

The ZEBRA MOZART Programme.

Part 1. MZA and MZB

ZEBRA ASSEMBLIES 11 AND 12

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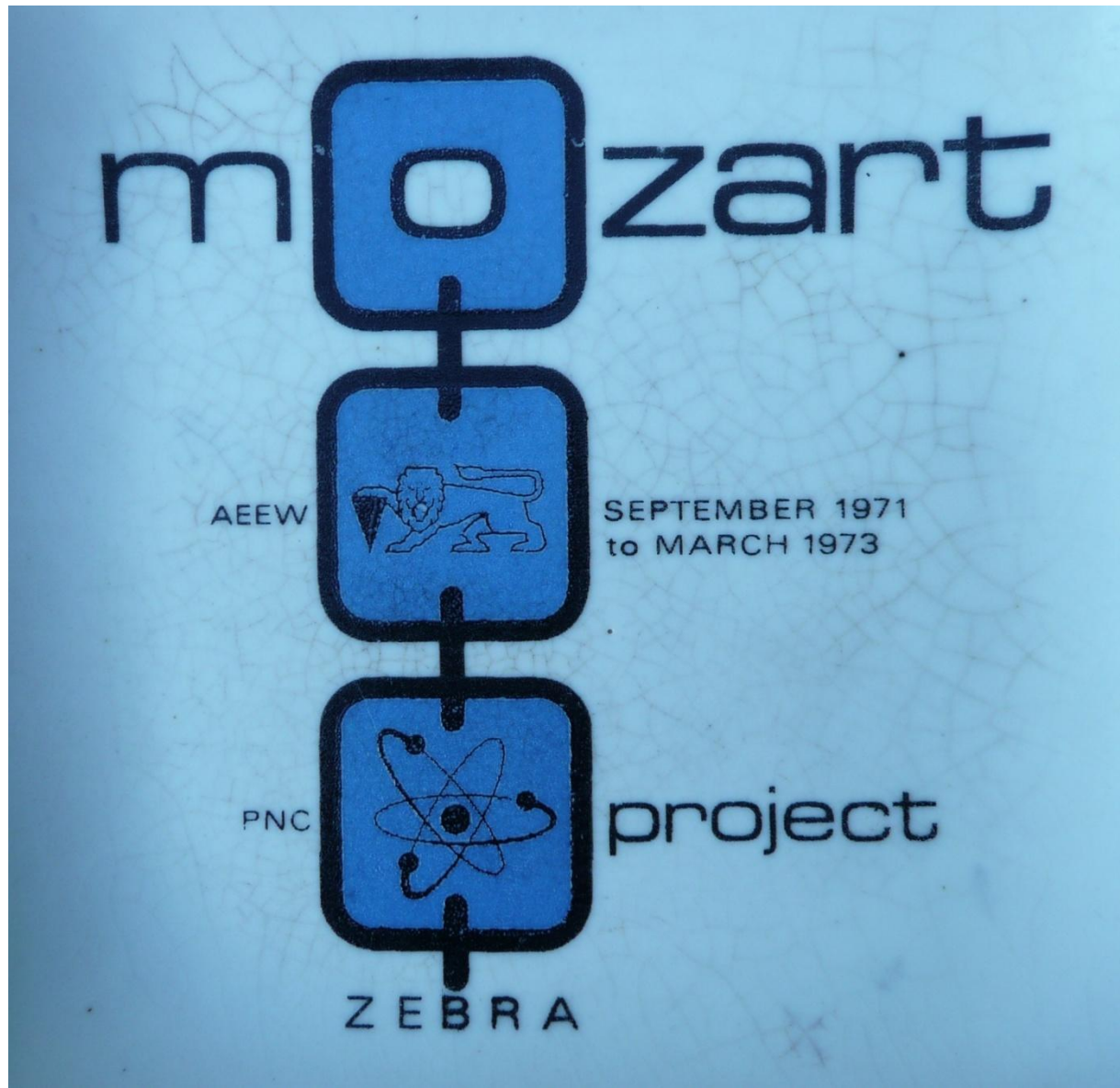
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The shielding series of experiments in the Mozart Programme is not covered in the present document. The programme was documented in the MTN series by:

A F Avery, J Butler, M J Grimstone, A D Knipe, A K McCracken, P C Miller, A Packwood, I C Rickard, Y Sekiguchi.

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Revision of 1 February 2010.

The main difference is the explicit representation of the superlattice grid plates in the detailed models and the removal of the corrections (made in the original 1970s documents and adopted in the previous version) for the effects of these (these corrections are now calculated to have been too large). Also the adjustments made to the k-effective values to be used with the simplified models have been reevaluated. The opportunity has also been taken of including k-effective values calculated using the more recent nuclear data libraries JEFF-3.1 and JENDL-3.3, calculated using MCNP5. MCNP models are included in Appendices.

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**UK-JAPAN FAST CRITICAL EXPERIMENTS IN SUPPORT OF MONJU DESIGN.
THE ZEBRA MOZART PROGRAMME, PART 1.
ASSEMBLIES MZA AND MZB, ZEBRA 11 AND 12.**

IDENTIFICATION NUMBER: ZEBRA-LMFR-EXP-002
CRIT-BUCK-SPEC-REAC-RRATE

KEY WORDS:

fast criticals, LMFR, ZEBRA, MOZART Programme, MONJU design, mixed uranium plutonium dioxide, uranium and plutonium metal, sodium, sodium voiding reactivity, spectral characteristics, reactivity effects, pin/plate reactivity differences, MCNP models, MONK Monte Carlo models.

Summary

The ZEBRA-MOZART Programme of critical assembly measurements was carried out by a joint Japanese-UK team using the ZEBRA Fast Critical Facility at the Atomic Energy Establishment, Winfrith, in the UK, between 1971 and 1973. The programme was in support of the design of the MONJU sodium cooled plutonium-uranium fuelled fast reactor.

The present document is Part 1 and describes the assemblies MZA and MZB. (MZA, the programme of control rod studies, forms Part 2, ZEBRA-LMFR-EXP-003.)

The measurements made in MZA and MZB include the criticality of the cores; axial and radial fundamental mode bucklings; neutron spectra measured using different measurement techniques; spectral indices; the reactivity effects of sodium voiding in both plate and pin geometry; reactivity effects of different materials; reaction rate distributions.

The core and blanket regions were built using materials in plate geometry form. In some experiments there were small regions containing pin geometry elements. These were used for reactivity effects measurements, including sodium voiding.

Three different radial blankets were used in the MZB studies and there was a programme of shielding studies (not described in the present document). The two sector blankets were used to study more realistic representations of oxide fuelled blankets, one containing natural uranium and the other depleted uranium. MCNP and MONK Monte Carlo code models are presented. The results of k-effective values and central spectral indices calculated using different nuclear data libraries are included.

Comparisons of calculations for MZA with those made for ZEBRA Assembly 22 (ZEBRA-LMFR-EXP-001) are informative because the cores of these assemblies are similar in size and composition but have different blanket regions, those of Zebra Assembly 22 being composed of natural uranium.

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The main difference is the explicit representation of the superlattice grid plates in the detailed models and the removal of the corrections (made in the original 1970s documents and adopted in the previous version) for the effects of these (these corrections are now calculated to have been too large). Also the adjustments made to the k-effective values to be used with the simplified models have been re-evaluated. The opportunity has also been taken of including k-effective values calculated using the more recent nuclear data libraries JEFF-3.1 and JENDL-3.3, calculated using MCNP5. MCNP models are included in Appendices.

1. DETAILED DESCRIPTION

1.0 Overview

The ZEBRA-MOZART series of experiments was a joint UKAEA/PNC Japan programme carried out using the zero power critical facility, ZEBRA, at the UKAEA establishment at Winfrith in Dorset, UK. The programme was in support of the design of the Japanese sodium cooled, plutonium-uranium oxide fuelled fast reactor, MONJU, and was based on the design for MONJU current in the early 1970s. The measurements were carried out in 1971, 72 and 73.

The Mozart measurement programme was divided into three phases called MZA, MZB and MZC these being related to MONJU design objectives. The first assembly was MZA, this being ZEBRA Assembly 11, having a simple one-region core designed for basic physics studies in preparation for measurements on assemblies MZB and MZC which were more closely related to the specific neutronics of MONJU design features, having the same core size and control rod design. For example, the neutron spectrum was measured on MZA. Spectral indices and small sample reactivity worths were also measured and a buckling was derived from the reaction rate distribution measurements.

Thanks are expressed here to the members of the joint Japan-UK team who carried out the measurement and analysis programme. Graham Campbell was division head and John Sanders the leader of the Zebra Group. S Kobayashi headed the team from PNC, Japan. The present document is based on the documents written by the following authors of the MTN series and members of the team:

A M Broomfield, B L H Burbidge, M D Carter, C G Campbell, P J Collins, C J Dean,
B Franklin, J P Hardiman, T Ichimori, G Ingram, D Jowitt, S Kobayashi, T Konishi, J Marshall,
C McCombie, J D MacDougall, H Nakamura, M Nakano, W Paterson, J Redfern, I Rickard,
J Samways, J Sanders, Miss P A Smart, Miss M P Smith, R W Smith, J Spanton,
J M Stevenson, A Sugawara, D Sweet, S Swoboda, W H Taylor, H Yoshida

The shielding series of experiments in the Mozart Programme is not covered in the present document. The programme was documented in the MTN series by:

A F Avery, J Butler, M J Grimstone, A D Knipe, A K McCracken, P C Miller, A Packwood,
I C Rickard, Y Sekiguchi.

MZB (ZEBRA Assembly 12) had a two-region core based on the MONJU design but without the control rods. This assembly was built in three versions which differed in the radial blanket arrangement (although the MZC programme could also be considered to form a fourth version of MZB). The radial blanket in Version 3 used the same type of cell as MZA, comprising natural uranium metal plates plus diluent plates. Versions 1 and 2 had 90° sectors which contained natural uranium oxide and depleted uranium oxide plates, respectively, in place of the natural uranium metal. MZB Version 4 (a slightly modified version of MZB/3) then provided the basis for the series of measurements for different patterns of MONJU mockup control rods carried out in the MZC phase.

In the first MONJU core design study, in around 1970, the aim was to achieve a higher breeding ratio, and hence lower doubling time, and a low sodium void reactivity, these being key objectives of the then current design studies generally in the world. Therefore detailed measurements of reaction rate distributions and sodium void reactivity as a function of position were made in MZB. In the sector blankets spatial distributions of reaction rates were emphasized since the neutron spectrum changed significantly as a function of spatial position and the values of C/E (the ratio of calculation to experiment) could be expected to change significantly between the core and the blanket. In order to get a higher breeding gain and to confirm the accuracy of the neutronic tools various types of blanket, including sector regions as large as the available materials and time for reassembly would permit, were considered for the MOZART Programme. The final phase of the programme, MZC, was regarded as an engineering mock-up and contained simulated control

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rods close to the MONJU designs. Reactivity worth and reaction rate distribution measurements were made for a large number of different control rod configurations.

In the MZC phase, (see ZEBRA-LMFR-EXP-003) measurements were made with different patterns of boron and tantalum control rods. Several different enrichments of boron were used in these rods.

MZB was designed to be critical at just below the size of MONJU, with the significant reduction in reactivity required relative to the MONJU fuel enrichments, (to compensate for the absence of control rods), achieved by lowering the enrichments in the two core regions. The primary aim was to match the neutron spectrum, with the sodium and steel fractions being closely similar to those of the MONJU design (see MTN-1). The calculated reaction rate ratios at the core centre and in the outer core were used to assess the spectrum match. Table 1.1 provides a comparison of the MOZART cores with the MONJU core design of that period.

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Quantities	MZA	MZB				MZC	Pre-MONJU (The First Design)
		1	2	3	4		
Date of Program	1971-1972	1972-1972	1972-1972	1972-1972	1972-1972	1972-1973	(around 1970)
Simulated Core Composition	Mixed PuO ₂ /UO ₂	Mixed PuO ₂ /UO ₂	Mixed PuO ₂ /UO ₂	Mixed PuO ₂ /UO ₂	Mixed PuO ₂ /UO ₂	Mixed PuO ₂ /UO ₂	Mixed PuO ₂ /UO ₂
Critical Mass, kg							
²³⁵ U	8		29			29~33	10
²³⁹ Pu + ²⁴¹ Pu	300		788			794~936	1138
Core Volume, litres	565		1778			1804~2058	2340
Core Height, cm	90.1		89.2			89.2	93.0
Core Radius, cm							
Inner Core	44.7		62.2			62.2	68.4
Outer Core	44.7		79.6			79.9~85.3	93.0
Core L/D	0.99		0.56			0.56~0.52	0.52
Core Volume Fractions (Fuel/Na/Steel)	0.36/0.48/0.16		0.37/0.47/0.16			0.36/0.48/0.16	
Core Configuration	Single Zone		Two Zone			Two Zone	Two Zone
Simulated Control Rods, Type	None		None			B ₄ C(Nat) ~B ₄ C(90%) Ta	B ₄ C(Enriched)
Control Rods Inserted	0		0			4 x B ₄ C(Nat) 1xB ₄ C(Enriched), 1xTa	19
Na Filled Rod Positions	0		0			4	19
No. of Pu Spikes	None	None		Dep. PuO ₂ /UO ₂		None	None
Fissile Atom Densities, x10 ²² /cm ³							
Inner Core	0.144		0.096			0.096	0.096
Outer Core			0.144			0.144	0.150
Fertile/Fissile Ratio							
Inner Core	3.95		6.35			6.35	6.35
Outer Core			3.95			3.95	3.95
Radial Blanket							
Composition	U, C, Na	<u>Non-Sector (I.R.B.)</u> U, C, Na		<u>Annular</u> U, C, Na		U, C, Na	Dep. UO ₂ , Na
		<u>Sector (I.R.B.)</u> U, C, Na		Dep. UO ₂ Na	U, C, Na		
		<u>Outer Radial Blanket</u> U, C, Al, O					
Thickness, cm	32		31			~30	~30
Axial Blanket							
Composition							
Thickness, cm	35		35			35	~30
Radial and Axial Reflector							
Composition	Steel		Steel			Steel	SU S
Thickness, cm	~15		~15			~15	~40

Table 1.0 Comparison of the Mozart Cores with the MONJU Core Design of 1970.

MZA had a single, uniform, core region having the composition of the outer core of MZB.

A complete description of the measurements, and the analyses made in the 1970s, can be found in the MTN series of Mozart Technical Notes, available from the OECD NEA on cd or dvd. Some revisions were made to the data in the course of the programme of measurements. The cross-section set used in the UK analyses of the measurements was changed from FGL4 (or FD4) to FGL5 and the delayed neutron data were revised. The reactivity scale used towards the end of the programme was thus changed and the earlier reactivity measurements have been revised to be consistent with this later scale. A further change was to use a reactivity scale normalised to the calculated worth of plutonium in the final interpretation of the MZC control rod measurements but this renormalisation has not been made in the present documentation. Other changes were to the fission rate distribution measurements to take account of revisions to the compositions of trace isotopes in the detectors.

The measurements which are recommended as reactor physics benchmarks are the criticality of the MZA and MZB cores, reaction rate ratio measurements, reaction rate scans, and the reactivity worth measurements (including the sodium voiding and material worth measurements). The spectrum measurements made using different techniques are presented in detail and their potential use is discussed. The measurements of the fundamental mode bucklings made in MZA are also summarised.

Comparisons of calculations for MZA with those made for ZEBRA Assembly 22 (ZEBRA-LMFR-EXP-001) are informative because the cores of these assemblies are similar in size and composition but have different blanket regions, those of Zebra Assembly 22 being composed of natural uranium.

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Description of the ZEBRA Zero Power Critical Assembly Facility

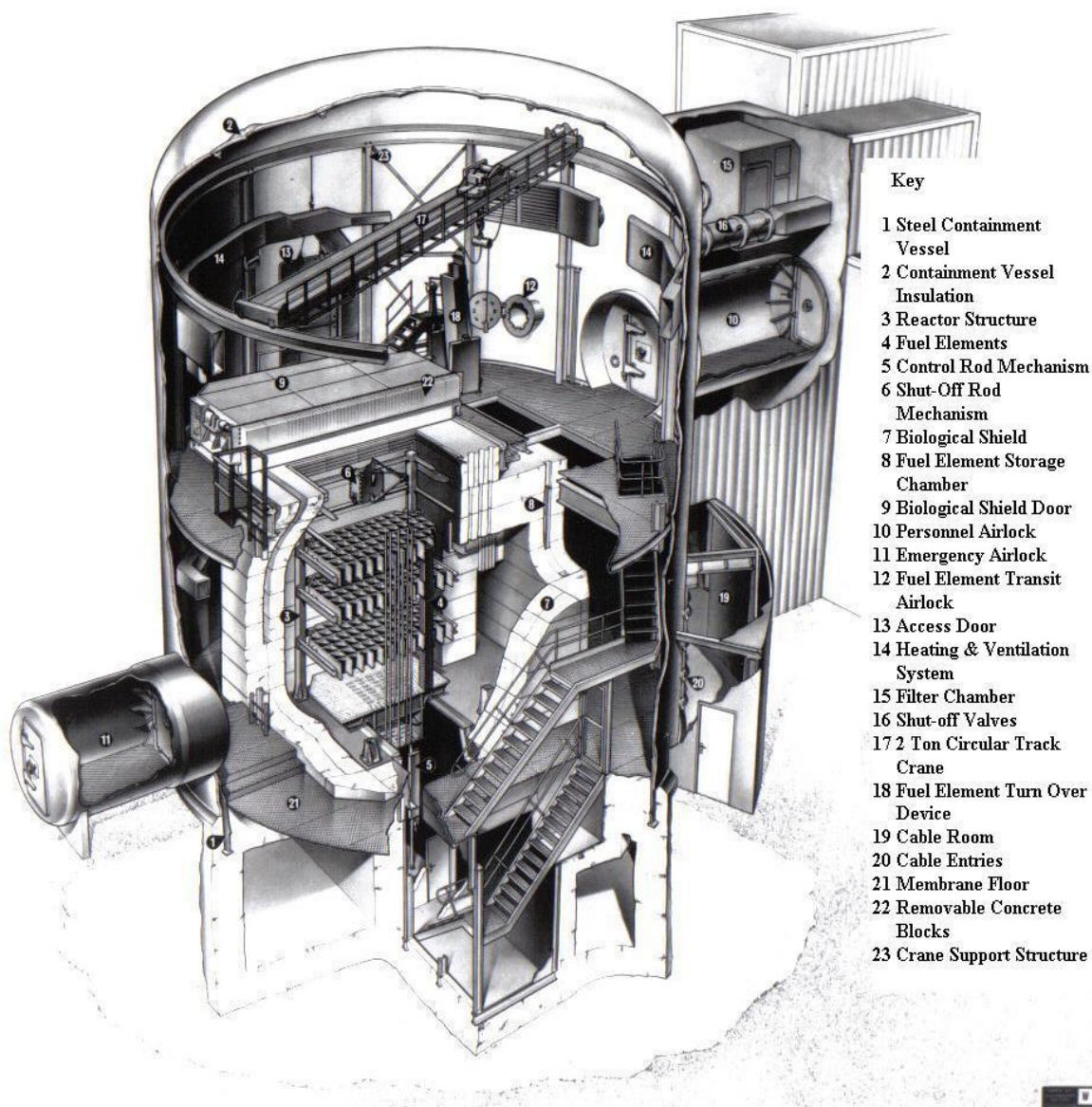


Figure 1.1 A Perspective View of the ZEBRA Critical Assembly Facility.

The cut-away reveals the central axial section of the facility.

(With thanks to Bernard Franklin and Atsushi Zukeran, for providing these illustrations of ZEBRA)

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ZEBRA (the Zero Energy Breeder Reactor Assembly) was located at the Winfrith Atomic Energy Establishment, AEEW, of the United Kingdom Atomic Energy Authority, UKAEA, and operated from 1962 to 1982. It was used to validate fast reactor neutronics methods and nuclear data.

The facility was housed in a cylindrical steel containment building, as shown in Figure 1.1. Figure 1.2 shows an element being loaded into the reactor and a vertical section is shown in Figure 1.3. Interconnected to the containment building were the fuel stores, the fuel element assembly room, fuel element stores, control room, laboratories and offices.

