FIXED CORE ARRAY

******* FIXED RCR ARRAY DESCRIPTION *******

Z LAYER	I, X COLUMN	I TO 15 LEFT TO RIGHT	Y ROW	I TO 15 BOTTOM TO TOP
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 24 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				

THI INITIAL CORE FIXED CORE ARRAY

******* FIXED RCR ARRAY DESCRIPTION *******

Z LAYER	I, X COLUMN	I TO 15 LEFT TO RIGHT	Y ROW	I TO 15 BOTTOM TO TOP
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 24 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5				

Full Assembly Arrays

THI INITIAL CORE MIXED CORE ARRAY

-------- MIXED BCX ARRAY DESCRIPTION --------

Z LAYER	I, X COLUMN	I TO I5 LEFT TO RIGHT	Y ROW	I TO I5 BOTTOM TO TOP
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 6 6 6 10 6 6 6 10 6 6 6 6 6				
6 6 6 10 6 6 6 6 6 6 6 10 6 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 10 6 6 10 6 6 6 10 6 6 10 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 6 6 6 6 6 20 6 6 6 6 6 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 10 6 6 10 6 6 6 10 6 6 10 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 6 10 6 6 6 6 6 6 6 10 6 6 6				
6 6 6 6 6 10 6 6 6 10 6 6 6 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				

THI INITIAL CORE MIXED CORE ARRAY

-------- MIXED BCX ARRAY DESCRIPTION --------

Z LAYER	I, X COLUMN	I TO I5 LEFT TO RIGHT	Y ROW	I TO I5 BOTTOM TO TOP
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 6 6 6 11 6 6 6 11 6 6 6 6 6				
6 6 6 11 6 6 6 6 6 6 6 11 6 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 11 6 6 11 6 6 6 11 6 6 11 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 6 6 6 6 6 20 6 6 6 6 6 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 11 6 6 11 6 6 6 11 6 6 11 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 6 11 6 6 6 6 6 6 6 11 6 6 6				
6 6 6 6 6 11 6 6 6 11 6 6 6 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6				

Full Assembly Arrays

THE INITIAL CORE MIXED CORE ARRAY

------- MIXED ROW ARRAY DESCRIPTION -------

Z LAYER 1, X COLUMN 1 TO 15 LEFT TO RIGHT Y ROW 1 TO 15 BOTTOM TO TOP

20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	0	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20

Peripheral Water

THE INITIAL CORE MIXED CORE ARRAY

------- MIXED ROW ARRAY DESCRIPTION -------

Z LAYER 1, X COLUMN 1 TO 1 LEFT TO RIGHT Y ROW 1 TO 8 BOTTOM TO TOP

2
2
2
2
2
2
2
26

Water Gap

THE INITIAL CORE MIXED CORE ARRAY

-------- MIXED BOX ARRAY DESCRIPTION --------

Z LAYER	1s X COLUMN	1 TO 15	LEFT TO RIGHT	Y ROW	1 TO 15	BOTTOM TO TOP
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 24 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						
6 6 6 6 6 6 6 6 6 6 6 6 6 6 6						

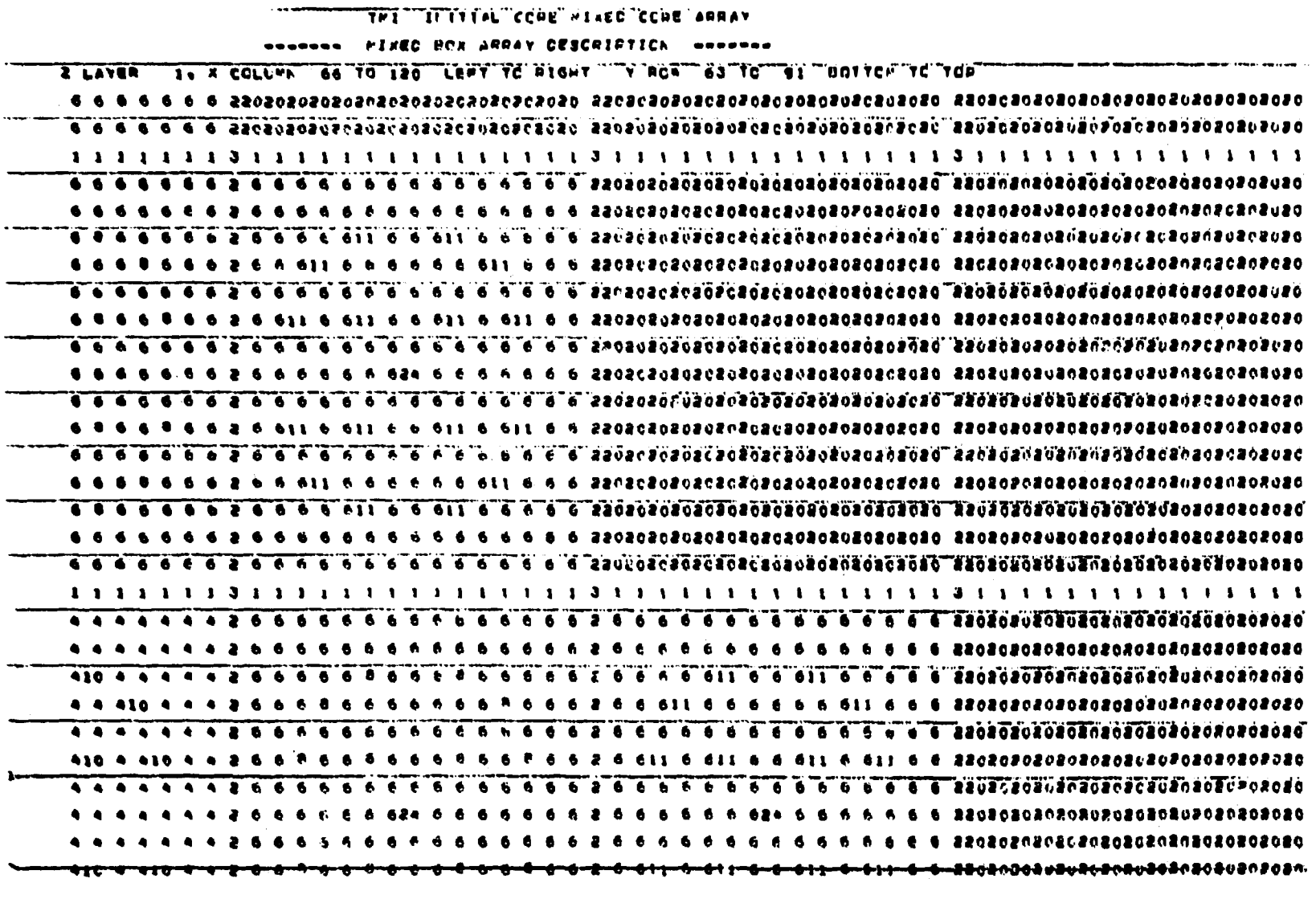
24th Subarray for Fuel C — LBP2

THE INITIAL CORE MIXED CORE ARRAY

-------- MIXED BOX ARRAY DESCRIPTION --------

Z LAYER	1s X COLUMN	1 TO 15	LEFT TO RIGHT	Y ROW	1 TO 15	BOTTOM TO TOP
11 21 17 21 17 21 16 21 16 21 16 21 16 21 16						
20 23 22 23 22 23 22 23 22 23 22 23 22 23 22						
16 21 13 21 16 21 17 21 17 21 16 21 16 21 16						
20 23 22 23 22 23 22 23 22 23 22 23 22 23 22						
8 21 12 21 14 21 12 21 24 21 17 21 16 21 16						
20 23 22 23 22 23 22 23 22 23 22 23 22 23 22						
9 21 14 21 12 21 15 21 12 21 24 21 17 21 16						
20 23 22 23 22 23 22 23 22 23 22 23 22 23 22						
8 21 12 21 15 21 12 21 15 21 12 21 17 21 16						
20 23 22 23 22 23 22 23 22 23 22 23 22 23 22						
9 21 13 21 12 21 15 21 12 21 14 21 16 21 17						
20 23 22 23 22 23 22 23 22 23 22 23 22 23 22						
7 21 12 21 13 21 .2 21 14 21 12 21 13 21 17						
20 23 22 23 22 23 22 23 22 23 22 23 22 23 22						
1 19 2 19 4 19 3 19 4 19 3 19 5 19 6						