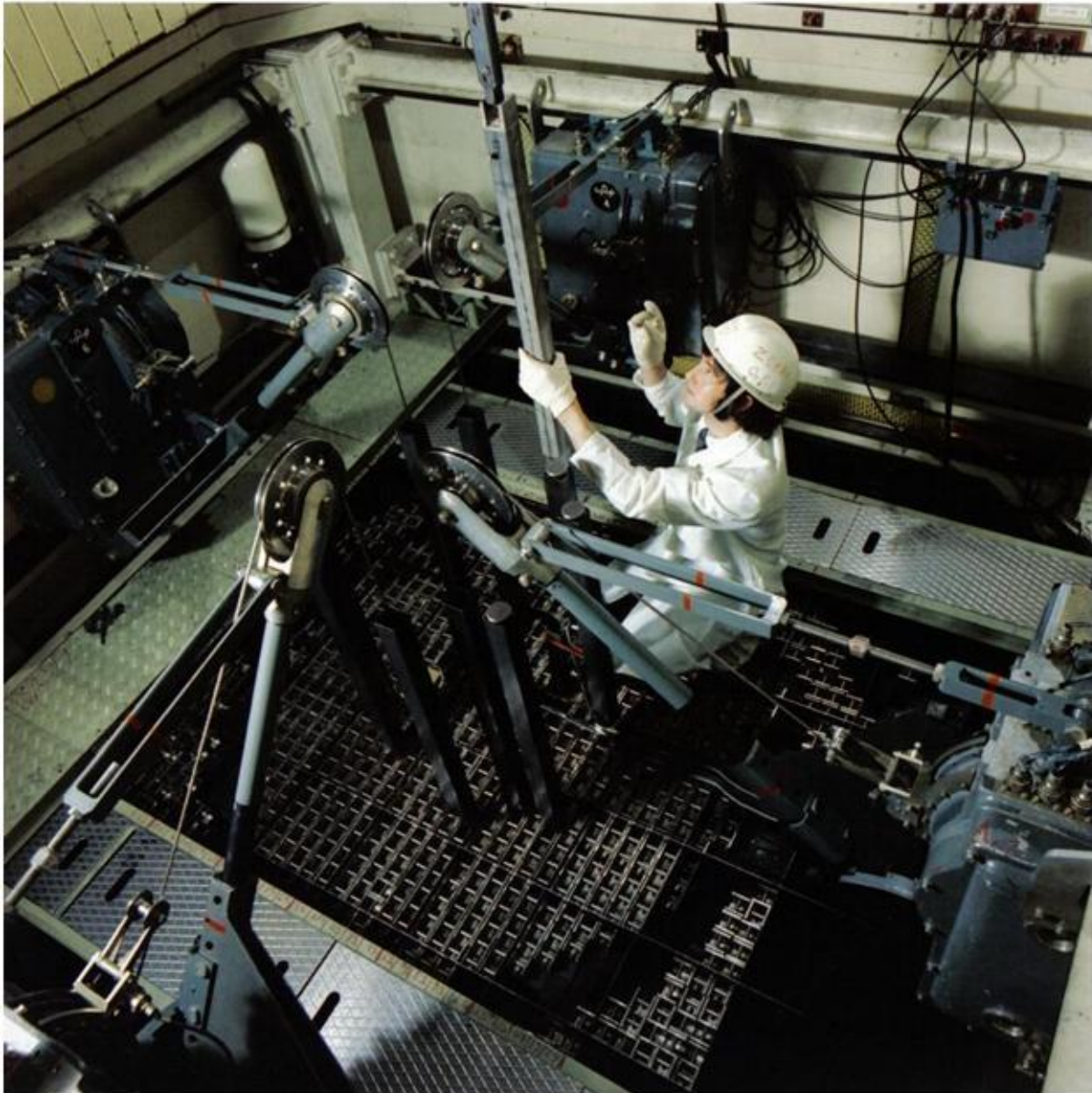


Figure 1.2 View of an Element being Loaded into a ZEBRA Assembly.

The figure shows the tops of the elements and the upper super-lattice grid (within which are the groups of 5x5 elements), with one element being loaded into the assembly. The cable mechanisms of the 4 control rods which are operated from above the assembly can also be seen.

The reactor could accommodate cores, blankets and shielding assemblies with a wide range of compositions and sizes up to a 3 m cube and containing up to about one ton of fissile material (Pu239, Pu241 and U235). The component materials were stacked in thin-walled steel sheaths to form the elements, nominally about 5 cm x 5 cm square and 3 m long, as shown in Figure 1.4. The elements were located in a bed-plate and supported vertically in a closely-packed array. The core region materials were in either plate form or consisted of mini-calandria containing a 4x4 array of pins.

The plate elements were built using 5 cm square plates having a range of thicknesses. Enriched uranium, natural uranium oxide, plutonium metal and mixed UPuO_2 fuel plates were used together with a wide range of diluent materials including sodium, steel, aluminium and graphite. Thicker plates were used in the blanket regions. Lateral support for groups of 5x5 elements was provided at their tops and at two intermediate positions by thin steel lattice plates. Tubular steel-spacers inside the fuel elements enabled cores to be built at various heights above the bed-plate. Similar spacers were used to fill the remainder of the element, to prevent movement of the plates when the element was being transported.

Figure 1.3 shows the dimensions of the reactor regions (in feet and inches). The top of the upper super-lattice grid plate is 3 m (~9ft 10in) above the top of the bedplate and the elements, which are 3 m long and slot into the bedplate, reach up to near the top of the upper super-lattice grid plate (being below this by the height of the location spigot at the bottom of the element). The tops of the elements and the upper super-lattice grid plates (surrounding the groups of 5x5 elements) can be seen in Figure 1.2. The core sections of the elements are located between the lower two super-lattice grids, these being 100.4 cm apart and having a height of 30.4 cm and thickness of 0.25 cm.

Concrete radial shielding surrounds the assembly structure, providing a square space about 3.5 m x 3.5 m within. The vertical steel structure which supports the bedplate and superlattice grid plates is in the four corners of this square space. This concrete radial biological shield includes places for the temporary storage of elements and there is a corridor within it with access to the assembly from the side, as can be seen in Figure 1.1.

A computer controlled automatic loading machine was used to load the very large numbers of plates which were required into the element sheaths, thus minimising the risks of loading errors and the exposure of staff to radiation during the loading process. The markings on the edges of the plates were identification marks for the loading process and all the plates in an element had the same orientation, as shown in Figure 1.4.

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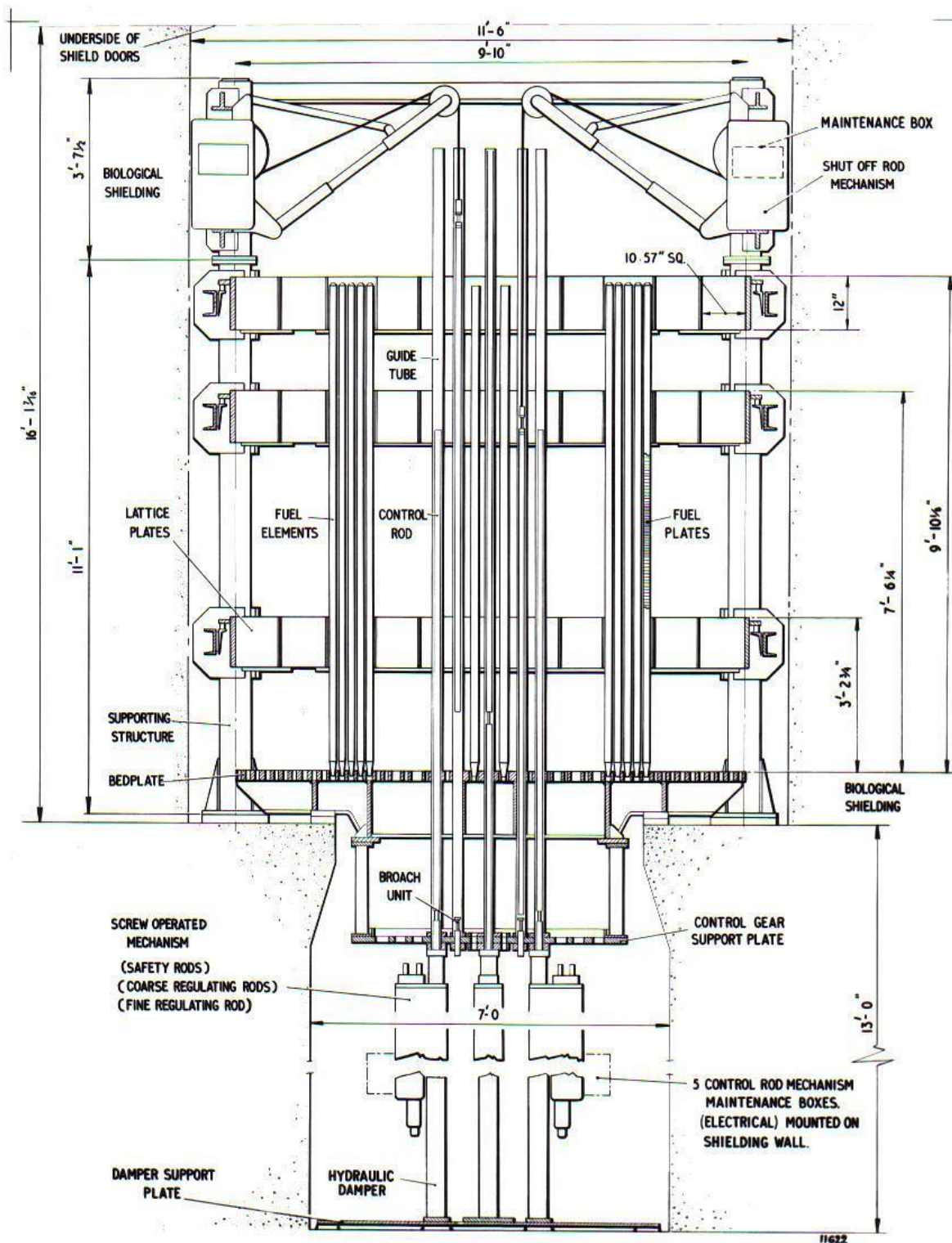


Figure 1.3 Vertical Sectional View of the ZEBRA Facility.

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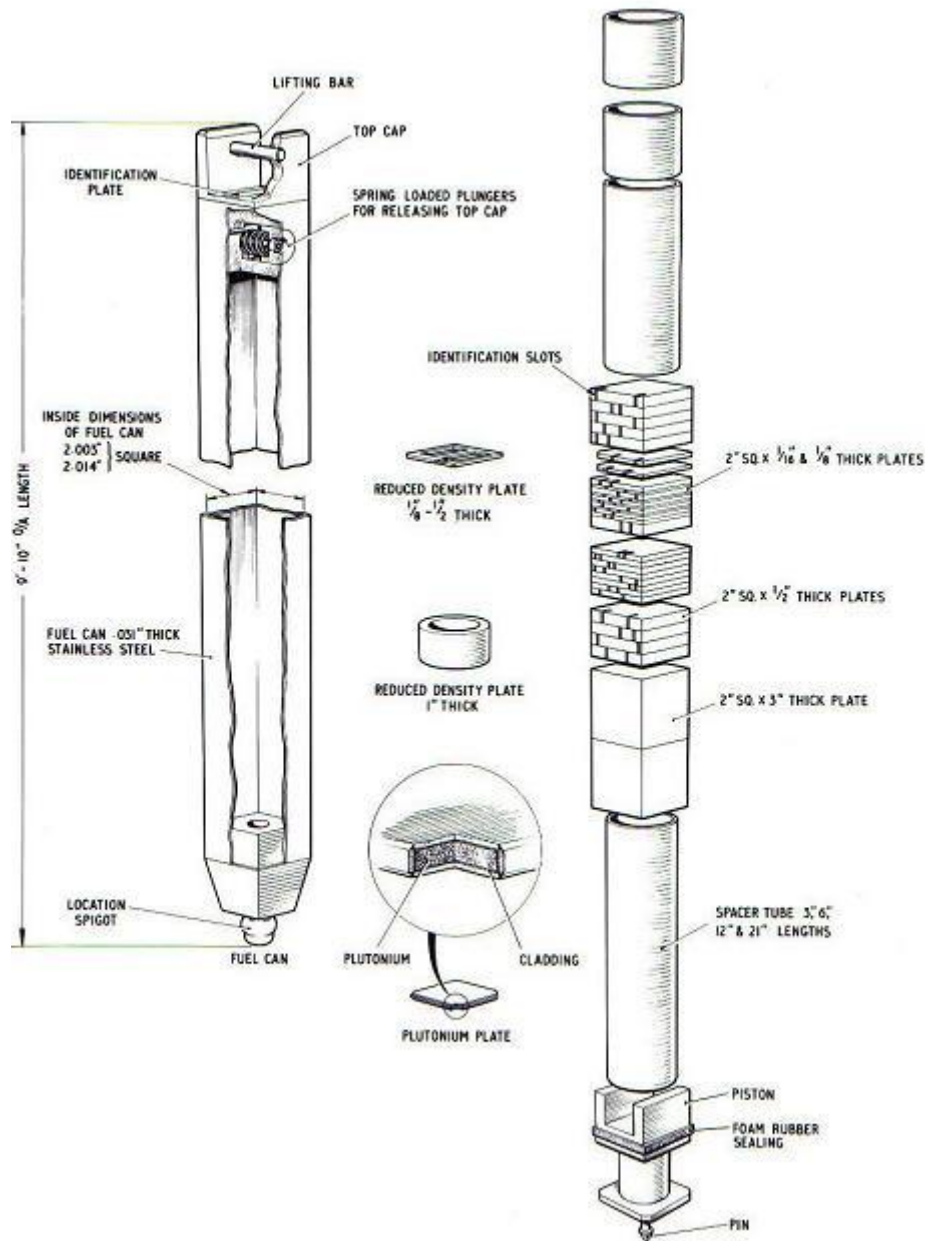


Figure 1.4 Diagram of a Fuel Element Containing Materials in Plate Form
(dimensions in inches).

A linear accelerator and pulsed neutron producing target, together with 50 m and 200 m flight tubes, were available for making time-of-flight spectrum measurements on beams extracted from the core centre. Spectrum measurements using other techniques were also made, both in core and in extracted beams. A view of the flight tube is shown in Figure 1.5.



Figure 1.5 General view of the ZEBRA Facility showing the Flight Tube used for Time-of-Flight Spectrum Measurements.

The reactor was controlled by means of nine control rods, using two different types of control rod mechanism, as can be seen in Figure 1.3. Four rods, the shut-off rods, were actuated by cable-type mechanisms located above the reactor. The remaining five rods were actuated by screw-type mechanisms located in the pit below the reactor bed-plate. These five rods comprised two safety-rods, two coarse regulating rods and a fine regulating rod. When the reactor was at power, the safety rods and shut-off rods were fully raised, while the regulating rods were used to balance the power level. The location of the control rods on the bed-plate, and their "fully raised" positions were variable. All the rods operated in guide tubes with the same external dimensions as normal elements. The core sections of control rods contained a similar plate arrangement to ordinary core elements. When required to meet the shut-down reactivity requirements, as in the case of the Mozart cores, boron absorber was loaded above the core regions of the rods. These absorber regions were in the core when the rods were dropped.

Reactivity changes are measured in terms of the balancing changes in the insertion of regulating control rods and are expressed in terms of "standard centimetres" of movement of the reference regulating rod. A "standard cm." is the worth per cm. of insertion at the point of maximum change in reactivity with insertion. The "std. cm." is then calibrated by kinetics measurements, analysed using the reference set of delayed neutron data, to give reactivities on an absolute scale.

Shielding was provided to enable personnel to work in the containment building when the reactor was operating at several hundred watts. The top shielding consisted of two motorised concrete doors, which, when fully open, allowed access to every lattice position in the reactor. Hung between the doors were removable shielding blocks which permitted limited access to the core for experimental purposes when the reactor was operating. The underside of the doors is over 1.5 m above the top of the elements, the space between being occupied by the control rod mechanisms for the four shut-off rods which are operated from above the assembly.

A 10 curie radium - beryllium source was available for use in cores when spontaneous fission was insufficient to provide an adequate neutron density for monitoring purposes when the reactor was shut-down. The source was moved into the reactor at shut-down and was motored to a position outside the reactor when the reactor was at power. The location of the source mechanism was variable.

1.1 Description of the Critical and/or Subcritical Configurations

1.1.1 Overview of Experiment

The measurements were made in the ZEBRA facility between 1971 and 1973 as the joint PNC, Japan - UKAEA "Mozart Programme" of measurements. The measurements were in three phases called MZA, MZB and MZC. The measurements in MZA and MZB are reviewed in the present document and the critical core, reaction rate ratio, reaction rate scan, and reactivity worth measurements are recommended as reactor physics benchmarks. The neutron spectrum measurements are also summarised.

Outline Description of Experimental Configurations

The MZA Assembly.

The reference version of MZA, with 213 core elements, is shown in plan view in Figure 1.6 and in a simplified cylindrical representation of the upper half of the assembly in Figure 1.7. The location of an element on the base plate is denoted by the X and Y coordinates, (X,Y), the centre of the core being the position (50,50) (also denoted as 50-50 in some documents).

The core is surrounded by a region of radial blanket elements outside which is a region of steel bars. There are about 6 rings of radial blanket elements surrounding the core and about 3 rings of steel bars surrounding these. Beyond the steel bars the approximately 3m cube volume is empty, apart from the super-lattice grid plates which hold the groups of 5x5 elements (see Figure 1.3).

Above and below the core region there are the upper and lower axial blanket regions, and there are plenum regions (low density steel regions simulating the plenum regions of a fast reactor, these being extensions of the fuel pins, voided of fuel material, for accommodating the fission gas release from the fuel) above and below these. Above and below the plenum regions are cylindrical mild steel spacer tubes which hold the array of core, blanket and plenum cells in position in an element (see Figure 1.4).

The 213 elements in the core form a symmetrical pattern and the radial blanket and reflector elements also follow this quadrant symmetry. Axially the core cells are not precisely symmetrical but the approximation resulting from treating the core as axially symmetrical is expected to be negligibly small. The basic pattern of plates comprising a core cell is shown in Table 1.1. It contains 2 Plutonium Metal plates, 4 UO₂ plates, 6 Sodium plates 1 Graphite plate and 1 Stainless Steel plate. It is these latter two plates which introduce the axial asymmetry into the cell. (In simplified models these two plates have been treated as one plate, having the average compositions and dimensions of the two plates.)

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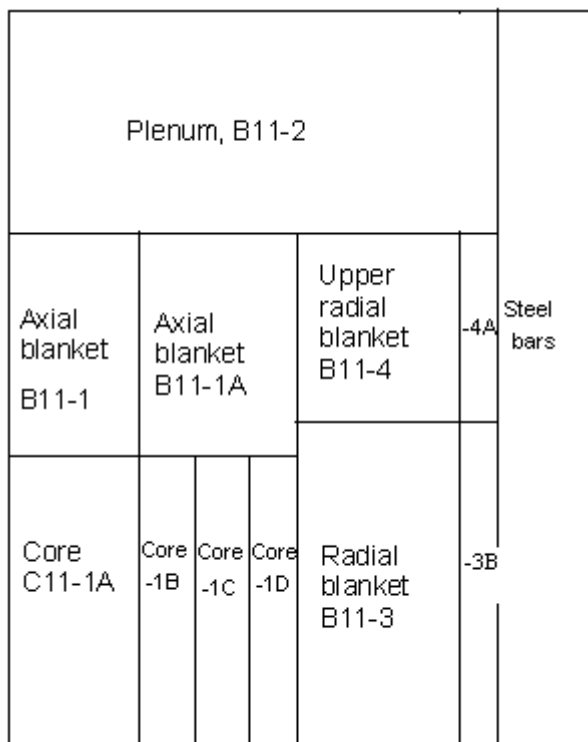
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67			
67																X	X	X	X	X															67			
66															X					X																66		
65											X	X	X	X							X	X	X	X												65		
64									X	X							OR	OR	OR							X	X									64		
63								X					OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR				X									63		
62							X				OR	OR													OR	OR			X								62	
61						X				OR	OR															OR	OR			X							61	
60					X					OR																	OR				X						60	
59				X				OR																				OR				X					59	
58				X			OR										D	D	D										OR			X				58		
57			X			OR	OR							D	D	D	C	C	C	D	D	D							OR	OR			X				57	
56			X			OR							D	D	C	4	C	C	C	C	C	D	D						OR			X					56	
55			X		OR							D	C	C	C	C	B	B	B	C	C	C	C	D							OR	X					55	
54			X		OR						D	D	C	6	B	B	B	B	B	B	B	2	C	D	D					OR	X						54	
53		X			OR						D	C	C	B	B	A	A	A	A	A	B	B	C	C	D					OR			X				53	
52	X				OR						D	C	C	B	A	A	A	A	A	A	B	B	C	8	D					OR				X			52	
51	X				OR	OR				D	C	C	B	B	A	A	A	A	A	A	A	B	B	C	C	D					OR	OR			X			51
50	X				OR	OR				D	C	C	B	B	A	A	A	A	A	A	A	B	B	C	C	D					OR	OR			X			50
49	X				OR	OR				D	C	C	B	B	A	A	A	A	A	A	A	B	B	C	C	D					OR	OR			X			49
48	X				OR					D	7	C	B	A	A	A	A	A	A	A	A	B	C	C	D						OR				X			48
47		X			OR						D	C	C	B	B	A	A	A	A	A	B	B	C	C	D						OR			X				47
46			X		OR						D	D	C	1	B	B	B	B	B	B	B	5	C	9	D						OR	X					46	
45			X		OR							D	C	C	C	C	B	B	B	C	C	C	C	D							OR	X					45	
44			X			OR							D	D	C	C	C	C	C	3	C	C	D							OR			X				44	
43			X			OR	OR							D	D	D	C	C	C	D	D	D								OR	OR		X				43	
42				X			OR										D	D	D											OR			X				42	
41				X				OR										D	D	D											OR			X			41	
40					X				OR																			OR					X				40	
39						X				OR	OR															OR	OR				X						39	
38							X				OR	OR													OR	OR				X							38	
37								X					OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR				X								37		
36									X	X							OR	OR	OR								X	X									36	
35										X	X	X	X									X	X	X	X												35	
34															X						X																34	
33																X	X	X	X	X																	33	
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67			

Figure 1.6 The MZA Assembly Loading Pattern (The 213 element Reference Core).