Subarray Combination for Mixed-Box Orientation Array



Portion of Mixed-Box Orientation Array

THE HALF CORE HALF CASE			
NUMBER OF GENERATIONS	100	START TYPE	0
NUMBER PER GENERATION	300	GENERATIONS BETWEEN CHECKPOINTS	0
NUMBER OF GENERATIONS TO BE SKIPPED	3	LIST INPUT X-SECTIONS READ FROM TAPE	NO
NUMBER OF ENERGY GROUPS	27	LIST 1-D MIXTURE X SECTIONS	YES
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2-D MIXTURE X-SECTIONS	NO
NUMBER OF INPUT NUCLIDES	20	LIST FISS. AND ABS. BY REGION	NO
NUMBER OF MIXTURES	11	USE X-SECTIONS FROM PREVIOUS CASE	NO
NUMBER OF MIXING TABLE ENTRIES	44	USE GEOMETRY FROM PREVIOUS CASE	NO
NUMBER OF GEOMETRY CARDS	81	USE VELOCITIES FROM PREVIOUS CASE	NO
NUMBER OF BOX TYPES	28	COMPUTE MATRIX K-EFFECTIVE BY UNIT	NO
NUMBER OF UNITS IN X DIRECTION	120	COMPUTE MATRIX K-EFFECTIVE BY BOX TYPE	NO
NUMBER OF UNITS IN Y DIRECTION	120	LIST FISS PROB MATRIX BY UNIT	NO
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALCULATION	NO
NUMBER OF NUCLIDES READ FROM TAPE	-20	USE EXPONENTIAL TRANSFORM	NO
ALBEDO TYPE	1	CALCULATE FLUX	NO
SEARCH TYPE	0	CALCULATE FISSION DENSITIES	YES
THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION			
THE ALBEDOS ARE +X = 0.0	-X = 1.000000E 00 +Y = 0.0	-Y = 1.000000E 00 +Z = 0.0	-Z = 0.0
MAXIMUM TIME = 2.1500 MINUTES			
STORAGE LOCATIONS REQUIRED FOR THIS JOB = 46394 REMAINING AVAILABLE LOCATIONS= 9830			

KENO-IV Control Parameters Edit

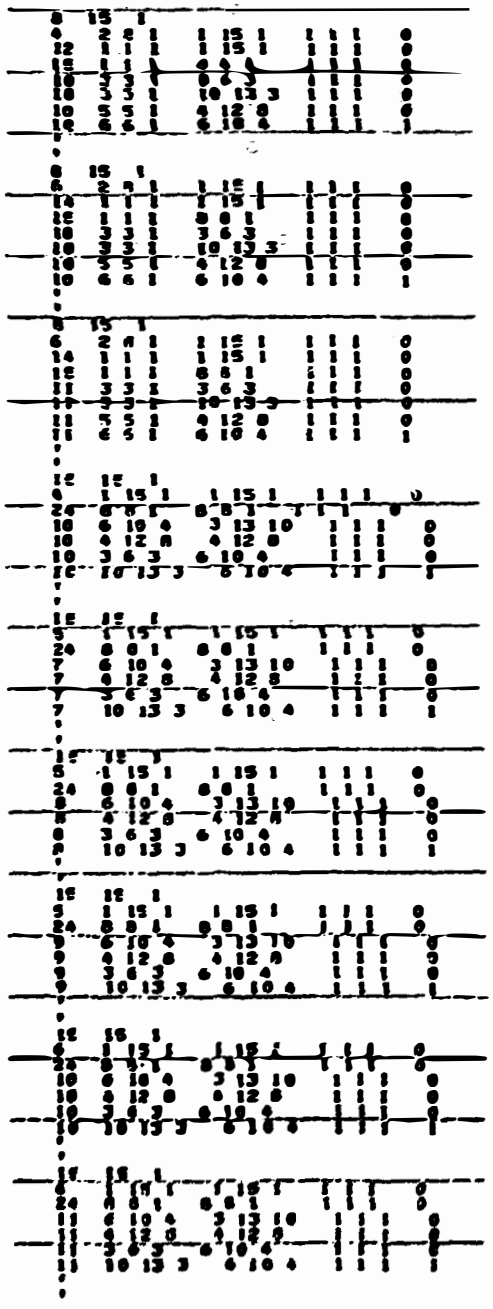
```
TPE MALF CCPE  MALF OXIDE

  MIXTURE   NUCLIDE    DENSITY
        1     =92235   4.487C1E-04
        2     =92235   6.643B7E-04
        3     =92235   6.7761EE-04
        8     =92235   2.542C5E-04
        1      92238   2.21663E-02
        2      92238   2.20C64E-02
        3      92238   2.19335E-02
        8      92238   1.19139E-02
        1       8016   4.5218CE-02
        2       8016   4.52214E-02
        3       8016   4.52231E-02
        4       8016   6.4652CE-02
        5       8016   6.47592E-02
        6       8016   6.48832E-02
        8       8016   4.06029E-02
       11       8016   3.33797E-02
        4       5010   4.23375E-04
        5       5010   3.84C53E-04
        6       5010   3.10333E-04
        8       5010   1.10700E-05
       11       5010   3.63C08E-05
        4       5011   1.42732E-03
        5       5011   1.45970E-03
        6       5011   1.27453E-03
        8       5011   4.43801E-05
       11       5011   1.85764E-05
        4       6012   5.624C0E-04
        5       6012   5.10709E-04
        6       6012   4.23315E-04
        4      13027   4.31L19E-02
        5      13027   4.31729E-02
        6      13027   4.32555E-02
        7      47107   2.37766E-02
        7      47109   2.16527E-02
        7      48000   2.72460E-03
        7      49113   3.47191E-04
        7      49115   7.46451E-03
        8       1001   2.08957E-02
       11       1001   6.67593E-02
        9      40302   4.25121E-02
       10      24304   1.74245E-02
       10      25055   1.73644E-03
       10      26304   5.53560E-02
       10      26304   7.72081E-03

CROSS SECTICAS READ FROM TAPE

 NUCLIDE #       1001   H 1269 Fe 1002 T 218 GP 032476(2)
 NUCLIDE #       5010   B-10 1273 218AGP 042375 P-3 293K
 NUCLIDE #       5011   B-11 1160 AT 1/EST 218AGP P-3 293K RE(042375)
 NUCLIDE #       6012   C-12 1274Fe1C65T 218 GP 032476(7)
 NUCLIDE #       8016   O-16 1276 218 GP 030476(7)
 NUCLIDE #      13027   AL-27 1193 218 GP 040375(5)
 NUCLIDE #      24304   CR 1191 AT SE-304(1/EST) P-3 293K SP=5+4(42375)'
 NUCLIDE #      25055   MN-55 1197 SIGP=5+4 NE=XLACS 218AGP P-3 293K
 NUCLIDE #      26304   FE 1192 AT SE-304(1/EST) P-3 293K SP=5+4(42375)'
 NUCLIDE #      28304   NI 1191 AT SE=304(1/EST) P-3 293K SP=5+4(42375)'
 NUCLIDE #      40302   ZR-2(1284) SIGP=5+4 NE=XLACS 293K 6-20-77 I/E WT.
 NUCLIDE #      47107   AG-107 1138 SIGP=5+4 NE=XLACS 218AGP P-3 293K
 NUCLIDE #      47109   AG-109 1139 SIGP=5+4 NE=XLACS 218AGP P-3 293K
 NUCLIDE #      48000   CD 1291 AT 1/EST 218AGP P-3 293K RE(042375)
 NUCLIDE #      49113   IN-113 (449) SIGP=5+4 NE=XLACS 218AGP P-3 293K
 NUCLIDE #      49115   IN-115 (449) SIGP=5+4 NE=XLACS 218AGP P-3 293K
 NUCLIDE #      92235   U-235 1261 SIGP=5+4 NE=XLACS 218AGP P-3 293K(3)
 NUCLIDE #      92238   U-238 218GP RE 5-17-78(1)
```