The Core elements are denoted by A, B, C, D and the control rods are numbered 1 to 9. The outer ring of *Italic OR* elements denotes the outer ring of blanket elements, these being B11-1B elements, the positions between the core and the OR elements being occupied by B11-1 blanket elements.

X denotes the outer ring of steel bars, the space between the OR blanket elements and the outer X boundary being occupied by these steel bars

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Element	Central Axial Region Cells	Upper Axial Region Cells	Upper Plenum Cells
Core: C11-1A	12 x C11-1A	4 x B11-1	B11-2
Core: C11-1B	12 x C11-1B	4 x B11-1A	B11-2
Core: C11-1C	12 x C11-1C	4 x B11-1A	B11-2
Core: C11-1D	12 x C11-1D	4 x B11-1A	B11-2
Radial Bkt.: B11-1	20 x B11-3	3 x B11-4	B11-2
Radial Bkt.: B11-1B	20 x B11-3B	3 x B11-4A	B11-2

Figure 1.7 Simplified Cylindrical Representation of the Upper Half of the MZA Assembly.

(The dimensions are described in Section 3.1.2.)

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Plate Number	Core Cell Plate contents	Plate Identifiers in Cell C11-1A
14	Sodium	NASTBR4
13	UO ₂	UO24R4
12	Sodium	NASTBR4
11	Plutonium Metal	PUV8
10	Graphite	GI8
9	UO ₂	UO24R4
8	Sodium	NASTBR4
7	Sodium	NASTBR4
6	UO ₂	UO24R4
5	Stainless Steel	STSTBR8
4	Plutonium Metal	PUV8
3	Sodium	NASTBR4
2	UO ₂	UO24R4
1	Sodium	NASTBR4

Table 1.1 Arrangement of Plates in the Core Cells of MZA.
(The plate numbering is used in reaction rate scan measurements.)

Four different elements were used in the MZA core: C11-1A, C11-1B, C11-1C and C11-1D, these also being the identifiers of the core region cells. They differ in the plutonium metal plates and also in the sodium plates used. The plutonium plates are respectively: PUV8, PUVI8, PUVII8 and PUVIII8. The sodium plate used in the C11-1A element is NASTBR4 and in the other three elements is NASTDL4. The effects of these differences are very small, however.

The dimensions of the components are described in detail in Section 1.1.2 and the compositions in Section 1.1.3.

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Plate Number	Axial Blanket Cell Plate Contents	Plate Identifiers in Cell B11-1
20	Sodium	NASTBR4
19	Uranium metal	U8
18	Graphite	GI8
17	Sodium	NASTBR4
16	Stainless Steel	STSTBR8
15	Uranium metal	U8
14	Sodium	NASTBR4
13	Graphite	GI8
12	Sodium	NASTBR4
11	Uranium metal	U8
10	Stainless Steel	STSTBR8
9	Sodium	NASTBR4
8	GI8	GI8
7	Sodium	NASTBR4
6	Uranium metal	U8
5	Stainless Steel	STSTBR8
4	Sodium	NASTBR4
3	Graphite	GI8
2	Uranium metal	U8
1	Sodium	NASTBR4

Table 1.2 Arrangement of Plates in the Axial Blanket Cells of MZA

The axial blanket cells contain 5 Natural Uranium Metal plates, 8 Sodium plates, 3 Stainless steel plates and 2 Graphite plates, again with differences in the sodium plate used in the different versions.

Plenum Materials	B11-2	B11-2A
	(upper plenum)	(lower plenum)
Aluminium	ALSC3	ALSC3
Mild Steel	MST1	MST3
Aluminium	ALSC3	ALSC3
Mild Steel	MST3	MST1
Aluminium	ALSC3	ALSC3

Table 1.3 Arrangement of Plates in the Axial Plenum Cells

There are 12 core cells in an element, 4 upper and 4 lower axial blanket cells. Above and below the axial blanket regions are the upper and lower plenum regions containing 3 blocks of aluminium (ALSC3 where the 3 denotes 3 inches), a mild steel plate (MST1) and a mild steel block (MST3) as shown in Table 1.3. The MST3 block is about three times thicker than the plate, having about the same thickness as the aluminium

block (~3 inches ~7.6 cm). Above and below these are the mild steel spacer tubes.

Two different radial blanket elements were used, B11-1 and B11-1B, the difference again being in the sodium plate used, and the element sheath material, and the effect of the difference is again very small. The major part of the blanket has the B11-1 element with the NASTBR4 sodium plate, whereas the outer region B11-1B elements contain the NASTDL4 plate, and a mild steel sheath in place of the stainless steel sheath used in the rest of the assembly. The central axial section of the element (corresponding to the core region) contains the cells B11-3 and above and below this section (corresponding in axial position to the axial blanket region) is the B11-4 cell. These are shown in Table 1.4. Above and below this are the same plenum regions and spacer tubes as used in the core elements.

All the core elements and also the radial blanket elements, B11-1, use stainless steel sheaths, whereas the B11-1B radial blanket elements use mild steel sheaths.

The axial region of the radial blanket corresponding in height to the core region contains natural uranium metal, sodium, graphite, stainless steel and mild steel plates. Above and below this axial region are regions containing aluminium plates in place of the sodium plates and outside these are the plenum regions.

The effect of using just a single type of core element (C11-1A) and radial blanket element (B11-1) in the calculational model is evaluated in Section 2.

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Plate Number	Radial Blanket Central Section	B11-3	Radial Blanket Upper and Lower Sections	B11-4
10	Sodium	NASTBR4	Aluminium	ALG8
9	Graphite	GII8	Mild Steel	MST8
8	Mild Steel	MST8	Graphite	GII8
7	Sodium	NASTBR4	Aluminium	ALG8
6	Graphite	GII8	Aluminium Oxide	AL2O34
5	Uranium Metal	U2	Uranium Metal	U2
4	Stainless Steel	STSTDL8	Aluminium	ALG8
3	Graphite	GII8	Aluminium	ALG8
2	Sodium	NASTBR4	Graphite	GII8
1	Graphite	GII8	Aluminium	ALG8
			Mild Steel	MST2
			Aluminium Oxide	AL2O34
			Graphite	GII8
			Aluminium	ALG8
			Uranium Metal	U2
			Aluminium	ALG8
			Graphite	GII8
			Aluminium Oxide	AL2O34
			Aluminium	ALG8
			Aluminium	ALG8

Table 1.4 Arrangement of Plates in the Radial Blanket Central Region (B11-3) and the Upper/Lower Cells (B11-4).

The Assembly MZB

Zebra 12, or MZB, was a clean mock-up of the then current design of the MONJU power reactor and formed the second assembly in the MOZART programme. The assembly was built in three versions which differed in aspects of the radial blanket. Version 3 used essentially the same type of radial blanket as MZA, containing natural uranium metal plates, whereas Versions 1 and 2 had sectors containing natural uranium oxide and depleted uranium oxide plates respectively. There was also MZB Version 4 but this was essentially just a repositioning of one of the ZEBRA control rods in preparation for the MZC MONJU Mock-up Control Rod programme (see ZEBRA-LMFR-EXP-003). Beyond the sector blanket was a graphite reflector region and beyond this a stack used for shielding experiments.

The core had two radial regions, an inner core region and an outer region which contained MZA core elements (supplemented by elements having an equivalent design). The control rods were located in the inner core (and in the calculational model they are replaced by core elements, making a total of 677 core elements). The element loading of the Inner Core, Outer Core and Radial Blanket are shown in Figures 1.8B to 1.10. This reference version of the core has a symmetrical array of 413 inner core elements (Figure 1.8B).

Plate Number	MZB Inner Core Cell	Cell C12-30A
14	Sodium	NASTDL4
13	Uranium Oxide	UO23R4
12	Sodium	NASTDL4
11	Mixed U-Pu Oxide	PUIV4
10	Sodium	NASTDL4
9	Uranium Oxide	UO23R4
8	Stainless Steel	STSTBR8
7	Sodium	NASTDL4
6	Uranium Oxide	UO23R4
5	Sodium	NASTDL4
4	Plutonium Metal	PUIX8
3	Sodium	NASTDL4
2	Uranium Oxide	UO23R4
1	Sodium	NASTDL4

Table 1.5 The MZB Inner Core Cell

The arrangement of the plates in an Inner Core cell is shown in Table 1.5. It comprises a mixed U-Pu Oxide plate and a Plutonium Metal plate, 4 Uranium Oxide plates, 7 Sodium plates, and a Stainless Steel plate. Axial symmetry is lost by there being 11 core cells in an inner core element and the asymmetry of the cell itself. The axial blanket and plenum regions are the same as those used in the MZA elements

Plenum, B11-2			Steel bars
Axial blanket over inner core, B12-30 and B12-30B	Axial blanket over outer core, B11-1 to 1AG	Upper radial blanket B11-4	
		Radial Blanket B11-3	
Inner Core C12-30A to D	Outer Core C11-1A to G		

Figure 1.8A Simplified Cylindrical Geometry Half-height Model of MZB/3

The outer core contains 264 elements arranged in a pattern which gives 90° rotational symmetry to the core (having 4 elements more than a model having symmetry by reflection), see Figure 1.9. The axial blanket regions are those used in MZA, or are equivalent ones, and most of the radial blanket elements are also those used in MZA, or are similar. However, in Version 1 and 2 of MZB there is also a radial blanket sector having modified characteristics (see Figure 1.10), Version 1 sector comprising elements containing natural uranium oxide plates and the Version 2 sector elements containing depleted uranium oxide plates (in place of the radial blanket elements containing natural uranium metal plates present in Version 3). Consequently Versions 1 and 2 of the assembly are not symmetrical, although they can be approximated as symmetrical about the north-south axis (or central Y axis, the diameter through the sector blanket).

The radial blanket is surrounded by steel bars, in a similar way to MZA. The regions containing steel bars extend radially in the central region of the assembly (by the numbers of positions indicated in the Figure). The graphite reflector region (the bottom region in Figure 1.10, comprising the elements B12-33 and B12-31 which contain graphite blocks) is present in all three versions of MZB and the arrangement of the core, radial reflector and steel bars is the same in all three versions (apart from the radial blanket elements comprising the sector).

This assembly formed the basis for the later MZC phase of measurements using arrays of MONJU Mock-up boron and tantalum control rods (this phase is described in ZEBRA-LMFR-EXP-003).

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	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67		
67																																				67	
66																																				66	
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61															D	D	D	D	D	D	D														61		
60													D	D	D	D	D	D	D	D	D	D	D												60		
59												D	D	D	D	G	G	G	G	G	D	D	D	D											59		
58										D	D	D	D	G	B	B	B	B	B	B	B	G	G	D	D	D									58		
57										D	D	G	B	4	B	B	B	B	B	B	B	2	B	G	D	D									57		
56									D	D	G	B	B		A	A	A	A	A	A	B		B	B	G	D	D								56		
55									D	D	7	B	B	B	A	A	A	A	A	A	A	A	A	B	B	B	5	D	D							55	
54									D	D		B	B	A	A	A	A	A	A	A	A	A	A	B	B		D	D							54		
53									D	D	D	B	B	B	A	A	A	A	A	A	A	A	A	A	A	B	B	D	D	D						53	
52									D	D	G	B	B	A	A	A	A	A	A	A	A	A	A	9	B	B	G	D	D							52	
51									D	D	G	B	B	A	A	A	A	A	A	A	A	A	A	A	B	B	G	D	D							51	
50									D	D	G	B	B	A	A	A	A	A	A	A	A	A	A	A	B	B	G	D	D							50	
49									D	D	G	B	B	A	A	A	A	A	A	A	A	A	A	A	B	B	G	D	D							49	
48									D	D	G	B	B	A	A	A	A	A	A	A	A	A	A	A	B	B	G	D	D							48	
47									D	D	D	B	B	A	A	A	A	A	A	A	A	A	A	B	B	B	D	D	D							47	
46									D	D	6	B	B	B	A	A	A	A	A	A	A	A	A	B	B	8	D	D								46	
45									D	D		B	B	B	A	A	A	A	A	A	A	A	B	B	B		D	D								45	
44									D	D	G	B	B	1	B	A	A	A	A	A	A	3	B	B	G	D	D									44	
43										D	D	G	B		B	B	B	B	B	B	B		B	G	D	D									43		
42										D	D	D	G	G	B	B	B	B	B	B	B	G	D	D	D	D										42	
41												D	D	D	D	G	G	G	G	G	D	D	D													41	
40													D	D	D	D	D	D	D	D	D	D	D													40	
39															D	D	D	D	D	D	D															39	
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	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67		

Figure 1.8B MZB Inner Core Elements.

A denotes C12-30A
B denotes C12-30B
G denotes C12-30BG
D denotes C12-30D

Control rod FR9 was moved from position 56-52 to 48-60 in MZB/4 and replaced by an element C12-30A.

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	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	
67																																				67
66																																				66
65																																				65
64														G	F	D	D	D	D	D	F	G													64	
63											D	D	C	D	C	C	C	C	C	C	D	D	F	G											63	
62									G	D	C	C	B	A	B	B	A	A	A	B	B	B	C	C	D	F									62	
61								D	C	C	B	A	A								A	A	B	C	D	D									61	
60							D	C	E	B	A											A	B	B	C	D									60	
59						D	C	B	A	A													A	A	B	C	D								59	
58					F	D	C	A																		A	B	D	G						58	
57				G	D	C	B	A																		A	B	C	D						57	
56				F	C	B	A																				A	B	C	D					56	
55				D	C	A																						A	C	D					55	
54			G	D	B	A																						A	B	D	G				54	
53			F	C	B																								B	D	F				53	
52			D	C	B																								B	C	D				52	
51			D	C	A																								A	C	D				51	
50			D	C	A																								A	C	D				50	
49			D	C	A																								A	C	D				49	
48			D	C	A																								A	C	D				48	
47			F	C	B																									B	C	F			47	
46			G	D	B	A																							A	B	C	G			46	
45				D	C	A																								A	C	D			45	
44				D	C	B	A																						A	B	C	F			44	
43				D	C	B	A																					A	B	C	D	G			43	
42				G	C	B	A																					A	C	D	F				42	
41					D	C	B	A	A																	A	A	B	C	D				41		
40					D	C	B	B	A																A	B	E	C	D					40		
39						D	D	C	B	A	A											A	A	B	C	C	D							39		
38							F	D	C	C	B	B	B	A	A	A	B	B	B	C	C	D	G											38		
37							G	F	D	D	C	C	C	C	C	C	C	C	C	D	D	D												37		
36										G	F	D	D	D	D	D	F	G																36		
35																																			35	
34																																			34	
33																																			33	
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	

Figure 1.9 MZB Outer Core Elements

A denotes C11-1A
D denotes C11-1D

B denotes C11-1B
E denotes C11-1BG

C denotes C11-1C
F denotes C11-1DG

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[illegible]

Figure 1.10 MZB Version 1 Radial Blanket with the Natural Uranium Oxide Radial Blanket Sector

V denotes B11-5

U denotes B12-33

Steel bars, denoted by s , surround the inner radial breeder (see Figure 2 in MTN-18). These extend sideways, in the central area, beyond the area shown, by the numbers of bars indicated in the rows (see Fig. 1.21).

MZB Version 2 contains the depleted uranium oxide elements B12-32 in the radial blanket sector.

ZEBRA Control Rods

Measurements were made to enable simplifications to be made to the calculational models used to calculate the criticality of the assemblies, and properties measured in central regions of the core, by replacing the nine control rods by core elements. However, for the calculation of the axial reaction rate scans (in particular) account should be taken of an asymmetry introduced by the asymmetrical loadings of the control rods, with an absorber section being at the top ends of the rods. For this application details of the control rod compositions are required.

The materials used in the control rods were chosen to match the core and blanket regions of the neighbouring elements but with a boron absorber section above the narrow upper axial blanket region. The control rods used in MZA (Zebra 11) were single elements while in MZB (Zebra 12) they were double elements, apart from the fine control rod, FR9, which was a single element.

The control rods were loaded so that when raised the centre line of the core section coincided with the centre line of the core section of the core elements. When lowered, the centre line of the boron absorber section took that position.

Details of the dimensions and compositions are given in the following sections, Sections 1.1.2 and 1.1.3.

1.1.2 Detailed Description of the Geometry of the Experimental Configurations

The assemblies consist of arrays of elements located on a horizontal bedplate by spigots at the base of the element tubes (or sheaths). These element tubes hold the stacks of plates or other components (such as the mini-calandria which contain 4x4 arrays of pins). Elements are held in groups of 5x5, separated by a small gap of 0.2665 cm, by the mild steel superlattice grids of width 0.25 cm, which are above and below the core sections of the elements. The grid plates extend (nominally) between 50.2 cm and 80.6 cm above and below the mid plane of the core, being 30.4 cm high, and being situated in the blanket/plenum areas of the elements. (The horizontally smeared density of the grids is quoted as being 0.154 g/cm³). The distance between the centres of elements within a group of 5x5 is 5.3721 cm and the overall average spacing is 5.4254 cm (the distance between the centres of two superlattices divided by 5). This latter spacing has been assumed in some ZEBRA calculational models and will be the value found in some MTN documentation. This is the Model C described in Section 3, where the effect of making this approximation is evaluated.

The identifiers and dimensions of the components used in the assemblies are listed in Table 1.6. Dimensions in the Tables are given in cm (the Zebra Materials Database gives them in mm and many were originally given in inches and later converted). The final number, N, in an identifier is based on the thickness of the component in inches, this indicating, nominally, either 1/N inches or N inches.

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Table 1.6 Dimensions of the Standard Size Plates

(All plates are nominally 5.067 cm square)

Identifier	Type of Plate Plates with a canned core region	Thickness (cm)	Core thickness (cm)	Can thickness (cm)	Core width (cm)
PUIV4	PuO ₂ /UO ₂	0.6278	0.55312	0.03734	4.953
PUII8	Pu metal Mk.II (pert. sample)	0.3175	0.2159	0.0508	4.671
PUIII8	Pu metal Mk.III (pert. sample)	0.3154	0.2138	0.0508	4.671
PUV8	Pu metal Mk.V	0.3256		0.04572	4.671
PUVI8	Pu metal Mk.VI	0.3282		0.04572	4.671
PUVII8	Pu metal Mk.VII	0.3260		0.04572	4.671
PUVIII8	Pu metal Mk.VIII	0.3274		0.04572	4.671
PUIX8	Pu metal Mk.IX	0.3265		0.04572	4.671
PUX8	Pu metal Mk.X	0.3264		0.04572	4.671
PUXI8	Pu metal Mk.XI	0.3261		0.04572	4.671
PUXII8	Pu metal Mk.XII	0.3260		0.04572	4.671
	(Average values used in calcs.)	0.3265	0.23506	0.04572	4.671
UO22R4	UO ₂ (2 radiused corners)	0.6289	0.55524	0.03683	4.851
UO23R4	UO ₂ (3 radiused corners)	0.6313	0.55764	0.03683	4.851
UO24R4	UO ₂ (4 radiused corners)	0.6279	0.55424	0.03683	4.851
UO2DP4	Depleted UO ₂	0.624			
NASTBR4	Sodium (1965 batch, bright can)	0.616	0.54234	0.03683	4.963
NASTDL4	Sodium (First batch 1971, dull can)	0.616	0.54234	0.03683	4.963
NASTDM4	Sodium (2nd batch 1971, dull can)	0.616	0.54234	0.03683	4.963
NAJI4	Sodium (PNC)	0.615	0.5055	0.05475	4.987
NAJII4	Sodium (PNC design)	0.615	0.5055	0.05475	4.987
NAST4P	Sodium (1965 batch, 2.36 cm dia. hole)	(0.6185)			
B4CNAT4	Natural Boron Pert. Sample	0.6198	0.54614	0.03683	4.963

Note: Thicknesses in brackets are assumed or nominal values.