KENO-IV Mixing Table for "Displaced-Fuel Slump" Model Analysis

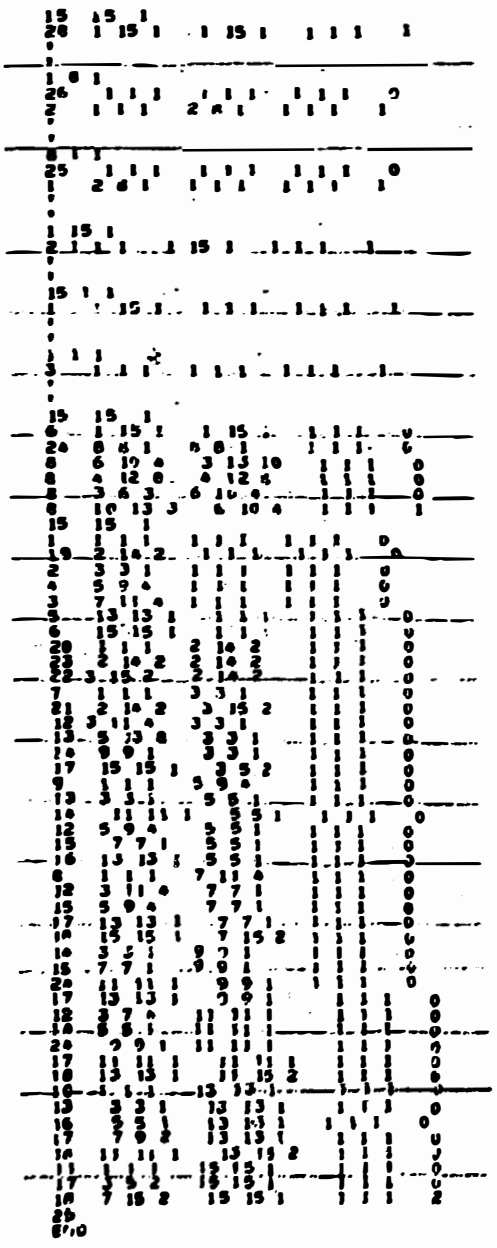
```
MODULE DATA-L
053 02  E   155 A2 20 33 14 A11 1 1  17
285 92235 -2 -3 92238 4016 5010 5011 6012 13027 47107 47109 48000
49113 49115 49342 24304 25055 26304 28304 1001
300
92236 293 2 0.07 0.452 80 0.0821 1 15.994 7.7 1 235.117 0.28 1 1
92235 293 2 0.07 0.452 2432 4.53-4 1 15.994 405 1 238.129 527 1 1
2 293 2 0.07 0.452 1424 6.94-4 1 15.994 209 1 238.125 301 1 1
3 293 2 0.07 0.452 1625 6.78-4 1 15.994 249 1 238.125 268 1 1
25-55 293 1 0.25 7.093 6266.7 1.736-3 1 55.85 389.6 1 58.69 77.8 1 1
47107 293 2 0.56 0.0033 143 2.378-2 1 106.9 96.5 1 110.9 2.53 1 1
47109 293 2 0.56 0.0033 197 2.165-2 1 106.9 6 1 110.9 2.78 1 1
49113 293 2 0.56 0.0833 9769.9 3.47-4 1 106.9 6611 1 106.9 374.8 1 1
49115 293 2 0.56 0.0833 444 7.65-3 1 106.9 300 1 106.9 17 1 1
48342 293 1 0.07 0.329 181.7 0.25-2 1 6R0 1
400  5293.6
27
END
```

```
MODULE MAKARAY
    THE  INITIAL CORE MIXED CORE ARRAY
  2  25
  0  0  1
  5  2  9  1   2  9  1   1  1  1   0
 10  1  1  1   1  1  1   1  1  1   0
 22  2  9  1   1  1  1   1  1  1   0
 13  1  1  1   2  9  1   1  1  1   0
 19  3  6  3   3  3  1   1  1  1   0
 19  5  5  1   5  5  1   1  1  1   0
 12  3  3  1   6  6  1   1  1  1   1
  0
 15  0  1
  5  1 15  1   2  9  1   1  1  1   0
 22  1 15  1   1  1  1   1  1  1   0
 16  3  9  1   1  1  1   1  1  1   0
  7  6  6  3   3  3  1   1  1  1   0
  7 10 13  3   3  3  1   1  1  1   0
  2  9 12  0   5  5  1   1  1  1   0
  7  6 10  4   6  6  1   1  1  1   1
  0
 15  0  1
  5  1 15  1   2  9  1   1  1  1   0
 22  1 15  1   1  1  1   1  1  1   0
 16  3  3  1   1  1  1   1  1  1   0
  8  3  6  3   3  3  1   1  1  1   0
  8 10 13  3   3  3  1   1  1  1   0
  2  9 12  0   5  5  1   1  1  1   0
  8  6 10  4   6  6  1   1  1  1   1
  0
 15  0  1
  5  1 15  1   2  9  1   1  1  1   0
 21  1 15  1   1  1  1   1  1  1   0
 16  0  9  1   1  1  1   1  1  1   0
 10  3  6  3   3  3  1   1  1  1   0
 10 10 13  3   3  3  1   1  1  1   0
 10  9 12  0   5  5  1   1  1  1   0
 10  6 10  4   6  6  1   1  1  1   1
  0
 15  0  1
  6  1 15  1   2  9  1   1  1  1   0
 23  1 15  1   1  1  1   1  1  1   0
 16  0  0  1   1  1  1   1  1  1   0
 10  3  6  3   3  3  1   1  1  1   0
 10 10 13  3   3  3  1   1  1  1   0
 10  9 12  0   5  5  1   1  1  1   0
 10  6 10  4   6  6  1   1  1  1   1
  0
 15  0  1
  6  1 15  1   2  9  1   1  1  1   0
 23  1 15  1   1  1  1   1  1  1   0
 16  0  0  1   1  1  1   1  1  1   0
 11  3  6  3   3  3  1   1  1  1   0
 11 10 13  3   3  3  1   1  1  1   0
 11  9 12  0   5  5  1   1  1  1   0
 11  6 10  4   6  6  1   1  1  1   1
  0
 15  0  1
  6  2  9  1   1 15  1   1  1  1   0
 12  1  1  1   1 15  1   1  1  1   0
 18  1  1  1   0  0  1   1  1  1   0
  7  3  3  1   3  3  1   1  1  1   0
  7  3  3  1  10 13  3   1  1  1   0
  7  0  0  1   6 12  0   1  1  1   0
  7  6  6  1   6 10  4   1  1  1   1
  0
 15  0  1
  6  2  9  1   1 15  1   1  1  1   0
 12  1  1  1   1 15  1   1  1  1   0
 18  1  1  1   0  0  1   1  1  1   0
  8  3  3  1   3  3  1   1  1  1   0
  8  3  3  1  10 13  3   1  1  1   0
  8  0  0  1   6 12  0   1  1  1   0
  8  6  6  1   6 10  4   1  1  1   1
  0
```

Input Stream for "In-Place Fuel Slump" Model Analysis



Input Stream for "In-Place Fuel Slump" Model Analysis



Input Stream for "In-Place Fuel Slump" Model Analysis

(continued)

```
MODULE KENO
   TRI COLD SHUTDOWN  FUEL SLUMPED PER STRATTON    3180 PPM BORON CR IN
   2.5  100  300  3  27.27.20  11  39.70  20.120.120.1.-20.1
   0  1.00  0  92
   0  -1.0  0  -1.0  0  0
   1  -92235  4.49701-4
   2  -2  6.04367-4
   3  -3  2.77616-4
   1  92238  2.21693-2
   2  92238  2.20064-02
   3  92238  2.19338-2
   1  8016  4.5218-2
   2  8016  4.52214-2
   3  8016  4.52231-2
   4  8016  4.46529-2
   5  8016  4.47592-2
   6  8016  6.48832-2
   11  8016  3.338-2
   4  5010  4.23075-4
   5  5010  3.34053-4
   6  5010  3.18333-4
   11  5010  3.534-5
   4  5011  1.62732-3
   5  5011  1.65878-3
   6  5011  1.37493-3
   11  5011  1.418-4
   4  6012  5.626-4
   5  6012  5.10709-4
   6  6012  4.23315-4
   4  13027  4.31619-2
   5  13027  4.31728-2
   6  13027  4.32555-2
   7  47107  2.37765-2
   8  47107  2.37706-2
   7  47109  2.16527-2
   7  48060  2.7246-3
   7  49113  3.4791-4
   7  49115  7.05451-3
   9  49302  4.25181-2
   10  24304  1.74249-2
   10  25055  1.73644-3
   10  26304  5.9356-2
   10  28304  7.72081-3
   11  1001  6.676-2
   BOX TYPE 1
   CUBOID  11 1.443  0  .17  0  365.7346  0
   270.5
   BOX TYPE  2
   CUBOID  11  .17  0  1.443  0 365.7346  0
   270.5
   BOX TYPE  3
   CUBOID  11 .17  0  .17  0  365.7346  0
   270.5
   BOX TYPE  4
   CYLINDER  1  .6275  205.2  0
   270.5
   CYLINDER  0  .6275  365.7346  0
   270.5
   CYLINDER  9  .680  365.7346  0
   270.5
   CUBOID  11 .7215  -.7215  .7215  -.7215  365.7346  0
   270.5
   BOX TYPE  5
   CYLINDER  2  .6275  205.2  0
   270.5
   CYLINDER  0  .6275  365.7346  0
   270.5
   CYLINDER  9  .680  365.7346  0
   270.5
   CUBOID  11 .7215  -.7215  .7215  -.7215  365.7346  0
   270.5
   BOX TYPE  6
   CYLINDER  3  .6275  205.2  0
   270.5
   CYLINDER  0  .6275  365.7346  0
   270.5
   CYLINDER  9  .680  365.7346  0
   270.5
   CUBOID  11 .7215  -.7215  .7215  -.7215  365.7346  0
   270.5
   BOX TYPE  7
   CYLINDER  4  .4572  365.7346  0
   270.5
   CYLINDER  9  .646  365.7346  0
   270.5
   CUBOID  11 .7215  -.7215  .7215  -.7215  365.7346  0
   270.5
   BOX TYPE  8
   CYLINDER  5  .4572  365.7346  0
   270.5
   CYLINDER  9  .646  365.7346  0
   270.5
   CUBOID  11 .7215  -.7215  .7215  -.7215  365.7346  0
   270.5
   BOX TYPE  9
   CYLINDER  6  .4572  365.7346  0
   270.5
   CYLINDER  9  .646  365.7346  0
   270.5
   CUBOID  11 .7215  -.7215  .7215  -.7215  365.7346  0
   270.5
   BOX TYPE  10
   CYLINDER  7  .86  365.7346  0
   270.5
   CYLINDER  10  .61  365.7346  0
   270.5
   CUBOID  11 .7215  -.7215  .7215  -.7215  365.7346  0
   270.5
```