The Core region dimensions are given for those plates which consist of two regions, for example a core of fuel material, or sodium, and a surrounding region of canning material (usually composed of steel).

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Table 1.6 continued

Identifier	Type of Plate Plates without a can	Thickness (cm)
U8	Natural Uranium	0.317
U2	Natural Uranium	1.2723
U3	Natural Uranium	7.6225
U8P	UNat (2.36 cm dia. hole)	(0.3175)
U16	Natural Uranium	0.1593
93U516	93% Enriched Uranium (Pert)	0.158
MST1	Mild Steel	2.5385
MST2	Mild Steel	1.2718
MST3	Mild Steel	7.6063
MST8	Mild Steel	0.3147
STSTBR8	Stainless Steel (bright)	0.3172
STSTD8	Stainless Steel (dull)	0.3236
STSTF8	Stainless Steel (40% density)	0.317
AL2O34	Alumina	0.6317
ALG8	45% Aluminium	0.3170
ALSC3	Aluminium cylinders	7.62
GI8	Graphite (W+G) Mk.1	0.3180
GII8	Graphite (Morganite) Mk.II	0.31775
GIH8	Graphite	0.319
G2	Graphite CY9	1.27025
G1	Graphite CY9	2.53873
G3	Graphite CY9	7.62
G75	Graphite CY9	19.05
G13	Graphite CS	33.3375
TA8	Tantalum Pert. Sample	0.318

Geometrical Forms of the Principal Plates.

The shapes and dimensions of a PUVIII8 plutonium metal plate, a UO₂3R4 uranium oxide plate and a sodium plate are illustrated in Figures 1.11 to 1.16.

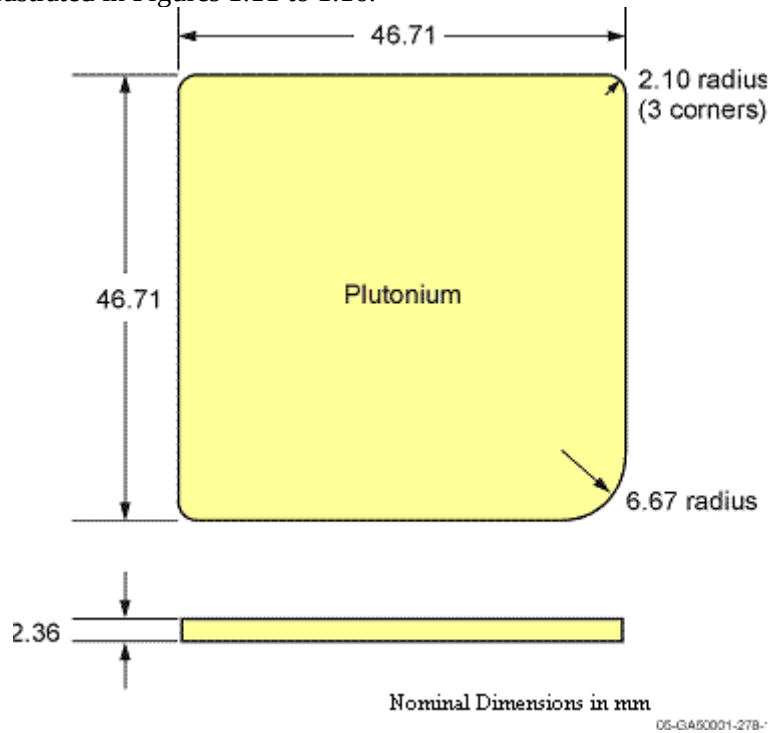
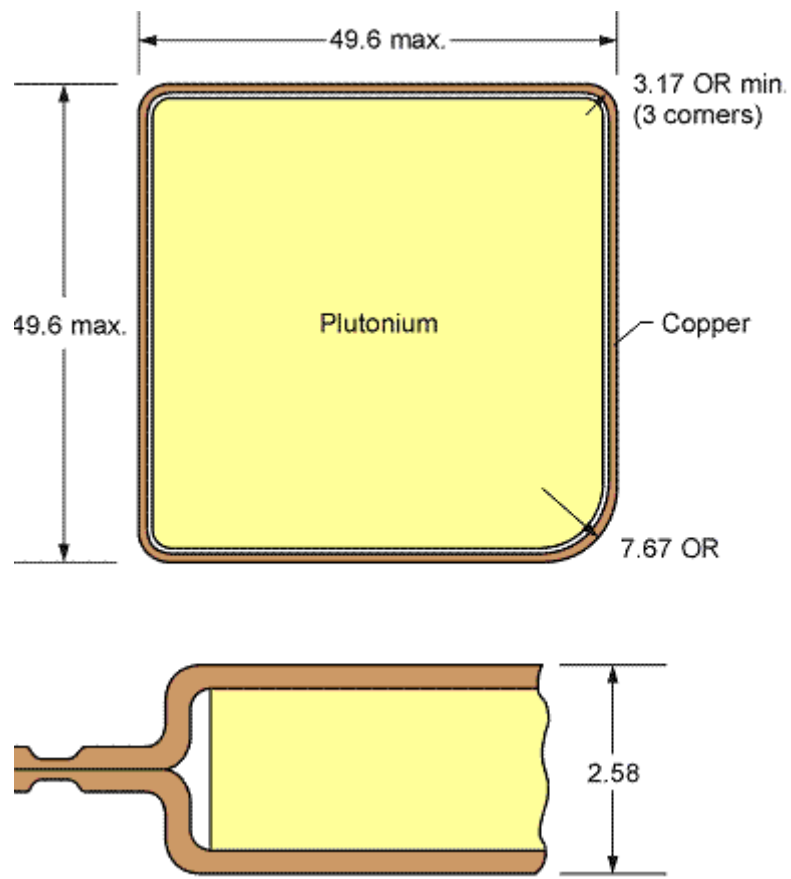


Figure 1.11 Core of the PUVIII8 Plutonium Metal Fuel Plate.

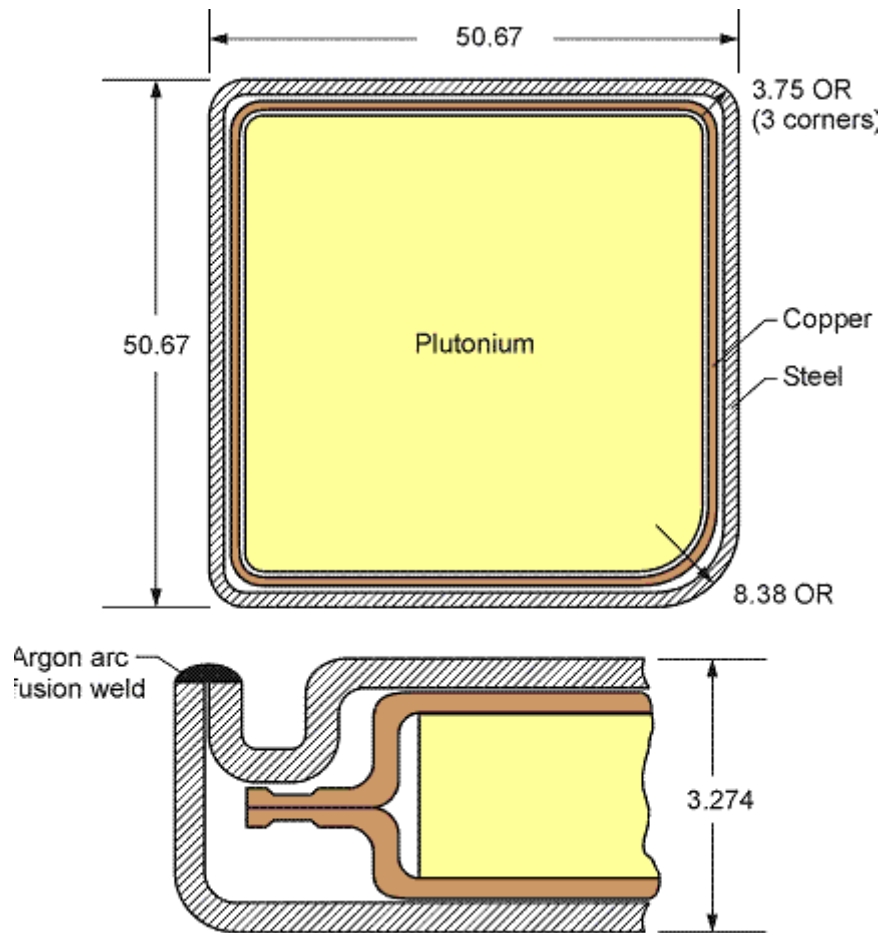
The thickness of the core region is not the same for all of the plutonium metal plates and an average value of 2.3506 mm is used in the calculational model.



Drawing not to scale. Nominal dimensions in mm.

Figure 1.12 Core and Copper Clad of a PUVIII8 Plutonium Metal Fuel Plate.

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Drawing not to scale. Nominal dimensions in mm.

Figure 1.13 Core, Copper and Steel Clad of a PUVIII8 Plutonium Metal Fuel Plate.

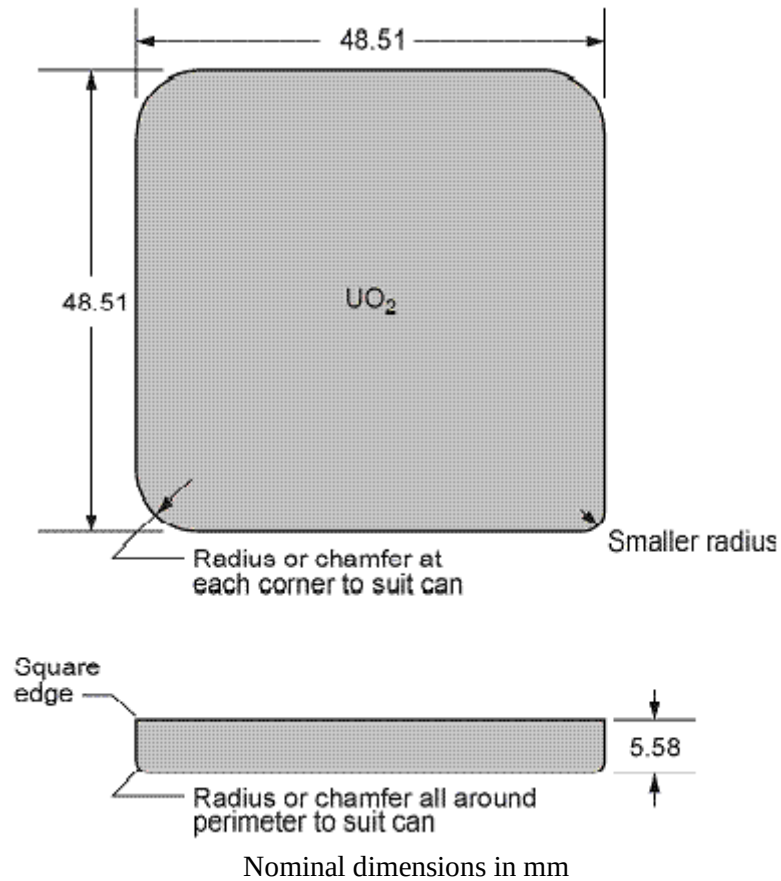
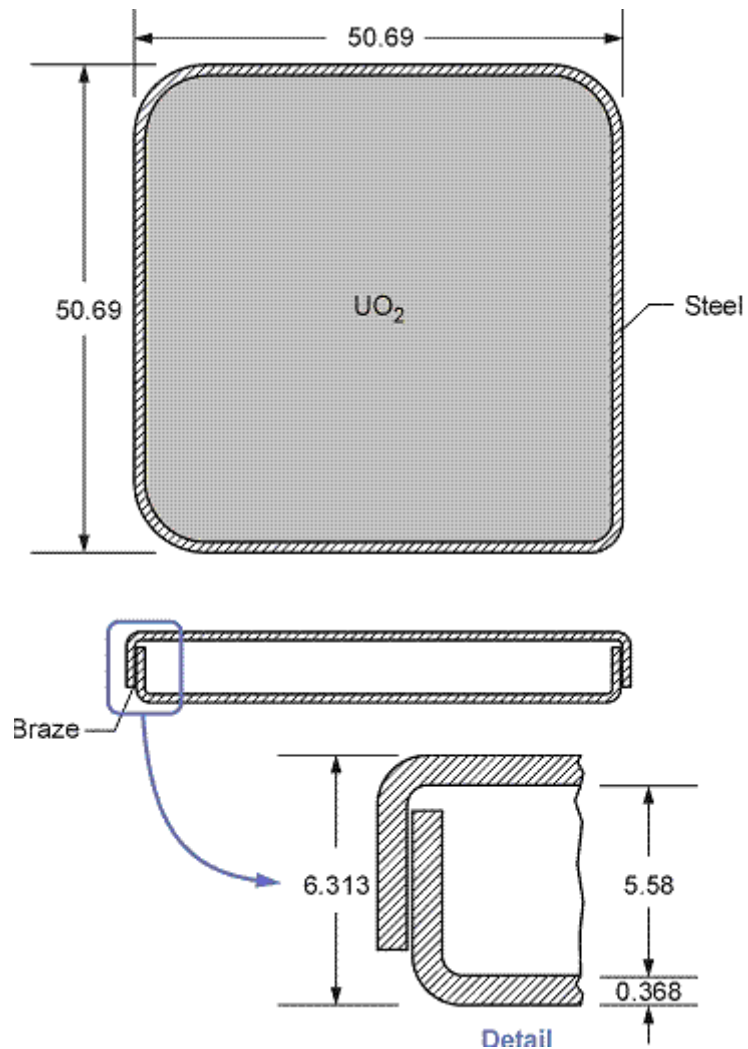


Figure 1.14 Core Region of the UO₂3R4 Uranium Oxide Plate.

(UO₂ 3R 4. The 3R denotes the plate with three “radiused” corners. The 4 denotes ~ ¼ inch)

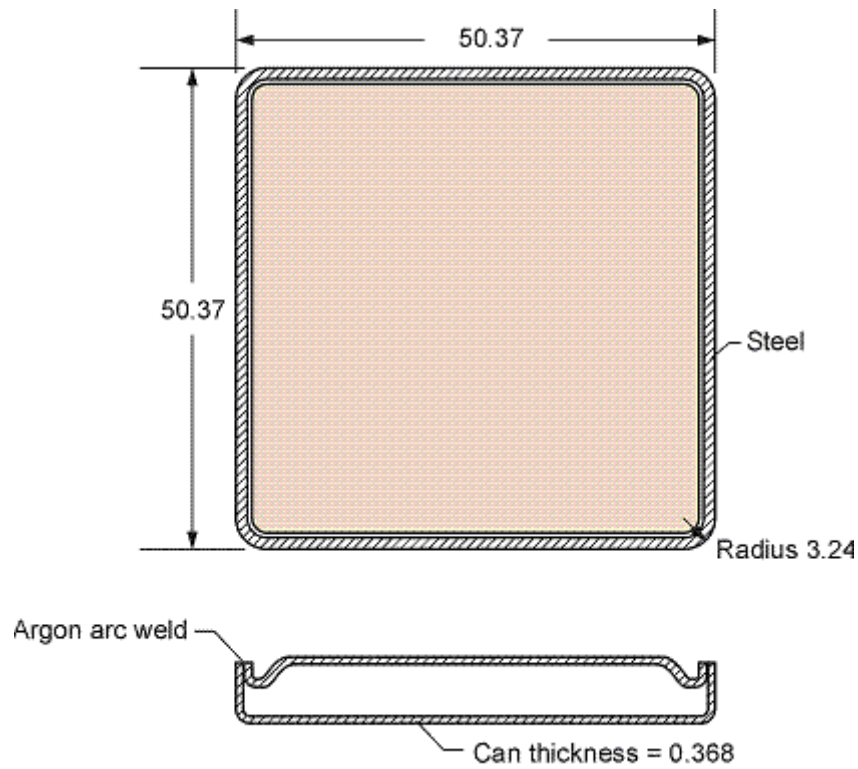
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Drawing not to scale. Nominal dimensions in mm.

Figure 1.15 Core and Can Regions of the UO23R4 Uranium Oxide Plate.

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Drawing not to scale. Nominal dimensions in mm.

Figure 1.16 Core Plus Can Regions of the NASTBR4, NASTDL4 and NASTDM4 Sodium Plates.

The plate thickness is 0.616 cm although it is found that the plates can compress.

Arrangements of the Plates in Cells

The patterns of the plates in the cells are given in Tables 1.7 to 1.12

Table 1.7 MZA Core Region and MZB Outer Core Region Cell Patterns

Cell C11-1A	Cell C11-1B	Cell C11-1BG	Cell C11-1C	Cell C11-1D	Cell C11-1DG	Cell C11-1G
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDL4	NASTDM4	NASTDM4
UO24R4	UO24R4	UO24R4	UO24R4	UO24R4	UO24R4	UO24R4
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDL4	NASTDM4	NASTDM4
PUV8	PUVI8	PUVI8	PUVII8	PUVIII8	PUVIII8	PuXII8
GI8	GI8	GI8	GI8	GI8	GI8	GI8
UO24R4	UO24R4	UO24R4	UO24R4	UO24R4	UO24R4	UO24R4
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDL4	NASTDM4	NASTDM4
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDL4	NASTDM4	NASTDM4
UO24R4	UO24R4	UO24R4	UO24R4	UO24R4	UO24R4	UO24R4
STSTBR8	STSTBR8	STSTBR8	STSTBR8	STSTBR8	STSTBR8	STSTBR8
PUV8	PUVI8	PUVI8	PUVII8	PUVIII8	PUVIII8	PuXII8
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDL4	NASTDM4	NASTDM4
UO24R4	UO24R4	UO24R4	UO24R4	UO24R4	UO24R4	UO24R4
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDL4	NASTDM4	NASTDM4
Height (cm)						
7.4940 cm	7.4992 cm	7.4992 cm	7.4948 cm	7.4976 cm	7.4976 cm	7.4948 cm
Core height						
89.9280 cm	89.9904 cm	89.9904 cm	89.9376 cm	89.9712 cm	89.9712 cm	89.9376 cm

Note: All cells are contained in stainless steel sheaths.

The cells differ in the plutonium plates and sodium plates used.

The height of the Cell C11-1 calculated using the average thickness of the plutonium plates (0.3265 cm) is 7.4958 cm and the height of 12 core region cells is 89.9496 cm. This compares with the average measured value of 89.94 cm.

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Table 1.8 MZB Inner Core Cell Patterns

Cell C12-30A	Cell C12-30B	Cell C12-30BG	Cell C12-30D
NASTDL4	NASTDL4	NASTDM4	NASTDM4
UO23R4	UO23R4	UO23R4	UO23R4
NASTDL4	NASTDL4	NASTDM4	NASTDM4
PUIV4	PUIV4	PUIV4	PUIV4
NASTDL4	NASTDL4	NASTDM4	NASTDM4
UO23R4	UO23R4	UO23R4	UO23R4
STSTBR8	STSTBR8	STSTBR8	STSTBR8
NASTDL4	NASTDL4	NASTDM4	NASTDM4
UO23R4	UO23R4	UO23R4	UO23R4
NASTDL4	NASTDL4	NASTDM4	NASTDM4
PUIX8	PUX8	PUX8	PUXI8
NASTDL4	NASTDL4	NASTDM4	NASTDM4
UO23R4	UO23R4	UO23R4	UO23R4
NASTDL4	NASTDL4	NASTDM4	NASTDM4
Height (cm)			
8.1087	8.1086	8.1086	8.1083
Core height (cm)			
89.1957	89.1946	89.1946	89.1913

Note: All these cells are contained in stainless steel sheaths.

The cells differ in the plutonium metal and sodium plates used. The UO₂ plate is different from that used in the MZA core and the MZB outer core.

Height of the cell C12-30A = 8.1087 cm. This is also the height of the cell calculated using the average plutonium metal plate thickness used in the calculation model.

Height of the 11 core region C12-30A cells = 89.1957 cm. This compares with the average measured value of 89.20 cm

Table 1.9 MZA and MZB Axial Blanket Cells

B11-1	B11-1A	B11-1AG	B12-30	B12-30G
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDM4
U8	U8	U8	U8	U8
GI8	GI8	GI8	GIII8	GIII8
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDM4
STSTBR8	STSTBR8	STSTBR8	STSTBR8	STSTBR8
U8	U8	U8	U8	U8
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDM4
GI8	GI8	GI8	GIII8	GIII8
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDM4
U8	U8	U8	U8	U8
STSTBR8	STSTBR8	STSTBR8	STSTBR8	STSTBR8
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDM4
GI8	GI8	GI8	GIII8	GIII8
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDM4
U8	U8	U8	U8	U8
STSTBR8	STSTBR8	STSTBR8	STSTBR8	STSTBR8
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDM4
GI8	GI8	GI8	GIII8	GIII8
U8	U8	U8	U8	U8
NASTBR4	NASTDL4	NASTDM4	NASTDL4	NASTDM4

Notes:

1. All these axial blanket cells, being in core elements, are contained in stainless steel sheaths.
2. The plate sequences of the axial blanket cells are the same in the top and bottom regions, not reflected.
3. The plenum cells appear in both stainless steel and mild steel sheaths as detailed in the Tables of element contents.

Height of the cell B11-1 = 8.7366 cm

Height of the 4 cells constituting the upper or lower axial blanket = 34.9464 cm.

This compares with the following measured values:

MZB inner core upper axial blanket = 35.03 cm . Outer core upper axial blanket = 35.03 cm .

MZB inner core lower axial blanket = 34.85 cm. Outer core lower axial blanket = 34.90 cm .

The GIII8 plate is slightly thicker than the GI8 plate (0.319 compared with 0.318 cm) and so the height of the cell B12-30 is 8.7406 and the height of the 4 cells is 34.9624 cm

Table 1.10 Plenum Region Cells

These regions simulate the plenum region of a fast reactor, the continuation of the fuel pin cans, not containing fuel, to accommodate fission gas release. The aluminium has been included to simulate the sodium coolant which flows outside the fuel pin cans.

B11-2	B11-2A
(upper)	(lower)
ALSC3	ALSC3
MST1	MST3
ALSC3	ALSC3
MST3	MST1
ALSC3	ALSC3

Height of plenum region = 33.0048 cm.

The mild steel spacer tubes above the upper plenum and below the lower plenum are denoted by MSTSTX where X is the length in inches.

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Table 1.11 Radial blanket cells

B11-3	B11-3A	B11-3B	B11-4/4A	B11-4B	B11-4C
NASTBR4	NASTDL4	NASTDL4	ALG8	ALG8	ALG8
GII8	GII8	GI8	MST8	MST8	MST8
MST8	MST8	MST8	GII8	GI8	GIII8
NASTBR4	NASTDL4	NASTDL4	ALG8	ALG8	ALG8
GII8	GII8	GI8	AL2O34	AL2O34	AL2O34
U2	U2	U2	U2	U2	U2
STSTD8	STSTD8	STSTD8	ALG8	ALG8	ALG8
GII8	GII8	GI8	ALG8	ALG8	ALG8
NASTBR4	NASTDL4	NASTDL4	GII8	GI8	GIII8
GII8	GII8	GI8	ALG8	ALG8	ALG8
			MST2	MST2	MST2
			AL2O34	AL2O34	AL2O34
			GII8	GI8	GIII8
			ALG8	ALG8	ALG8
			U2	U2	U2
			ALG8	ALG8	ALG8
			GII8	GI8	GIII8
			AL2O34	AL2O34	AL2O34
			ALG8	ALG8	ALG8
			ALG8	ALG8	ALG8

Note: Cells B11-3 and B11-4 are in stainless steel sheaths, the remainder (including B11-4A) are in mild steel sheaths.

Height of the cell B11-3 = 5.0296. Height of 20 cells = 100.592 cm

The cell B11-3B is 0.001 cm thicker because the plate GI8 is 0.00025 cm thicker than GII8.

Height of the cell B11-4 = 10.1502 cm. Height of 3 cells = 30.4506 cm.

Again the cells B11-4B and 4C differ slightly because of the small differences between the thicknesses of the graphite plates, G.

Table 1.12 Inner Radial Blanket Cell Patterns for Sectors

B12-31	B12-31A	B12-36
UO23R4	UO22R4	UO2DP4
NAJII4	NAJI4	NAJI4
UO23R4	UO22R4	STSTF8
NAJII4	NAJI4	UO2DP4
UO23R4	UO22R4	NAJI4
UO23R4	UO22R4	UO2DP4
NAJII4	NAJI4	STSTD8
UO23R4	UO22R4	NAJI4
		UO2DP4

Note: All these cells are in mild steel sheaths.

The height of the cell B12-31 = 5.0015 cm. 20 cells have a height of 100.03 cm.

The height of the cell B12-36 = 4.9816 cm 20 cells have a height of 99.632 cm

The Arrangements of the Cells in Elements

The arrangements of the cells in the elements are presented in Tables 1.13 to 1.17

Table 1.13 MZA Core and MZB Outer Core Element Loadings

Region	C11-1A	C11-1B	C11-1BG	C11-1C	C11-1D	C11-1DG	C11-1G	Height (cm)
Upper plenum	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	33.00
Upper axial blanket	4 cells B11-1	4 cells B11-1A	4 cells B11-1AG	4 cells B11-1A	4 cells B11-1A	4 cells B11-1AG	4 cells B11-1AG	35.03
Core	12 cells C11-1A	12 cells C11-1B	12 cells C11-1BG	12 cells C11-1C	12 cells C11-1D	12 cells C11-1DG	12 cells C11-1G	89.94
Lower axial blanket	4 cells B11-1	4 cells B11-1A	4 cells B11-1AG	4 cells B11-1A	4 cells B11-1A	4 cells B11-1AG	4 cells B11-1AG	34.90
Lower plenum	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	33.00

Note: Core and axial blanket heights are averages from measurements on eight MZB elements in slotted sheaths (the slots being along the sides of the sheaths to enable height measurements to be made). The values differ very slightly from those measured on MZA where averages for six elements were obtained.

In MZA the values were:

Upper axial blanket = 35.03 cm, Lower axial blanket = 34.92 cm, Core = 89.97 cm
with an uncertainty of ± 0.06 cm on these average values.

The plenum heights are nominal.

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Table 1.14 MZB Inner Core Element Loadings

Region	C12-30A	C12-30B	C12-30BG	C12-30D	Height (cm)
Upper plenum	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	33.00
Upper axial blanket	4 cells B12-30	4 cells B12-30	4 cells B12-30G	4 cells B12-30G	35.03
Core	11 cells C12-30A	11 cells C12-30B	11 cells C12-30BG	11 cells C12-30D	89.20
Lower axial blanket	4 cells B12-30	4 cells B12-30	4 cells B12-30G	4 cells B12-30G	34.85
Lower plenum	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	33.00

Note: Core and axial blanket heights are averages from measurements on six elements having slotted sheaths. The plenum heights are nominal.

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Table 1.15 Radial Blanket Element Loadings

Region	B11-1	B11-1B	B11-1C	B12-30	B12-30A	B12-32	Height (cm)
Upper plenum	1 cell	1 cell	1 cell	1 cell	1 cell	1 cell	33.00
	B11-2	B11-2	B11-2	B11-2	B11-2	B11-2	
Upper outer radial blanket	3 cells	3 cells	3 cells	3 cells	3 cells	3 cells	30.45
	B11-4	B11-4A	B11-4B	B11-4C	B11-4C	B11-4C	
Inner radial blanket or special	20 cells	20 cells	20 cells	20 cells	20 cells	20 cells	See note (b)
	B11-3	B11-3B	B11-3C	B12-31	B12-31A	B12-36	
Lower outer radial blanket	3 cells	3 cells	3 cells	3 cells	3 cells	3 cells	30.45
	B11-4	B11-4A	B11-4B	B11-4C	B11-4C	B11-4C	
Lower plenum	1 cell	1 cell	1 cell	1 cell	1 cell	1 cell	33.00
	B11-2A	B11-2A	B11-2A	B11-2A	B11-2A	B11-2A	

Notes:

(a) All elements have mild steel sheaths except B11-1 which have stainless steel sheaths.

(b) The heights of the central regions, based on plate thicknesses in Table 1.6, and rounded to the nearest mm, are:

For element types B11-1, B11-1B and B11-1C 100.6 cm

For element types B12-30 and B12-30A 100.0 cm

For element type B12-32 containing the B12-36 cells 99.6 cm

The height of the central region of element type B12-32, based on measurements of two elements having slotted sheaths is 99.2 cm.

Table 1.16 Loadings of Steel and Graphite Reflector Elements

Element Type B11-5 (mild steel)	Height (cm)
Spacer material	67.31
18 x MST3 plates + 1 x MST2 plate	138.43
Spacer material	66.04

Element Type B12-33 (graphite)	Height (cm)
3 x STSTF8 shims	0.95
7 x G3 plates	53.34
5 x G13 plates	166.69
7 x G3 plates + 2 x G1 plates	58.42

Element Type B12-31 (graphite)	Height (cm)
4 x STSTF8 shims	1.27
7 x G3 plates + 9 x G75 plates + 7 x G3 plates	278.13

Element Type B12-31A (graphite)	Height (cm)
4 x STSTF8 shims	1.27
1 x G2 plate + 1 x G1 plate + 36 x G3 plates	278.13
5 x G13 plates	166.69

Notes:

1. Dimensions are nominal.
2. Element types B11-5, B12-31 and B12-31A are contained in stainless steel sheaths. Element type B12-33 is contained in a mild steel sheath.
3. Element types B12-33, B12-31 and B12-31A do not have a piston at the bottom of the stack of plates (7.62 cm).

Location of the mild steel superlattice grid plates

Elements are held in groups of 5x5, separated by a small gap of 0.2665 cm, by the mild steel superlattice grids of width 0.25 cm, which are above and below the core sections of the elements. The grid plates extend (nominally) between 50.2 cm and 80.6 cm above and below the mid plane of the core, being 30.4 cm high, and being situated in the blanket/plenum areas of the elements.

ZEBRA Control Rods

All plates are nominally 4.318 cm square (an area of 18.6451 cm²). The control rod outer sheath has an outer dimension of 5.2544 cm square, the same as the standard elements. The control rods 1 to 8 in MZB are double element rods, with the same dimension plates being used and the same outer element dimension.

The components of the control rods are detailed in Tables 1.17 to 1.23.

Table 1.17 Control Rod Plate Identifiers

(All plates are 4.318 cm square)

Identifier	Type of Plate	Thickness (cm)
PUIVC4	Pu02/U02	0.635
PUIIC8	Pu metal Mk.II	0.3175
PUIIIC8	Pu metal Mk.III	0.3154
U02C4R4	U02 (4 radiused corners)	0.6279
UC8	Natural uranium	0.3167
NASTC4	Sodium (1965 batch)	0.616
GC8	Graphite (CY9)	0.3155
STSTC8	Stainless steel	0.3180
ALCG8	45% aluminium	0.3167
B10C2	B10	1.27

Table 1.18 Control Rod Sheaths

Identifier	Type of sheath
CRSHEATH	Single element rod
DCRSH	Double element rod (MZB except FR9)

In the Shut-off rods (SOR3 and SOR4) used in MZB a B10 pellet assembly was used at the top of the elements. This consisted of six steel tubes per double rod. The tubes were of ID = 1.80 cm, OD = 2.05 cm and 98.1 cm length and one tube weighed 455 g. They each contained 72 pellets, 1.73 cm OD and total length 92.7 cm, filled at each end by brass pieces protruding 2.5 cm into the bottom end and ~2.8 cm into the top end. The brass pieces extended 1.3 cm beyond the end of the tube and then had spigots 1.0 cm long which fitted into holes in steel pieces 1.3 cm thick and 4.3 cm square, to hold the tubes upright. Thus the assembly of tubes, end pieces and steel pieces had a total length of 103.2 cm. The pellets consisted of about 2.72 g B10 in 3.03 g boron, 1.10 g carbon and 0.02 g aluminium stearate.

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Table 1.19 Control Rod Core Region and Blanket Region Cell Patterns

	Cell C11-2A	Cell C11-2B	Cell C 12-32		Cell B11-5
	U02C4R4	U02C4R4	U02C4R4		ALCG8
	NASTC4	NASTC4	PUIVC4		GC8
	PUIIC8	PUIIC8	U02C4R4		UC8
	NASTC4	NASTC4	NASTC4		ALCG8
	U02C4R4	U02C4R4	U02C4R4		ALCG8
			PUIVC4		UC8
			NASTC4		STSTC8
			U02C4R4		ALCG8
			PUIIC8		
			U02C4R4		
			NASTC4		
			U02C4R4		
			PUIVC4		
			U02C4R4		
			NASTC4		
Height	2.8032 cm	2.8053 cm	9.0767 cm		2.5337 cm

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Table 1.20 Control Rod Boron Absorber Region Cell Patterns

	Cell B11-6	Cell B11-7	Cell B11-8	Cell B11-9
	3 x ALCG8	ALCG8	3 x ALCG8	10 x ALCG8
	B10C2	B10C2	B10C2	B10C2
	2 x ALCG8	3 x ALCG8	7 x ALCG8	10 x ALCG8
		B10C2	B10C2	
		3 x ALCG8	7 x ALCG8	
		B10C2	B10C2	
		3 x ALCG8	3 x ALCG8	
		B10C2		
		3 x ALCG8		
		B10C2		
		3 x ALCG8		
		B10C2		
		3 x ALCG8		
		B10C2		
		ALCG8		
Height	2.8535 cm	15.224 cm	10.144 cm	7.604 cm

	Cell B12-32	Cell B12-33	Cell B12-34	Cell B12-35
	2 x ALCG8 B10C2 3 x ALCG8	2 x ALCG8 B10C2 2 x ALCG8	5 x ALCG8 B10C2 5 x ALCG8	12 x ALCG8 B10C2 12 x ALCG8
Height	2.8535 cm	2.5368 cm	4.437 cm	8.8708 cm

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Table 1.21 Control Rod Element Loadings in MZA

Element Type C11-2/1 Used in Safety Rods 1+2 Shut-off Rods 5+6	Element Type C11-3/1 Used in Shut-off Rods 3+4	Height (cm)	Element Type C11-4/1 Used in Control Rods 7+8	Element Type C11-5/1 Used in Fine Rod 9	Height (cm)
16xUC8 Plates	16xUC8 Plates	5.1	16xUC8 Plates	16xUC8 Plates	5.1
32 cells B11-6	6 cells B11-7	91.3	9 cells B11-8	12 cells B11-9	91.3
24xUC8 Plates	24xUC8 Plates	7.6	24xUC8 Plates	24xUC8 Plates	7.6
3 cells B11-5	3 cells B11-5	7.6	3 cells B11-5	3 cells B11-5	7.6
32 cells C11-2A	32 cells C11-2A	89.70	32 cells C11-2B	32 cells C11-2B	89.77
3 cells B11-5	3 cells B11-5	7.6	3 cells B11-5	3 cells B11-5	7.6
199xUC8 Plates	199xUC8 Plates	63.0	199xUC8 Plates	199xUC8 Plates	63.0

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Table 1.22 Control Element Loadings in MZB

Region	Element Type C12-32 Used in Safety Rods 1+2	Element Type C12- 34 Used in Shut off Rods 5+6	Element Type C12-35 Used in Control Rods 7+8	Height (cm)
Top shims	16 x STSTC8 plates	15 x STSTC8 plates	23 x STSTC8 plates	(b), (d)
Absorber	32 cells B12-32	36 cells B12-33	20 cells B12-34	See note (c)
Upper blanket	6 cells B11-5	6 cells B11-5	6 cells B11-5	15.20
Core	10 cells C12-32	10 cells C12-32	10 cells C12-32	90.77
Lower blanket	14 cells B11-5	14 cells B11-5	14 cells B11-5	35.47
Bottom Shims	16 x STSTC8 plates	16 x STSTC8 plates	16 x STSTC8 plates	5.09

Notes:

- (a) All rods except FR9 are double rods, each element position containing the loading described.
- (b) Shut-off Rod SOR5 contains 16xSTSTC8 plates as top shims. The thickness of the shims is 0.318 cm.
- (c) Absorber section lengths are:
- | | |
|------------|---------|
| SR1 and 2 | 91.3 cm |
| SOR5 and 6 | 91.3 cm |
| CR7 and 8 | 88.7 cm |
- (d) The top shims go to the top cap of the sheaths. The bottom shims sit on a 30.5 cm spacer for all rods except FR9 when the bottom shims go down to the piston. (However, it is not considered necessary to represent regions outside the shims.)

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Table 1.23 Shut-off Rods 3 and 4 and Fine Control Rod FR9 in MZB.

Region	Element Type C12-33 Used in Shut off Rods 3+4	Height (cm)		Element Type C12-36 Used in Fine Rod 9	Height (cm)
Top shims	2 x STSTC8 plates	0.636		24 x UC8 plates	7.60
Absorber	B10 pellet assembly	See note (a)		10 x B12-35	88.71
Upper blanket	3 cells B11-5	7.60		24 x UC8 plates	7.60
				3 cells B11-5	7.60
Core	10 cells C12-32	90.68		10 cells C12-32	90.77
Lower blanket	14 cells B11-5	35.47		3 cells B11-5	7.60
Bottom Shims	16 x STSTC8 plates	5.09		200 x UC8 plates	63.30

(a) The B10 pellet assembly consists of six steel tubes per double rod. The tubes have ID = 1.80 cm, OD = 2.05 cm and 98.1 cm length. 72 pellets (1.73 cm OD and total length 92.7 cm) are contained in each tube which is filled at each end by brass pieces protruding 2.5 cm into the bottom end and ~2.8 cm into the top end. The brass pieces extend 1.3 cm beyond the end of the tube and then have spigots 1.0 cm long which fit into holes in steel pieces 1.3 cm thick and 4.3 cm square, to hold the tubes upright. Thus the assembly of tubes, end pieces and steel pieces has a total length of 103.2 cm.

The area of steel (per element) associated with the B10 pellet assembly is 2.2678 cm². The area of boron pellets (assumed to fill the space within the 1.8 cm diameter tubes) is 7.6341 cm² per element.

The k-effective value of MZA and the Model Simplifications Proposed by the Measurers.

The excess reactivity of the assembly was determined on 29th November, 1971. Corrections to the reactivity were measured for the presence of the control rods, the reactor instrument holes in the blanket and the irregular core outline (to obtain an equivalent uniform cylindrical model). A correction for the high core temperature on that date was also derived. Thus an experimental k-value for an unperturbed 213 core element loading with an equivalent cylindrical outline at 23.5°C (the containment temperature) on 29th November, 1971 was obtained on the basis of the original series of measurements. In the present benchmark model the k_{eff} value relating to the geometry of the as-built 213 element core, with its irregular boundary, is given first (by omitting the correction and additional uncertainty associated with the cylindrical boundary).

(a) Correction for the Partial Insertion of the Control Rods

The 213 element loading became critical with the control rods partially inserted. The true critical position (i.e. that corresponding to zero neutron source) was determined by plotting the balancing control rod position (in standard cm) against inverse reactor power and extrapolating to infinite power. The critical rod positions found were:

	CR7	53.111 cm
	CR8	71.006 cm
and	FR9	51.393 cm.

The extrapolated position of CR7 is to be compared with a balance position of 53.000 cm at 61% on the deviation meter. The degree of subcriticality at this power was $\sim 1.2 \times 10^{-5}$ dk/k.

Using the control rod profiles determined in MTN/6, and discussed in Section 1.4, the reactivity held by the partially inserted control rods in "standard cm" was determined. The "standard cm" is the reactivity change resulting from 1 cm of movement of the reference rod, FR9, at the point of insertion where the change of reactivity with insertion is a maximum. The change of reactivity, (as measured by period measurements, or source multiplication measurements) along the length of the rod (the rod profile) is then related to this unit. The period measurements, also described in detail in MTN/6 and summarised in Section 1.4 and further evaluated in Section 2.4, allowed these results to be converted into absolute dk/k units by analysing the period measurements using the chosen set of delayed neutron data (discussed in Section 2.4.) The reactivity changes corresponding to movements of the other rods were then related to the movement of the calibrated rod by source multiplication measurements (with Rod 8 being taken to be identical to Rod 7.) In the initial interpretation in MTN/8 the "standard cm" of FR9 was equivalent to 0.493×10^{-4} dk/k. The reactivity of the system with all rods raised was then determined to be 1.0068 ± 0.0001 (the uncertainty value arising from the control rod profiles and not including the uncertainty from the delayed neutron data used in the rod calibrations).

The above period/reactivity relationship was calculated using the FD4 nuclear data set and the Stevenson - ZEBRA delayed neutron data. A later calculation was made using the FGL5 data set and the Smith-Tomlinson delayed neutron data (see MTN/96 and MTN/104) and this gave a "**reactivity worth per standard cm**" about 1.8% higher **in MZA, 0.502×10^{-4} dk/k** (see Table 1.49). In the present document the aim is to standardise on the FGL5/Smith-Tomlinson values and so the MZA reactivity changes measured in MZA using the control rods and expressed in terms of the FGL4/Stevenson-ZEBRA nuclear data have been increased by 1.8%. The resulting value of the reactivity with all rods raised is therefore very slightly higher, 1.0069 ± 0.0001 , and again the $\pm 5\%$ uncertainty associated with the period-reactivity relationship is to be added (based on the final reactivity correction, when all of the reactivity corrections have been made to k_{eff}).