Input Stream for "In-Place Fuel Slump" Model Analysis

(continued)

```
    BOX TYPE  11
    CYLINDER  10  .6096  365.7346  0
    2700.5
    CUBOID    11 .7215 -.7215  .7215  -.7215  365.7346  0
    2701.5
    BOX TYPE  12
    ZMEMICYL+X  1  -.6275  205.2  0
    2701.5
    ZMEMICYL+X  0  .6275  365.7346  0
    2702.5
    ZMEMICYL+X  9  .68  365.7346  0
    2704.5
    CUBOID    11 .7215  0  .7215  -.7215  365.7346  0
    2705.5
    BOX TYPE  13
    ZMEMICYL+X  2  .6275  205.2  0
    2706.5
    ZMEMICYL+X  0  .6275  365.7346  0
    2707.5
    ZMEMICYL+X  9  .68  365.7346  0
    2708.5
    CUBOID    11 .7215  0  .7215  -.7215  365.7346  0
    2709.5
    BOX TYPE  14
    ZMEMICYL+X  3  .6275  205.2  0
    2710.5
    ZMEMICYL+X  0  .6275  365.7346  0
    2711.5
    ZMEMICYL+X  9  .68  365.7346  0
    2712.5
    CUBOID    11 .7215  0  .7215  -.7215  365.7346  0
    2713.5
    BOX TYPE  15
    ZMEMICYL+X  11  .56067  365.7346  0
    2714.5
    ZMEMICYL+X  9  .62611  365.7346  0
    2715.5
    CUBOID    11 .7215  0  .7215  -.7215  365.7346  0
    2716.5
    BOX TYPE  16
    ZMEMICYL+Y  11  .56067  365.7346  0
    2717.5
    ZMEMICYL+Y  9  .62611  365.7346  0
    2718.5
    CUBOID    11 .7215  -.7215  .7215  0  365.7346  0
    2719.5
    BOX TYPE  17
    CUBOID    11 .7215  0  .17  0  365.7346  0
    2720.5
    BOX TYPE  18
    CUBOID    11  .17  0  -.7215  0  365.7346  0
    2721.5
    BOX TYPE  19
    CUBOID    11  .7215  0  .7215  0  365.7346  0
    2722.5
    BOX TYPE  20
    CUBOID    11  1.443  0  1.443  0  365.7346  0
    2723.5
    BOX TYPE  21
    ZMEMICYL+Y  1  .6275  205.2  0
    2724.5
    ZMEMICYL+Y  0  .6275  365.7346  0
    2725.5
    ZMEMICYL+Y  9  .68  365.7346  0
    2726.5
    CUBOID    11 .7215  -.7215  .7215  0  365.7346  0
    2727.5
    BOX TYPE  22
    ZMEMICYL+Y  2  .6275  205.2  0
    2728.5
    ZMEMICYL+Y  0  .6275  365.7346  0
    2729.5
    ZMEMICYL+Y  9  .68  365.7346  0
    2730.5
    CUBOID    11 .7215  -.7215  .7215  0  365.7346  0
    2731.5
    BOX TYPE  23
    ZMEMICYL+Y  3  .6275  205.2  0
    2732.5
    ZMEMICYL+Y  0  .6275  365.7346  0
    2733.5
    ZMEMICYL+Y  9  .68  365.7346  0
    2734.5
    CUBOID    11 .7215  -.7215  .7215  0  365.7346  0
    2735.5
    BOX TYPE  24
    CYLINDER  11  .56067  365.7346
    2736.5
    CYLINDER  9  .62611  365.7346  0
    2737.5
    CUBOID    11 .7215  -.7215  .7215  -.7215  365.7346  0
    2738.5
    BOX TYPE  25
    CUBOID    11  .7215  0  .17  0  365.7346  0
    2739.5
    BOX TYPE  26
    CUBOID    11  .17  0  .7215  0  365.7346  0
    2740.5
    CORE BOX  0  183.5275  0  183.5275  0  365.7346  0
    2741.5
    CUBOID    11 183.5275  0  183.5275  0  365.7346  -20.
    2742.5
    END
 MODULE KENO     IS FINISHED.
```

Input Stream for "In-Place Fuel Slump" Model Analysis

THI CCLD SHUTDOWN FUEL SLUMPED PER STRATTON 3100 PPM BORON CR IN

NUMBER OF GENERATIONS	100	START TYPE	0
NUMBER PER GENERATION	500	GENERATIONS BETWEEN CHECKPOINTS	0
NUMBER OF GENERATIONS TO BE SKIPPED	3	LIST INPUT X-SECTIONS READ FROM TAPE	NO
NUMBER OF ENERGY GROUPS	27	LIST 1-D MIXTURE X SECTIONS	YES
MAX. NUMBER OF ENERGY TRANSFERS	27	LIST 2-D MIXTURE X-SECTIONS	NO
NUMBER OF INPUT NUCLIDES	20	LIST FISS. AND ABS. BY REGION	NO
NUMBER OF MIXTURES	11	USE X-SECTIONS FROM PREVIOUS CASE	NO
NUMBER OF MIXING TABLE ENTRIES	30	USE GEOMETRY FROM PREVIOUS CASE	NO
NUMBER OF GEOMETRY CARDS	70	USE VELOCITIES FROM PREVIOUS CASE	NO
NUMBER OF BOX TYPES	26	COMPUTE MATRIX K-EFFECTIVE BY UNIT	NO
NUMBER OF UNITS IN X DIRECTION	120	COMPUTE MATRIX K-EFFECTIVE BY BOX TYPE	NO
NUMBER OF UNITS IN Y DIRECTION	120	LIST FISS RATE MATRIX BY UNIT	NO
NUMBER OF UNITS IN Z DIRECTION	1	ADJOINT CALCULATION	NO
NUMBER OF NUCLIDES READ FROM TAPE	-20	USE EXPONENTIAL TRANSFORM	NO
ALBFCO TYPE	1	CALCULATE FLUX	YES
SEARCH TYPE	0	CALCULATE FISSION DENSITIES	YES

THIS PROBLEM WILL BE RUN WITH SPECULARLY REFLECTING BOUNDARY CONDITION

THE ALBEDOS ARE +X = 0.0 -X = 1.000000 00 +Y = 0.0 -Y = 1.000000 00 +Z = 0.0 -Z = 0.0

MAXIMUM TIME = 2.5000 MINUTES

STORAGE LOCATIONS REQUIRED FOR THIS JOB = 49831
REMAINING AVAILABLE LOCATIONS= 2393

Input Stream for "In-Place Fuel Slump" Model Analysis

```
TMI COLD SHUTDOWN  FUEL SLUMPED PER STRATTON    3180 PPM BORON CR IN

      MIXTURE  NUCLIDE    DENSITY
            1    -92235  4.487018E-04
            2        -2  8.043678E-04
            3        -3  6.776168E-04
            1     92235  2.216038E-02
            2     92235  2.200648E-02
            3     92235  2.193398E-02
            1      8016  4.521808E-02
            2      8016  4.522148E-02
            3      8016  4.522318E-02
            4      8016  4.465258E-02
            5      8016  4.479928E-02
            6      8016  4.488328E-02
           11      8016  4.379008E-02
            4      5010  4.23.758E-04
            5      5010  3.840438E-04
            6      5010  3.183338E-04
           11      5010  3.538008E-05
            4      5011  1.827328E-03
            5      5011  1.658788E-03
            6      5011  1.378938E-03
           11      5011  1.411 30E-04
            4      6012  5.426008E-04
            5      6012  5.107098E-04
            6      6012  4.233158E-04
            4     13027  4.310198E-03
            5     13027  4.311728E-03
            6     13027  4.328558E-03
            7     47107  2.377668E-02
            8     47107  2.377668E-02
            7     47109  2.169278E-02
            7     48000  2.724608E-03
            7     49113  3.471918E-04
            7     49115  7.854518E-05
            8     49102  4.231818E-02
           10     24304  1.748498E-02
           10     25055  1.773448E-03
           10     26101  5.939608E-02
           10     28064  7.720818E-03
           11      1001  6.679908E-02

CROSS SECTIONS READ FROM TAPE

NUCLIDE =      1001   H 1269 F. 1002 T 218 GP 032479(2)
NUCLIDE =      8010   O-10 1273 218NGP 042375 P-3 293K
NUCLIDE =      5011   B-11 1160 WT 1/EST 218NGP P-3 293K RE(042378)
NUCLIDE =      6012   C-12 1274F.1065T 218 GP 030479(7)
NUCLIDE =      8016   O-16 1276 218 GP 030479(7)
NUCLIDE =     13027   AL-27 1193 218 GP 040379(8)
NUCLIDE =     24304   CR 1191 WT 33-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     25055   MN-55 1197 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =     26304   FE 1192 WT 33-304(1/EST) P-3 293K SP=5+4(42375)'
NUCLIDE =     28304   NI 1190 WT 33-304(1/EST) P-3 293K 9-20-77 1/E WT.
NUCLIDE =     40302   ZR-2(1284) SIGP=5+4 NEWXLACS 293K 9-20-77 1/E WT.
NUCLIDE =     47107   AG-107 1138 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =     47109   AG-109 1139 SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =     48000   CD 1281 WT 1/EST 218NGP P-3 293K RE(042379)
NUCLIDE =     49113   IN-113 (449) SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =     49115   IN-115 (449) SIGP=5+4 NEWXLACS 218NGP P-3 293K
NUCLIDE =     92235   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =        -2   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =        -3   U-235 1261 SIGP=5+4 NEWXLACS 218NGP P-3 293K(3)
NUCLIDE =     92238   U-238 218GP RE 9-17-78(1)
                      TMI COLD SHUTDOWN  FUEL SLUMPED PER STRATTON    3180 PPM BORON CR IN
```

Input Stream for "In-Place Fuel Slump" Model Analysis