(b) Correction for the Replacement of the Control Rods by Core Elements

This section describes in detail the measurements made in order to correct the reactivity of the critical core to allow for the replacement of the control rods by normal core elements when modelling the assembly in calculation. As can be seen in Figure 1.6, control rods 1 to 8 lie in the region of the C11-1C type elements and FR9 is in the region of the C11-1D elements. Four rods are at a radius of $\sqrt{32.p}$ (in terms of element pitches, p), four at $\sqrt{40.p}$ and FR9 at $\sqrt{52.p}$. The reactivity effect of replacing the rods by 8 C11-1C's and one C11-1D element, as appropriate, was estimated in three stages.

(i) The reactivity worth of the boron absorber sections of the control rods

Two simulated control rods, SCR1 and SCR2, were assembled, each consisting of a control rod moving tube fitted inside a standard fuel element and resting on a standard piston. Each moving tube was filled with control-rod-size plates arranged as in the standard rods, and positioned so that the core section of the simulated rod coincided with the core section of the surrounding standard elements. The simulated rods contained PuII plutonium fuel plates. The absorber section of SCR1 contained 6 of the 7 absorber cells as found in the shut-off rods SOR3 and SOR4. Because the moving tube resting on the piston in a standard element is lower than the moving tube of a normal control rod in the raised position, there was not room in the moving tube of the simulated rod for the top absorber cell. This cell is in a position of negligible worth, being level with the top caps of the surrounding elements when the rod is raised. The "absorber" section of SCR2 contained no B10 plates, only 45% Aluminium plates. The steel contents of the simulated rod and an actual rod were matched by adding shim steel around the moving tube in the simulated rod.

The difference in worth between the two simulated rods, SCR1 and SCR2, in position (44,52) (radius $\sqrt{40.p}$, in lattice pitch units which corresponds to the radial position of rods SOR3 and SOR4) was compensated by $+ 0.779 \pm 0.019$ standard cm of rod 9, (the uncertainty arising from the drift in reactor reactivity). Thus the reactivity worth of the B10 plates found in SOR3 or SOR4 when in the raised position, was $- 0.391 \times 10^{-4}$ dk/k (applying the correction for normalisation to the Smith-Tomlinson delayed neutron data). It was assumed that the worths of the B10 sections in the other rods in the raised position could be obtained from the calculated ratios of their worths in the lowered (in-core) position. Table 1.24 shows the in-core worths and the out-of-core worths deduced in this way. The total out-of-core worth was thus estimated to be $(- 2.8 \pm 0.3) \times 10^{-4}$ dk/k. Removal of the B10 would increase the system reactivity by the corresponding amount.

Table 1.24 Worths of B10 Plates of Rods in Raised Position

Rod	Calculated In-Core B10 Worth ($\times 10^{-2}$ dk/k)	Out-of-Core B10 Worth with Smith-Tomlinson revision ($\times 10^{-4}$ dk/k)
1	0.580	0.360
2	0.580	0.360
3	0.630	0.391
4	0.630	0.391
5	0.580	0.360
6	0.580	0.360
7	0.405	0.251
8	0.405	0.251
9	0.137	0.086
Total		2.810×10^{-4} dk/k

Notes:

1. Out-of-core worth was measured for Rods 3 and 4. Other values were obtained by assuming out-of-core worth was proportional to calculated in-core worth.
2. A standard error (or uncertainty) of $\pm 0.3 \times 10^{-4}$ dk/k (i.e. 10%) was considered appropriate for the total.

(ii) Replacement of rods containing the Pu Mk.II plates by core elements

Measurements were made, in terms of the compensating movement of the regulating control rod, FR9, of the reactivity effect of replacing a core element by the simulated control rod with no absorber plates. The results are given in Table 1.25.

Table 1.25 Reactivity Effects of Simulated Control Rod (without absorber section)

Position	Radius (in units of p)	Element type replacing rod	Δ FR9 to compensate (a) (std. cm)	Worth of replacing rod by core element (dk/k)
(45,52)	$\sqrt{29.p}$	C11-1C	2.065 ± 0.030	1.036×10^{-4}
(44,52)	$\sqrt{40.p}$	C11-1C	1.992 ± 0.022	1.000×10^{-4}
(46,52)	$\sqrt{52.p}$	C11-1D	1.663 ± 0.026	0.835×10^{-4}
	$\sqrt{32.p}$	C11-1C		1.026×10^{-4} (b)

(a) The uncertainties are assumed to be one half of the correction for drift, obtained from the clean core measurements, one effect causing drift being the cooling of the core during the measurements. This does not include the dominant source of uncertainty which is the delayed neutron data used to convert the period measurements into reactivity units, $\pm 5\%$. Uncertainties of $\sim 0.1\%$ of the worth arise from the reproducibility of such measurements. (See MTN6 Table 4 for MZA results and MTN23 Table 2 for MZB/1 results).

(b) The value at this position has been estimated by interpolation, no position being available for a direct measurement.

From the results in the final column of Table 1.25 it is found that replacement of the nine rods, assumed to be containing PuII fuel but no B10 plates, by appropriate core elements would produce a reactivity increase of

$(9.0 \pm 0.1) \times 10^{-4} \text{ dk/k.}$

(iii) Allowance for rods containing Pu MkIII plates

The reactivity difference between the two types of fuel was determined using normal core elements, (C11-1E's and C11-1F's) loaded with the two fuels, instead of the simulated control rods. Three elements of each type were made and the difference in reactivity worth of the two sets in positions (45,52), (47,55) and (44,52) was equivalent to 6.7 ± 0.08 standard cm of rod 9, i.e. $(3.36 \pm 0.04) \times 10^{-4} \text{ dk/k}$, the elements containing the Mk.II plutonium plates being the more reactive. The uncertainty is taken to be equal to the estimated correction for reactor drift, and is larger than the reproducibility indicated by measurements in cores with no drifts. It was then assumed that a replacement in position (45,52) (radius = $\sqrt{29.p}$) and in (47,55) (radius = $\sqrt{34.p}$) would be negligibly different from two replacements at a position of radius $\sqrt{32.p}$. Hence the replacement of the six elements containing Mk.III fuel in the rod positions by elements containing Mk.II fuel would increase the system reactivity by twice the measured value for the three elements, i.e. $(6.72 \pm 0.08) \times 10^{-4} \text{ dk/k}$. For the replacement of the six control rods containing Mk.III fuel by control rods containing Mk.II fuel, this result is divided by 1.075 (the ratio of fuel masses in a core element and in a control rod containing the same type of fuel) giving:

$(6.25 \pm 0.08) \times 10^{-4} \text{ dk/k.}$

(iv) Total Control Rod Correction

Table 1.26 Reactivity Effects of Control Rod Replacement

Item	10^{-4} dk/k
Removal of B10 sections in raised position	2.8 ± 0.3
Replacement of 6 rods containing Mk.III fuel by rods containing Mk.II fuel	6.25 ± 0.04
Replacement of 9 rods containing Mk.II fuel by 8 C11-1C's and 1 C11-1D	9.0 ± 0.1
Total	$18.1 \pm 0.3 \text{ (a)}$

(a) An increased uncertainty of $\pm 10\%$, or $\pm 2 \times 10^{-4}$ was included to allow for possible additional sources of error.

The total reactivity effect of replacing the nine control rods in MZA by core elements was obtained by adding together the three contributions detailed in Table 1.26. The total is a reactivity increase of $(18.1 \pm 2) \times 10^{-4} \text{ dk/k}$.

(c) Correction for the Axial Channels in Blanket Elements

There were five blanket elements with 2.36 cm diameter holes for pulse counters, an area of 4.374 cm^2 . (These elements were in positions 46,59, 46,41, 54,59, 54,41 and 42,57.) The holes extended to 30.5 cm above the assembly centre plane.

The reactivity loss associated with these holes was estimated by measuring the reactivity change when four standard blanket elements in positions (59,46), (41,54), (41,46) and (59,54) were replaced by empty sheaths, the area of an empty channel within an element sheath being 26.03 cm^2 . This produced a movement of 7.926 ± 0.006 standard cm of FR9, i.e. $3.979 \pm 0.003 \times 10^{-4} \text{ dk/k}$ (the uncertainty being half the correction for reactivity drift). A similar uncertainty was expected from reproducibility of such measurements. A scaling-down to correspond to the size of the five holes produces a reactivity of $(0.8 \pm 0.2) \times 10^{-4} \text{ dk/k}$, the assumed uncertainty arising from the assumption that the effect is proportional to the area of the hole and independent of the length of the hole. It is thus estimated that the reactivity of the system would be increased by this amount if the holes were not present.

The counters located in the channels are almost at the bottom of the elements and therefore have a negligible reactivity effect. The support tubes and leads are below the counters.

(d) Temperature Correction

The extrapolated critical position of the control rods and hence the excess reactivity of the standard assembly configuration was determined on 29th November, 1971 with a temperature reading of 70°C from a resistance bulb at the centre of the element in position (52,54). Following this, various improvements were made to the cooling system to reduce the core temperature. **The reactivity change associated with reducing the whole core to the containment air temperature of 23.5°C as recorded on that day was estimated as follows:**

Eight resistance bulbs were installed in the core at the positions shown in MTN/8 addendum. Each bulb was actually in a special aluminium plate which took the place of a sodium plate, or, in two cases, a UO₂ plate. Three balances at different powers were taken in the early part of one day after the reactor had been left undisturbed overnight with the core cooling air flow at maximum. The (steady) temperature readings were recorded. The air flow was then reduced and after a minimum of changes to the reactor during the rest of the day, three balances were taken the following morning and the (almost steady) temperature readings recorded. These readings are shown in MTN/8 addendum. The temperature changes indicated that in a steady state condition the temperature differences between various points in the core and the containment air vary proportionately. Those results which show poor agreement are where the temperature differences are small.

The reactor balances at each of the three powers and the extrapolated critical position all indicated that the higher temperature core was less reactive by an amount balanced by approximately 5.6 std. cm FR9. Using the proportionality suggested above, and considering the readings from the middle resistance bulb in (52,54), the reactivity increase on reducing the core with an observed temperature of 70°C at this point to a uniform temperature equal to the containment air temperature (23.5°C) is given by

$$5.6 \times (70.0 - 23.5) / (71.6 - 57.8) = 18.9 \text{ std. cm FR9}$$

(The small change in containment air temperature from 15.7°C to 15.0°C between Day 1 and Day 2 has been ignored in this expression.)

The worth of the std. cm FR9 was 0.502×10^{-4} dk/k, using the Smith-Tomlinson evaluation of the delayed neutron data. Hence, 18.9 std. cm is equal to 9.5×10^{-4} dk/k. A standard error of one-third of this value was assigned in view of the simplified treatment of the temperature effects. The residual reactivity correction from 23.5°C to the standard nuclear data library value of room temperature will be smaller than this uncertainty of $\pm 3 \times 10^{-4}$ dk/k.

(e) The Pu239 Content Uncertainty

A calculation was made using the FD4 data set and a 1D cylindrical model of MZA using the cell which contains the PUV8 plutonium plate. The critical axial buckling was obtained and used in a calculation with the Pu239 content increased by 1%. The k-value increased by 0.00496 (a factor of about 0.5 times the fractional change in Pu239 content).

The uncertainty in the Pu239 content of each type of plutonium metal plate is $\sim 0.1\%$ arising approximately equally from the isotopic and chemical analyses. Because a large number of each type of fuel plate is used in the assembly, the difference of the average weight of the plates used from the overall average will be smaller. Assuming the uncertainty to be systematic for the various fuel types, a pessimistic assumption, the associated uncertainty in reactivity is $\pm 5 \times 10^{-4}$ dk/k. The uncertainties in other plate weights will have smaller effects on the k-value. For example the standard error in the mean U238 content of the UO₂ plates is $\pm 0.04\%$ and the (negative) worth of four UO₂ plates in a cell is 1/6 that of the two plutonium plates (MTN/96).

(f) The Effect of Pu241 Decay

The effect of Pu241 decay was not measured in MZA but calculated in a simple way. The most recent JEFF-3.1 half-life value, released in 2005, is 14.33 years, which corresponds to a decrease of 0.4 % per month in the Pu241 content. The Pu241 contents of all the plutonium plates used in MZA are similar. The reactivity effect of the Am241 produced by the Pu241 decay is only about 3% of the Pu241 effect and was not included in the calculation of the effect of the decay. The reactivity variation from the decay was estimated to be 1.0×10^{-4} dk/k per month and an uncertainty of $\pm 20\%$ is assumed. (Note: a measurement was made in Zebra Assembly 13, which followed the Mozart Programme, and compared with an FGL5 calculation. The calculated value was 20% smaller than the measured value. FGL5 was a later data library than FD4 which was used in the above very approximate calculation.)

The Pu241 half-life being assumed in the present reanalysis is 14.35 years, (2.5% higher than the value used in the original analysis and slightly higher than the more recent JEFF-3.1 value). The Pu241 and Am241 contents of the fuel plates given in the Zebra Database have been corrected from the data measured in the chemical and isotopic analysis to values appropriate for the reference date of the Database, that is, January 1971. The Am241 values could be in error by about 2.5% (depending on the date of the analysis). In MZA the average Am241 content of the core is about 7% of the Pu241 content and the uncertainty will thus be less than 2.5% of this, the consequent uncertainty in the Pu241 content associated with the decay will be less than 0.175%. This would translate to an uncertainty in k_{eff} of 0.4×10^{-4} which is negligible compared with the other uncertainties.

The criticality calculations are made using atomic compositions for Pu241 and Am241 corrected to the date of core criticality. To cover the uncertainty in the revised Pu241 and Am241 contents of the assemblies an uncertainty of $\pm 5\%$ in the estimate of the change in reactivity between the Database date and criticality is assumed, a figure of $\pm 0.5 \times 10^{-4}$ for the 10 months of decay between the Database reference date of January 1971 and the date of criticality of MZA, November 1971. (The k_{eff} value is to be calculated using the atomic compositions calculated for the date of criticality).

Note that the values for the Am241 content in the Zebra Database are sometimes negative when the plutonium was produced at a later date than the reference date for the Database, January 1971, the compositions having been calculated backwards from the analysis date to this reference date.

(g) Uncertainties in the Axial Dimensions of MZA Core Elements

Measurements were made of the axial dimensions within six elements using a special sheath with a vertical slot along its length. The standard uncertainty (operator error, using a metal rule) of each measurement was not more than 0.5 mm. The results suggest that there were no significant differences between the various core element types. The averages, together with standard deviations for a single element, are shown in Table 1.27. The consistency of the components below the lower axial blanket is reflected in the negligible variation in the first measurement. The half core height is measured as 44.983 cm and the average of the upper and lower axial blanket thicknesses is 34.976 cm. These figures compare well with the sum of the plate dimensions, given in Table 1.6, of 44.9748 cm (see footnote to Table 1.7) and 34.9464 cm (see footnote to Table 1.9), the differences being 0.02% and 0.08% respectively.

The reactivity uncertainty associated with the uncertainty in core height was estimated by making an FD4 infinite slab calculation with the core height increased by 1% and the volume fraction decreased to conserve mass. The critical radial buckling for the reference case was used and the k-value obtained was 0.99470. Assuming an uncertainty of $\pm 0.07\%$ in the core height, as in the footnote to Table 1.27, the associated uncertainty in reactivity is $\pm 4 \times 10^{-4}$ dk/k.

The misalignments of the core boundaries are considered less important as they produce similar reactivity changes at the top and bottom boundary. It was considered that any errors in the axial blanket thickness (and

the radial blanket heights) will give negligible reactivity uncertainties.

Any axial expansions caused by the alpha-decay heating of the core will have been allowed for in the temperature correction.

Table 1.27 Results of Measurements in the Slotted Element

Parameter	Measured Distance (mm)	
	Average	Standard Deviation for a Single Element
From base plate to:-		
Bottom of lower axial blanket	686.3	0.0
Bottom of core	1035.6	1.3
Middle of core	1486.1	1.3
Top of core	1935.0	1.5
Top of upper axial blanket	2285.5	2.2
Core height	899.7	1.5
Lower axial blanket thickness	349.2	1.3
Upper axial blanket thickness	350.3	1.0

Note: The standard errors on the mean heights were obtained by dividing the standard deviations of the measurements for the single elements by $\sqrt{6}$. In particular the standard error on the mean core height is 0.6 mm, i.e. $\pm 0.07\%$

(h) Uncertainty in the Radial Dimension of the MZA Core

The elements in a Zebra assembly are held firmly in position by the lattice plates. The horizontal dimensions of these lattice plates are well known and at ambient temperature correspond to average element pitches of 5.372 cm between elements not separated by a lattice plate and 5.425 cm as an overall average including the lattice plate separations. Any expansion in these dimensions because of the core alpha-decay heating will have been accounted for in the temperature correction. The uncertainty in the position of the element relative to the physical centre of the core. (Both axially and radially the uncertainties in the positioning of an element are estimated to be about ± 1 mm.)

For the model which assumes a uniform spacing of elements with a pitch of 5.4254 cm (the generally assumed value in the original analyses of Zebra assemblies) the core area will be different from the actual area. The area of 213 elements becomes 0.6270 m^2 whereas the area contained within the outline of the 213 core element loading, based on the adjacent element pitch and the lattice plate thickness, is 0.6251 m^2 , about 0.3% less. Calculations for earlier Zebra cores with similar L/D ratios had indicated that a fractional increase in the circular area with a corresponding (uniform) density change to conserve mass, gives the same change in the k-value as the same fractional increase in the core height. Assuming that the density increase throughout the core is uniform, the calculated k-value would therefore be $16 \times 10^{-4} \text{ dk/k}$ higher when the core area is reduced by 0.3%. The uniform density increase is only an approximation to the actual situation where the localised core density varies as a function of the position relative to the lattice plates. Any streaming gaps between elements and between groups of 5x5 elements will be lost by any homogenisation of the sheath material over the space between the plates and the lattice boundary. Calculations made to explore these effects are described in Section 3 .

In the original analysis the additional uncertainty introduced by the approximation of a uniform lattice was estimated to be $4 \times 10^{-4} \text{ dk/k}$. Although this approximation is not being made here the same uncertainty is adopted, although the uncertainty in the positioning of elements, and the possibility of a slight bowing of the elements, are effects expected to be well within this range of uncertainty in position. The variations in

densities of the blankets and the steel bar region were considered to be sufficiently small to have negligible effects on the k-value.

(i) Uncertainty in the Silver-Copper braze material used on the UO₂ plates used in MZA.

The effect of the silver-copper braze material was not recognised in the original analysis of MZA. In fact the effect is quite large, resulting in a reduction in k_{eff} of 40×10^{-4} . How accurately is the mass of this material known? A 30% uncertainty could be the order of magnitude, with a consequent uncertainty in k_{eff} of $\pm 12 \times 10^{-4}$.

(j) Effect of the Lattice plates in the Axial Blanket

The plates, which separate the groups of 5x5 elements, are situated in the axial blanket region. A calculation was made in the original study for MZB by homogenising the material over the axial blanket. This increases the density of iron by about 15.4%. A spherical geometry calculation was made to estimate the effect, which was given as $+ 8 \pm 4 \times 10^{-4}$, the uncertainty being assumed to be 50% of the effect. ***The same figure was taken for MZA in the earlier version of this document. The effect has now been recalculated, using an explicit representation of the lattice plates in a MONK Monte Carlo model. The reactivity difference calculated for the lattice plates in MZA is $+ 2 \pm 3 \times 10^{-4}$, and for MZB is $+ 3 \pm 3 \times 10^{-4}$, both values being within the uncertainty of the MONK calculations. No correction is now proposed for this effect and the calculational model described in Section 3 now represents the lattice plates.***

(k) Reproducibility of an assembly

The value measured in MZB is assumed, $\pm 0.8 \times 10^{-4} \text{dk/k}$.

Summary of Reactivity Corrections, and Associated Uncertainties, Determined by the Measurers to Simplify the Assembly Models.

There is a $\pm 5\%$ uncertainty associated with all reactivity corrections which are measured using the control rods. These were calibrated by period measurements, using the period-reactivity relationship and a chosen set of delayed neutron data. This uncertainty is to be applied to the final reactivity correction, when all of the reactivity corrections have been made to k_{eff} .

- (a) The correction for the partial insertion of the control rods is to increase the measured value of k_{eff} by 1.0069 ± 0.0001
- (b) The correction for the replacement of the control rods by standard core elements is to increase the measured value of k_{eff} by $(18.1 \pm 2) \times 10^{-4} \text{ dk/k}$.
- (c) The correction for the axial channels in the five blanket elements which hold the pulse counters is to increase the measured k_{eff} by $(0.8 \pm 0.2) \times 10^{-4} \text{ dk/k}$
- (d) The temperature correction increases the measured value of k_{eff} by $(9.5 \pm 3) \times 10^{-4} \text{ dk/k}$
- (e) The uncertainty in the Pu239 content of a fuel plate is estimated to be 0.1%. Assuming this uncertainty to be systematic, a pessimistic assumption, produces an uncertainty of $\pm 5 \times 10^{-4} \text{ dk/k}$.
- (f) The Pu241 decay produces a reactivity change of $-1.0 \times 10^{-4} \text{ dk/k}$ per month. A 5% uncertainty in the decay data would result in an uncertainty of $\pm 0.5 \times 10^{-4}$ in the change over the 10 months from the data in the Database to the date of criticality.
- (g) An uncertainty of $\pm 0.6 \text{ mm}$ in the mean core height produces an uncertainty of $\pm 4 \times 10^{-4} \text{ dk/k}$.
- (h) The use of the average element pitch of 5.4254 cm to obtain the core area gives an error of $(-16 \pm 4) \times 10^{-4} \text{ dk/k}$. No correction is made for this effect because the superlattice spacing is adopted in the reference model of the assembly; however the same uncertainty of $\pm 4 \times 10^{-4} \text{ dk/k}$ is adopted here to cover uncertainties in the radial dimensions of the assembly.
- (i) The uncertainty in the silver-copper braze material on the UO_2 plates used in MZA is estimated to introduce an uncertainty in k_{eff} of $\pm 12 \times 10^{-4}$. No correction is made to the measured k -effective value, as has been done in some analyses, because the braze material is represented in the canning material composition.
- (j) In the original analyses a correction was made for the effect of the neglect of the super-lattice grid plates present in the axial blanket areas. This correction is not made in the present document, the lattice plates being represented in the reference model.
- (k) The reproducibility of the critical condition of an assembly was measured in MZB and found to be $\pm 0.8 \times 10^{-4} \text{ dk/k}$. This value is also adopted for MZA.
- (l) There is no mention of the need for corrections for any special elements, other than the correction for holes in blanket elements.

The recommended measured value of k_{eff} for MZA is given in Table 1.28. Following this the measured corrections to obtain a cylindrical representation are described. The need for any further corrections is discussed in Section 2.1.

Table 1.28 The Experimental k-effective Value of MZA (*revised)

Experimental k-value with all control rods raised	1.0069 ± 0.0001
Correction for replacement of control rods by core elements	+ 0.0018 ± 0.0002
Correction for removal of holes in blanket elements	+ 0.00008 ± 0.00002
Correction to reduce core temperature to 23.5°C	+ 0.0009 ± 0.0003
Uncertainty in the Pu239 content	± 0.0005
Uncertainty in core height	± 0.0004
Uncertainty in core diameter	± 0.0004
Uncertainty in the quantity of silver-copper braze material on the uranium oxide plates	± 0.0012
Uncertainty in Pu241 data following calculated correction for Pu241 decay	± 0.00005
Reproducibility of an assembly	± 0.00008
Effect of the systematic ± 5% uncertainty in control rod calibration	± 0.0005
Experimental k-effective for the as-built geometry at 23.5°C on 29th November, 1971.	1.0097 ± 0.0016

It should be noted that the difference of k_{eff} from unity is dependent on the calculated period-reactivity relationship and the delayed neutron data used. The value used here is 0.502×10^{-4} dk/k per standard cm of FR9, as given in MTN/104. An uncertainty of ± 5% in this parameter is assumed.

Correction for the Irregular Core Outline - the Cylindrical Model of MZA

In the calculational models used in the early 1970s, cylindrical geometry was assumed and a correction for the irregular core outline was required. To obtain the necessary corrections the reactivity differences of C11-1D core elements and B11-1 radial blanket elements were measured in four positions near the core-blanket boundary. The results are given in Table 1.29.

Table 1.29A. Edge Element Worths

Position	Radius	Change	$\Delta CR7$ (standard cm) to compensate
52-58	448.1	C11-1D replacing B11-1	- 8.87 $\pm$ 0.02
51-58	438.3	C11-1D replaced by B11-1	+ 9.36 $\pm$ 0.02
44-56	459.6	C11-1D replacing B11-1	- 7.90 $\pm$ 0.01
45-56	423.3	C11-1D replaced by B11-1	+ 10.59 $\pm$ 0.01

Note: The uncertainties are half the correction for reactor drift with time, obtained from balances in the unperturbed reactor. A further uncertainty of $\pm 0.1\%$ of each measured value is added, associated with the reproducibility of such measurements.

A linear fit of the worth against radius allowed reactivity worths to be assigned to annuli in the protrusions each side of the circular boundary. By this means the circular core was found to be $(10 \pm 1) \times 10^{-4}$ dk/k more reactive than the as-built core. The uncertainty arises from the uncertainty in the slope of the fitted line. It was assumed that the irregular outlines between the very similar core regions, and the irregular outer blanket boundaries have negligible reactivity effects. The addition of 1 element at the equivalent core radius was measured to be worth some 8.9 std. cm CR7, i.e. 9.44×10^{-4} dk/k. This corresponds to an increase of 46.9×10^{-4} dM/M (ignoring the slight differences between the various types of core elements). Hence $f = (dM/M)/(dk/k) \approx 5.0$ showing good agreement with the preliminary calculated value of 5.2 using infinite cylindrical geometry and FD4 data, made at the time of the original analysis.

An additional correction is required for the use of a uniform lattice model and the absence of the representation of the superlattice plates in this model (this additional correction being the difference between models C and A, described in Section 3).

Table 1.29B. Corrections to be applied to the Experimental k-effective value to obtain the value for the Cylindrical Model of MZA

Corrections for the use of a Cylindrical Model	
Use of a uniform plan mesh and neglect of the lattice plates (Model C-Model A)	See Section 3.1.1
Correction to a circular outline (see Section 3 for the model)	+ 0.0010 $\pm$ 0.0001

References for MZA reactivity

1. J. M. Stevenson and S. F. Swoboda. Revised Proposals for MOZART Assemblies. MTN/1
2. J. M. Stevenson and S. F. Swoboda. Description of Subcritical and Critical Loadings of Zebra 11 (MZA). MTN/5.
3. J. Marshall, J. M. Stevenson and S. F. Swoboda. Control Rod Calibrations in Zebra 11 (MZA). MTN/6.
4. J. M. Stevenson. Delayed Neutron Data for use in Interpretation of Zebra Experiments. FRIDWP/P(71)14 (Internal UKAEA document).
5. J. M. Stevenson and S. F. Swoboda. Reactivity Measurements with Plate Samples in Zebra 11 (MZA). MTN/9.
6. J. M. Stevenson and S. F. Swoboda. Further Information on the Experimental Reactivity of the 213 Core Element Loading of Zebra 11 (MZA). MTN/8 (Addendum)

The Experimental Reactivity of the Reference Loadings of MZB Versions 1, 2 and 3 (ZEBRA 12/1, 12/2 and 12/3) and the Corrections Determined Experimentally.

The final experimental k-value for the unperturbed reference loading of Version 1 (including a model with an equivalent cylindrical outline) at 21°C on 9th May, 1972 was determined in the original analysis (MTN/18) (and this has been revised here to take account of later revisions to the reactivity scale based on the later cross-section set, FGL5 and the Smith-Tomlinson delayed neutron data, as described in MTN/104, an increase in reactivities of 3.3%). Most of the corrections and uncertainties apply equally to Versions 2 and 3, additional data being given in MTN/31 and MTN/42 for Version 2 and 3 respectively.

MZB Version 4 differed from Version 3 only in the position of the control rod FR9 which was moved in preparation for the MZC programme of control rod measurements (MTN/49).

(a) Correction for Partial Insertion of the Control Rods

During the reactor period measurements on 9th May 1972, the true critical position of the control rod CR7 was determined by plotting the balancing rod position (in standard cm.) against inverse reactor power and extrapolating to infinite power with control rods CR8 and FR9 fully raised. The critical position of CR7 was 47.110 std. cms. The excess reactivity available in CR7 was therefore 33.5 std. cm. Using the revised reactivity worth for CR7 given in MTN/104 Table 7, (see Table 1.49) based on FGL5/Smith Tomlinson data (0.784×10^{-4} dk/k per std cm), **the k_{eff} value of MZB Version 1 with all rods fully raised was 1.00263 ± 0.00005** , the uncertainty arising from the rod profile and not including the systematic uncertainty in the reactivity scale associated with the delayed neutron data (etc).

In MZB Versions 2 and 3 the critical position was measured using both the rods FR9 and CR7 and good consistency was found between the two measurements. The multiplication factor with all rods raised calculated using the revised delayed neutron data of MTN-104 Table 7 is **1.00182 ± 0.00003 in Version 2 and 1.00173 ± 0.00003 in Version 3**. (Again the uncertainty in the delayed neutron scale has not been included).

(b) Correction for the Replacement of the Control Rods by Core Elements

As can be seen in Figure 1.8B, the control rods lie mainly in the region of the C12-30B elements of the inner core. All the rods have the same core cell and only differ in the absorber sections, as described in MTN/18 and summarised earlier in this section. FR9 also contains several natural uranium metal plates to give it the required weight. The reactivity worth of replacing the eight double rods and one single rod by standard core elements was estimated in two stages:-

(i) The worth of the absorber sections

No extra B10 plates were available for use in measuring this quantity. In view of the small correction, the following method of estimation was considered sufficient. The calculated worths of the absorber sections obtained in predicting the rod worths of MZB (see MTN/16) were modified according to the ratios between predicted and measured total rod worths, as described in MTN/23. The error in this assumption will be only a few percent as most of the total worths arise from the absorber section.

In assembly MZA, the ratio of the out-of-core worth to the in-core worth for the absorber section was found to be 0.61×10^{-2} dk/k. In MZB, the calculated central perturbation cross-section of B10 is 1.16 times its value in MZA. The B10 cross-sections when raised in the upper half of the upper axial blankets will be very similar in the two assemblies. Hence the out-of-core to in-core worth ratio in MZB is taken to be $0.61 \times 10^{-2} / 1.16 = 0.53 \times 10^{-2}$ dk/k. The results are given in Table 1.30. The total worth of the raised absorber sections of all rods was estimated to be $-(3 \pm 1) \times 10^{-4}$ dk/k, the standard deviation being chosen to allow for the uncertainties in the various assumptions that were made.

(ii) The relative worths of core and blanket sections of the rods

Two simulated rods were assembled, each consisting of a single moving control rod tube inside a standard fuel sheath, and resting on a standard piston. Each moving tube was filled with control-rod-size plates in identical cells to those found in half a double control rod, and positioned so that the core section in the simulated rod coincided with the core section in the surrounding standard core elements. The "absorber" sections consisted of reduced density aluminium plates only. The steel content of each simulated rod was matched to that of half a double control rod by adding shim steel to the outside of the moving tube in the simulated rod.

When the simulated rods replaced C12-30B elements in positions (42,51) and (58,49) an increase of 4.25 std cm in the position of FR9 (ie. 1.63×10^{-4} dk/k using the conversion factor of MTN/104 Table 7) was required to compensate the reactivity loss. These positions are close to the average radius of all the control rods in MZB, and Table 1.31 shows the calculated ratios (all fairly close to unity) of the core worths at the rod positions to that at the radius of the measurement with the simulated rods. The total reactivity change of replacing all the raised control rods (with no absorber sections) by standard elements is then calculated to be $+ 13 \times 10^{-4}$ dk/k. The presence of some natural uranium in the rod FR9 and the difference in steel contents per position for the single rod compared with the double rods have been ignored. The only other source of error is the relative core perturbation worth and an associated uncertainty of 1×10^{-4} is considered to be more than adequate.

(iii) Total Control Rod Correction.

The total reactivity change on replacing the nine control rods in MZB/1 by standard core elements is obtained by adding together the two contributions of $(3 \pm 1) \times 10^{-4}$ and $(13 \pm 1) \times 10^{-4}$ dk/k - i.e. **$(16 \pm 2) \times 10^{-4}$ dk/k.**

Table 1.30 Estimated Worths of B10 Sections of the Control Rods in the Raised Position

Rod	In Core	Out of Core
	$\times 10^{-2}$	$\times 10^{-4}$ dk/k
1	0.70	0.37
2	0.70	0.37
3	0.73	0.39
4	0.73	0.39
5	0.60	0.32
6	0.60	0.32
7	0.38	0.20
8	0.38	0.20
9	0.16	0.08
Total		2.64×10^{-4} dk/k

This figure has then been rounded to 3×10^{-4} dk/k .

Table 1.31 Reactivity Effects of Simulated Control Rods

Position or rod number	Measured worth of introducing one simulated rod ($\times 10^{-4}$ dk/k)	Calculated relative core perturbation worth	Worth of replacing rod (per position) ($\times 10^{-4}$ dk/k)
(42,51)	-0.79	1.00	-
1, 2, 3, 4	-	1.04	+0.82
5, 6, 7, 8	-	0.90	+0.71
9	-	1.11	+0.88

Total reactivity change on replacing 17 rod positions by standard elements is

$$+ (8 \times 0.82 + 8 \times 0.71 + 1 \times 0.88) \times 10^{-4} = + 13 \times 10^{-4} \text{ dk/k}$$

(calculated using the earlier delayed neutron data and associated reactivity scale, but the difference is within the uncertainty).

(c) Temperature Correction

A reactivity correction is required because the core temperature was above ambient temperature. This was estimated by comparing critical balances on FR9 with the reactor at a steady condition with the core cooling fully on and then after the air-flow had been varied over a weekend to allow a steady state at higher temperatures to be reached.

Eight elements, each with three resistance bulbs were present in the reactor and their positions and the temperature readings on both days are given in Table 1.32. The readings at full air-flow from the five elements which were still in the same positions as for the standard assembly loading agreed closely with those found on 9th May when the reactivity excess was determined.

The ratios of temperature differences $(D_2 - C)/(D_1 - C)$ in Table 1.32 indicate that the assumption that the temperature differences between any points in the core and the containment vary proportionately only apply well to points near the core mid-plane.

Table 1.32 Temperature Readings from Resistance Bulbs

Bulb Position		Temperature Reading (°C)		(D2 - C) / (D1 - C)
Element (Core region)	Approx Height above core centre line (mm)	Day 1 (D1) 19.5.72	Day 2 (D2) 22.5.72	
52,38 (outer)	-66 +3 +65	39.0 39.5 40.0	59.5 59.8 60.0	2.2 ± 0.1 2.1 ± 0.1 2.1 ± 0.1
51,53 (inner)	-311 -105 +298	38.0 46.5 37.0	62.0 75.0 64.0	2.4 ± 0.1 2.2 ± 0.1 2.7 ± 0.2
50,56 (inner)	-419 +12 +441	27.3 47.6 27.0	48.0 77.0 44.5	4.5 ± 0.9 2.1 ± 0.1 4.1 ± 0.8
55,50 (inner)	-292 +12 +319	36.0 40.3 36.0	59.0 68.5 57.0	2.6 ± 0.2 2.5 ± 0.1 2.4 ± 0.2
50,62 (outer)	-291 +16 +328	32.5 47.0 32.0	61.5 77.0 59.5	3.6 ± 0.4 2.2 ± 0.1 3.6 ± 0.4
52-62 (outer)	-166 +3 +189	36.0 42.0 37.0	69.0 75.0 70.0	3.3 ± 0.2 2.6 ± 0.1 3.1 ± 0.2

Notes:

- (1) The containment temperature (C) on both days was 21.4°C.
- (2) The element in position (50,62) was in position (64,54) for the standard loading.
- (3) The uncertainty on a temperature reading is taken to be ± 1°C.

The reactivity loss on allowing the core to heat up was compensated by raising CR7 by 11.4 std cm . Hence the reactivity increase on reducing the core temperature from that at full air flow to a uniform 21.4 C is given by multiplying the observed reactivity change by $(D_1 - C)/(D_2 - D_1)$. A mean value for this ratio, weighted somewhat towards the mid plane values, is estimated as 0.70 with a standard deviation of ± 0.2.

The reactivity increase on cooling to a uniform core temperature of 21.4°C, (the containment temperature) would therefore be 8.0 ± 2.7 std cm CR7 or $(6 \pm 2) \times 10^{-4}$ dk/k (1 std cm CR7 = 0.784×10^{-4} dk/k)

(d) Correction for Holes in Blanket Elements

In MZB the five holes in the radial blanket for the reactor instruments are further out into the blanket than they were in MZA when their worth was 0.8×10^{-4} dk/k. The perturbation effect of these holes is therefore considered negligible in MZB.

(e) The Pu239 Content Uncertainty

The FD4 data set was used in the original analysis to produce cross-sections for the inner and outer core cells, assuming all plutonium metal plates were of type PUV8, as described in MTN/1. The cell calculations

were repeated with the Pu239 contents increased by 1% and the calculation for a 1D cylindrical model of MZB repeated with these new cells, using the axial buckling which gave criticality for the standard cells. The k-value found was 1.0049, an increase in k of 0.49 times the percentage change in the Pu239 content.

The uncertainty in the Pu239 content of a metal plate is 0.1% arising approximately equally from the isotopic and chemical analyses. Because a large number of plates of each type have been used, the difference between the average weights of the plates used and the Database values is considered to be negligibly small. The uncertainty in the plutonium content of the mixed oxide plate will not significantly change the overall error in the plutonium content. **Assuming the 0.1% uncertainty to be systematic for all the fuel types, the associated uncertainty in reactivity will be ± 0.0005 dk/k. The uncertainties in other plate weights have smaller effects on the k_{eff} value uncertainty.**

(f) The effect of Pu241 decay

An analysis of the compositions of the plutonium plates was made at Aldermaston and the results received on 5/5/1972. However, it can be seen that the Pu241 and Am241 contents of the plutonium plates given in the Zebra Database were calculated back in time to refer to the reference date of the Database, January 1971, resulting in some negative values for the Am241 contents of the plates manufactured later than this date. The uncertainty in the compositions calculated for the date of criticality of MZB/1 (9 May 1972) will not be as large as the uncertainty in the change from the data of the Database because the decay time is short.

A 1D infinite cylinder calculation was run with the Pu241 content of both core regions reduced by 25%. The k-value was reduced by 0.0055. The Pu241 contents of all the metal fuel plates are very similar and this result is applicable to the actual assembly. The reactivity worth of the Am241 produced from the Pu241 decay in a similar assembly was calculated to be about 3% of the Pu241 worth and was ignored.

The Pu241 half-life of 14.35 years corresponds to a decrease of 0.40% per month. Hence the reactivity loss from this decay is estimated to be about 0.00009 dk/k per month. However, as described above, this figure has an uncertainty of about $\pm 20\%$. The k_{eff} values are actually to be calculated using the compositions calculated for the date of criticality of MZB/1, 9 May 1972, which requires the measured k_{eff} values of MZB/2 and MZB/3 to be increased by 0.0002 ± 0.00004 and 0.0005 ± 0.0001 , respectively (assuming the $\pm 20\%$ uncertainty).

An uncertainty of $\pm 5\%$ has then been assumed for the calculation of the variation in composition from the reference data of the Database, January 1971, giving the additional uncertainties of ± 0.00007 , ± 0.00008 and ± 0.0001 , respectively, for MZB/1, MZB/2 and MZB/3. (The reactivity is actually to be calculated using the compositions calculated for the date of criticality of MZB/1, 9 May 1972). The total uncertainties are thus ± 0.00007 , ± 0.00009 and ± 0.00014 , respectively, for MZB/1, MZB/2 and MZB/3.

(g) Uncertainties in the Axial Dimensions of Core Elements

The results of measurements of the axial dimensions of inner and outer core elements are given in MTN/18. In particular the mean core heights were 892.0 mm and 899.4 mm respectively. Standard errors on both these means have been estimated as ~ 0.6 mm. An error of 1mm in the height of the core zones gives an error of about 3×10^{-4} in k_{eff} (MTN/42) and hence **an error of 0.6 mm gives $\pm 2 \times 10^{-4}$ dk/k.**

When the calculations of k-values for MZB use the same core height for both the inner core and the outer core a correction and associated uncertainty must be applied. The integrated worths of core material in each core region imply a weighting of 1.75 to 1 in favour of the inner core. The weighted average core height is therefore 894.7 mm. A standard error of ~ 1.0 mm allows for the uncertainties in the height of each core region and in the weighting factor. The reactivity uncertainty associated with such an uncertainty in the core height is therefore $\pm 6 \times 10^{-4}$ dk/k, based on the calculated result for MZA (MTN/8 Addendum). The core heights were measured at ambient temperatures and any changes in the axial dimensions caused by the alpha decay heating in the core will have been accounted for in the temperature correction.

(h) Uncertainty in the Radial Dimensions of the Core

The procedure described in Section 7 of MTN/8 Addendum was used to compare the total core area using the overall average pitch of 5.4254 cm and secondly using the actual element pitch of 5.372 cm within a lattice square and the lattice plate thicknesses. The areas found for the standard loading were calculated to be 1.9927 m^2 for the average pitch and 1.9929 m^2 for the actual dimensions. This difference is negligible and will not introduce a significant reactivity error. The localised density variations near the lattice plates in such a large core are also expected to produce a negligibly small error. To introduce some caution, half of the uncertainty adopted for MZA was assumed, (the radial leakage being reduced relative to that in MZA) an uncertainty of $\pm 2 \times 10^{-4}$ dk/k

(i) Uncertainty in the silver-copper braze material.

The oxide plates which have this braze are only in the outer core region and the reactivity weighting of this region is less than 50%. The uncertainty is taken to be half the figure for MZA, that is, $\pm 6 \times 10^{-4}$ dk/k

(j) Effect of the Lattice plates in the Axial Blanket

A correction for these was made in the original analyses and has now been recalculated for MZB using an explicit representation in the MONK Monte Carlo code. The reactivity effect of the plates is calculated to be $(3 \pm 3) \times 10^{-4}$ dk/k. However, no correction is made here for omitting the lattice plates because they are represented in the reference model.

(k) Reproducibility of an assembly

This was measured in MZB and found to be $\pm 0.8 \times 10^{-4}$ dk/k.

(l) Corrections for any special elements

There is no mention of the need for any such corrections, other than the correction for holes in blanket elements.

The summary of the critical assembly reactivities established by the measurement team for the three versions of MZB is presented in Table 1.33. Following the Table the measured corrections required to obtain a cylindrical representation are also described. The need for any further corrections is discussed in Section 2.1

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Table 1.33. The Experimental k-effective value for MZB Versions 1, 2 and 3 (Revised)

	Version 1	Version 2	Version 3
Date	9th May, 1972	18 July, 1972	31 October, 1972
Experimental k-value for standard loading with all rods raised (not including the β_{eff} uncertainty)	1.0026 ± 0.00005	1.0018 ± 0.00003	1.0017 ± 0.00003
Correction for removal of control rod singularities	$+0.0016 \pm 0.0002$		
Correction to reduce core temperature to 21.4°C	$+0.0006 \pm 0.0002$		
Correction for removal of blanket holes	0.0000		
Correction for Pu241 decay from the database date of 9 May 1972 to date of core criticality	± 0.00007	$+0.0002 \pm 0.00009$	$+0.0005 \pm 0.00014$
Reproducibility of an assembly	± 0.00008		
Uncertainty in the silver copper braze material	± 0.0006		
Uncertainty arising from Pu239 content	± 0.0005		
Core height	± 0.0002		
Radial dimensions	± 0.0002		
Reactivity scale (β_{eff}) $\pm 5\%$	± 0.0002		
Experimental keff for the as-built system at 21.4°C on 9 May 1972 (Revised)	1.0048 ± 0.0009	1.0042 ± 0.0009	1.0044 ± 0.0009
Directly measured differences in reactivity between the assemblies			
MZB(1) to MZB(2)	-0.00072 ± 0.00003		
MZB(2) to MZB(3)		$+0.00023 \pm 0.00003$	

It should be noted that all these corrections are based on the control rod calibrations described in MTN/23 and revised in MTN/104.

Correction for the Irregular Core Outlines – the Cylindrical Geometry Model of MZB

In simple calculational models, a cylindrical geometry, with region areas equal to those contained in the irregular outlines, is assumed. A reactivity correction for the irregular core outlines of the as-built assembly is required. Reactivity differences of inner core against outer core elements, outer core against standard radial blanket elements and also outer core against natural oxide sector elements were measured at the relevant boundaries. These measurements were made with CR7 near its point of inflexion and CR8 and FR9 fully raised.

Reactivity differences were measured for pairs of adjacent element positions to reduce any effects of asymmetries introduced by the rod positions. The results are given in Table 1.34.

Table 1.34A. Element Worths at Core Boundaries

Position	Change	$\Delta CR7$ (standard cm) to compensate
39,46	C11-1A replaced by C12-30D	+ 3.497
39,47	C12-30D replaced by C11-1G	- 3.752
54,64	C11-1A replaced by B11-1G	+ 4.460
55,64	B11-1G replaced by C11-1A	- 4.210
54,36	C11-1A replaced by B12-30	+ 4.553
55,36	B12-30 replaced by C11-1A	- 4.301

Note: The corrections for reactivity drift varied from zero to ~ 0.015 and the associated errors are therefore small. An uncertainty of $\sim 0.1\%$ of each element worth is expected from the reproducibility of such measurements.

The worths of core elements against standard radial blanket elements (B11-1) are very similar to those against sector elements (B12-30). It is probable that some of the small difference is due to the asymmetry produced by the control rod positions.

Moreover, the change in reactivity with radius is the same for outer core elements versus standard radial blanket elements and versus natural uranium oxide sector elements. With the symmetrical outer core loading, the smoothing correction could therefore be calculated for a single quadrant and scaled up. A straight line plot of the worth against radius obtained from each pair of measurements allowed reactivity worths to be assigned to annuli in the protrusions each side of the circular boundaries. The treatment was revised in MTN/30. For converting the inner core-outer core boundary to a circular outline of equal area a decrease in reactivity by $(2.5 \pm 0.5) \times 10^{-4} dk/k$ is estimated and for converting the outer core-radial blanket boundary to a circular outline of equal area an increase in reactivity by $(+ 2.6 \pm 0.5) \times 10^{-4} dk/k$. Thus the total correction for core smoothing was estimated in MTN/30 to be $(0 \pm 1) \times 10^{-4} dk/k$.

The reactivity effects of irregular boundaries between zones of slightly different types of inner or outer core elements, and the irregular outer blanket boundaries are negligible.

The cylindrical model assumes a regular cell pattern and neglects the lattice plates and so a correction is to be applied to the measured keff value used with this model to allow for this approximation.

Table 1.34B. Corrections to be applied to the Experimental k-effective value to obtain the value for the Cylindrical Model of MZB

Cylindrical model representation of MZB	
Corrections to produce circular outlines	-0.0000 ± 0.0001
Corrections for the use of a uniform lattice model and neglect of the lattice plates (Model C – Model A)	See Section 3.1.1

References for the MZB Criticality Measurement.

1. J. M. Stevenson and S. F. Swoboda. Description of the Standard Loading of Zebra Assembly 12(l) - the First Version of MZB. MTN/18
2. J. Marshall, J. M. Stevenson and S. F. Swoboda. Control Rod Calibrations in Zebra 12(l) - the First Version of MZB. MTN/23
3. J. M. Stevenson and S. F. Swoboda. The Final Design of MZB. MTN/16

1.1.3 Material Data

The dimensions and compositions have been copied from the ZEBRA Database. However, in some cases the numbers have been rounded to fewer significant figures, when it was thought that the extra figures had arisen because of data manipulation on a computer which had resulted in extra figures being added. In some cases the Database includes the weights in percentage terms, as well as absolutely (in particular, in the case of plate canning material). In other cases (in particular for the core regions of plates) the percentage weights included in the present document have been calculated, and again rounded when it seemed most probable that the weights had originally been given in percentage terms and to fewer significant figures.

All weights in the following tables are in g.

Mixed Uranium-Plutonium Oxide Plate PUIV4

COMMENTS: (Not corrected for Pu241 decay. The reference date for the compositions of the plates in the ZEBRA Database is January 1971.) This plate is the same as the PuO₂/UO₂ plate used in the ZEBRA 8 series of measurements.

Core region:

Nuclide	Weight (g)	Percentage by weight
C	0.0168	0.013
O	15.4510	11.824
AL	0.0168	0.013
SI	0.0168	0.013
FE	0.0168	0.013
NI	0.0168	0.013
U234	0.0040	0.003
U235	0.6120	0.468
U238	85.4890	65.419
NP237	0.0010	0.001
PU239	25.7100	19.674
PU240	2.8860	2.208
PU241	0.2920	0.223
PU242	0.0260	0.020
AM241	0.1237	0.095
Total	130.6787	

Can region

Nuclide	Weight (g)	Percentage by weight
H	0.00008	0.0005
C	0.00858	0.05
SI	0.07036	0.41
P	0.00342	0.02
S	0.00343	0.02
CR	3.07163	17.90
MN	0.25568	1.49
FE	11.92100	69.47
NI	1.71428	9.99
NB	0.11154	0.65
Total	17.16000	

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Plutonium Metal Plates

(Not corrected for Pu-241 decay. The reference date for the compositions of the plates in the ZEBRA Database is January 1971. The compositions of the plutonium plates given in the Database have been corrected from the measured values to refer to this reference date. This has the curious consequence that the Am241 compositions can be negative when the plutonium was produced at a date later than January 1971 and this is the case for a number of the later plutonium plates.

Suppose the plutonium is produced at a time, t , after the reference date of the database (and contained no Am241 at that time) and the amount of Pu241 is $N_0(\text{Pu241})$. The figure recorded in the database, $N_t(\text{Pu241})$, is this figure increased by the factor $\exp(\lambda t)$ where λ is the Pu241 decay constant

$$N_t(\text{Pu241}) = N_0(\text{Pu241}) \cdot \exp(\lambda t)$$

and the amount of Am241 is given as the negative quantity:

$$N_t(\text{Am241}) = N_0(\text{Pu241}) \cdot (1 - \exp(\lambda t))$$

The amount of Pu241 plus Am241 is equal to $N_0(\text{Pu241})$ and at the time t following the reference date (at the plutonium production date) the amount of Am241 is then calculated to be zero and at subsequent times the Pu241 and Am241 content is calculated correctly.

See also the Appendix to this section provided by the reviewer Atsushi Zukeran.

Core region weights (g)

Identifier	PUV8	PUVI8	PUVII8	PUVIII8	PUIX8	PUX8	PUXI8	PUXII8
Nuclide								
U238	0.0027	0.0005	0.0019	0.0014	0.0107	0.0029	0.0014	0.0034
PU238	0.0590	0.0750	0.0640	0.0620	0.0720	0.0690	0.0760	0.0750
PU239	59.7070	58.9820	59.0970	59.1110	59.0300	59.2570	59.0190	59.1690
PU240	13.8870	15.0100	14.2300	14.1820	14.2030	14.1300	14.2510	14.1040
PU241	2.1640	2.5260	2.4540	2.4750	2.4990	2.4870	2.5280	2.5410
PU242	0.3430	0.4150	0.3860	0.3870	0.3720	0.3820	0.3810	0.3710
AM241	0.1069	0.0205	0.0116	-0.0083	-0.0343	-0.0861	-0.0944	-0.1024
H	0.0015	0.0009	0.0012	0.0011	0.0013	0.0009	0.0015	0.0015
C	0.0256	0.0234	0.0208	0.0434	0.0288	0.0302	0.0234	0.0269
N	0.0016	0.0029	0.0008	0.0029	0.0011	0.0012	0.0014	0.0008
O	0.0069	0.0049	0.0074	0.0121	0.0078	0.0062	0.0057	0.0057
AL	0.0050	0.0040	0.0039	0.0053	0.0053	0.0050	0.0043	0.0040
SI	0.0057		0.0026	0.0034	0.0068	0.0038	0.0044	0.0053
CR	0.0023	0.0014	0.0018	0.0016	0.0027	0.0019	0.0027	0.0041
MN	0.0005	0.0005	0.0004	0.0007	0.0008	0.0005	0.0005	0.0004
FE	0.0079	0.0092	0.0050	0.0078	0.0062	0.0071	0.0106	0.0071
NI	0.0059	0.0034	0.0045	0.0043	0.0134	0.0081	0.0088	0.0119
GA	1.3315	1.3393	1.2168	1.2022	1.2582	1.3311	1.3354	1.3676
MO	0.0016							
Sum of wts	77.6656	78.4189	77.5097	77.4949	77.4848	77.6378	77.5607	77.5963

Gallium is the metallic plutonium stabilising material

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Can region weights (g)

The can region weights are separated into the steel can and the copper plating region.

Nuclide	PUV8	PUVI8	PUVII8	PUVIII8	PUIX8	PUX8	PUXI8	PUXII8
Steel can								
H	0.000073	0.000076	0.000075	0.000075	0.000075	0.000074	0.000073	0.000072
C	0.006023	0.007407	0.007371	0.007360	0.007342	0.007821	0.007675	0.007584
SI	0.063171	0.055929	0.055659	0.055574	0.055437	0.078954	0.077486	0.076564
P	0.003085	0.002267	0.002256	0.002253	0.002247	0.004469	0.004386	0.004334
S	0.001616	0.0				0.002681	0.002632	0.002600
TI						0.001490	0.001462	0.001445
CR	2.600303	2.660410	2.647563	2.643516	2.636999	2.800630	2.748554	2.715842
MN	0.223303	0.256972	0.255731	0.255340	0.254711	0.253249	0.248540	0.245582
FE	10.35378	10.80279	10.75063	10.73419	10.70775	10.21330	10.02339	9.904100
NI	1.439716	1.330207	1.323783	1.321758	1.318502	1.534389	1.505858	1.487937
Steel Can Wt.	14.691	15.116	15.043	15.020	14.983	14.897	14.620	14.446
CU can								
CU	5.709	5.709	5.709	5.709	5.709	5.792	5.792	5.792
Total wt	20.400	20.825	20.752	20.729	20.692	20.689	20.412	20.238

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Percentage Weights (Not corrected for Pu-241 decay.)

CORE

	PUV8	PUVI8	PUVII8	PUVIII8	PUIX8	PUX8	PUXI8	PUXII8
Nuclide								
U238	0.0035	0.0006	0.0025	0.0018	0.0138	0.0037	0.0018	0.0044
PU238	0.0760	0.0956	0.0826	0.0800	0.0929	0.0889	0.0980	0.0967
PU239	76.8770	75.2140	76.2447	76.2773	76.1827	76.3249	76.0939	76.2523
PU240	17.8805	19.1408	18.3590	18.3006	18.3300	18.1999	18.3740	18.1761
PU241	2.7863	3.2212	3.1661	3.1938	3.2251	3.2033	3.2594	3.2746
PU242	0.4416	0.5292	0.4980	0.4994	0.4801	0.4920	0.4912	0.4781
AM241	0.1376	0.0261	0.0150	-0.0107	-0.0443	-0.1109	-0.1217	-0.1320
H	0.0019	0.0011	0.0015	0.0014	0.0017	0.0012	0.0019	0.0019
C	0.0330	0.0298	0.0268	0.0560	0.0372	0.0389	0.0302	0.0347
N	0.0021	0.0037	0.0010	0.0037	0.0014	0.0015	0.0018	0.0010
O	0.0089	0.0062	0.0095	0.0156	0.0101	0.0080	0.0073	0.0073
AL	0.0064	0.0051	0.0050	0.0068	0.0068	0.0064	0.0055	0.0052
SI	0.0073	0.0000	0.0034	0.0044	0.0088	0.0049	0.0057	0.0068
CR	0.0030	0.0018	0.0023	0.0021	0.0035	0.0024	0.0035	0.0053
MN	0.0006	0.0006	0.0005	0.0009	0.0010	0.0006	0.0006	0.0005
FE	0.0102	0.0117	0.0065	0.0101	0.0080	0.0091	0.0137	0.0091
NI	0.0076	0.0043	0.0058	0.0055	0.0173	0.0104	0.0113	0.0153
GA	1.7144	1.7079	1.5699	1.5513	1.6238	1.7145	1.7217	1.7625
MO	0.0021	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total core wt.	77.66541	78.42035	77.50955	77.49477	77.48470	77.63765	77.56055	77.59615

CAN Percentage weights for the combined steel and copper regions

CAN	PUV8	PUVI8	PUVII8	PUVIII8	PUIX8	PUX8	PUXI8	PUXII8
H	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
C	0.0295	0.0356	0.0355	0.0355	0.0355	0.0378	0.0376	0.0375
SI	0.3097	0.2686	0.2682	0.2681	0.2679	0.3816	0.3796	0.3783
P	0.0151	0.0109	0.0109	0.0109	0.0109	0.0216	0.0215	0.0214
S	0.0079					0.0130	0.0129	0.0128
TI						0.0072	0.0072	0.0071
CR	12.7466	12.7751	12.7581	12.7528	12.7441	13.5368	13.4654	13.4195
MN	1.0946	1.2340	1.2323	1.2318	1.2310	1.2241	1.2176	1.2135
FE	50.7534	51.8738	51.8049	51.7831	51.7479	49.3655	49.1051	48.9378
NI	7.0574	6.3876	6.3791	6.3764	6.3720	7.4165	7.3773	7.3522
CU	27.9853	27.4142	27.5106	27.5411	27.5904	27.9956	28.3755	28.6194
Total	20.400	20.825	20.752	20.729	20.692	20.689	20.412	20.238

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**Repeat of the above data for the U-Pu isotopes compared with other reported values.
The current Zebra Database values (Reference date 1/1971)**

	PUV8	PUVI8	PUVII8	PUVIII8	PUIX8	PUX8	PUXI8	PUXII8
CORE								
U238	0.0027	0.0005	0.0019	0.0014	0.0107	0.0029	0.0014	0.0034
PU238	0.0590	0.0750	0.0640	0.0620	0.0720	0.0690	0.0760	0.0750
PU239	59.7070	58.9820	59.0970	59.1110	59.0300	59.2570	59.0190	59.1690
PU240	13.8870	15.0100	14.2300	14.1820	14.2030	14.1300	14.2510	14.1040
PU241	2.1640	2.5260	2.4540	2.4750	2.4990	2.4870	2.5280	2.5410
PU242	0.3430	0.4150	0.3860	0.3870	0.3720	0.3820	0.3810	0.3710
AM241	0.1069	0.0205	0.0116	-0.0083	-0.0343	-0.0861	-0.0944	-0.1024

Estimate allowing for decay of Pu-241 to 12/1971. 4% of the Pu-241 will have decayed to Am241 by this date.

PU241	2.0774	2.4250	2.3558	2.3760	2.3990	2.3875	2.4269	2.4394
AM241	0.1935	0.1215	0.1098	0.0907	0.0657	0.0134	0.0067	-0.0008

(The PUXII8 plate had clearly not been manufactured this early)

Values given in the MTN/7 MZA Printouts used in the original analysis.

	PUV8	PUVI8	PUVII8	PUVIII8	PUIX8	PUX8	PUXI8	PUXII8
CORE								
U238	0.0000	0.0000	0.0000	0.0000				
PU238	0.0000	0.0000	0.0000	0.0000				
PU239	59.6980	58.9630	59.0940	59.1280				
PU240	13.8890	15.0050	14.2320	14.1720				
PU241	2.0544	2.4243	2.3499	2.3642				
PU242	0.3400	0.4150	0.3860	0.3880				
AM241	0.1200	0.0160	0.0030	0.0000				

The MTN/7 printouts for MZA (for 12/1971) give data which differ from the current version of the Zebra database (reference date 1/1971, although this was probably revised at a later date and calculated back to the reference date). The MTN/7 data are simpler in that the contents for U238 and Pu238 in the plutonium metal plates are zero. The reference date is given as 11/1971.

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Plutonium Metal Plates used in Small Sample Perturbation Measurements

The plutonium plates used in the core elements contain ~18% Pu240 whereas these PUII and PUIII plates contain ~5% and ~10% respectively. In the perturbation measurements a plate replaces an empty can and so the perturbation is due to the core material of the plate. The PUII8 plate is the one used in the ZEBRA 8 series of experiments (the Pu241 content having reduced by decay since those measurements).

CORE	PUII8		PUIII8	
	Weight (g)	Weight %	Weight (g)	Weight %
NP237	0.0230	0.0317		
PU239	67.4920	92.9236	63.0260	86.756
PU240	3.5100	4.8326	7.3240	10.082
PU241	0.1920	0.2643	0.7620	1.049
PU242			0.0640	0.088
AM241	0.0845	0.1163	0.2512	0.346
H	0.0012	0.0017	0.0012	0.002
C	0.0098	0.0135		
AL	0.0098	0.0135		
SI	0.0098	0.0135		
FE	0.0098	0.0135		
NI	0.0098	0.0135		
GA	1.2800	1.7623	1.2190	1.678
Total core wt.	72.6317	100.000	72.6474	100.001

SteelCan	Weight (g)	Weight %	Weight (g)	Weight %
H	0.000081	0.0005	0.000078	0.0005
C	0.011291	0.07	0.010938	0.07
SI	0.054842	0.34	0.053128	0.34
P	0.003226	0.02	0.003125	0.02
S	0.003226	0.02	0.003125	0.02
CR	2.925974	18.14	2.834551	18.14
MN	0.151622	0.94	0.146884	0.94
FE	11.49423	71.26	11.1350	71.26
NI	1.485571	9.21	1.439153	9.21
Steel Can wt.	16.13	73.32	15.626	73.45
CU region.				
CU	5.87	26.68	5.649	26.55
Total can region. wt	22.00	100.00	21.275	100.00

The weight % of the components of the steel can are relative to the total steel can weight.

The Natural Uranium Oxide Plates

UO22R4

CORE

Nuclide	COMPOSITION GRAMS WT.	Percentage of weight
H	0.0005	0.0004
C	0.0024	0.0018
N	0.0059	0.0044
O	15.8200	11.8520
AL	0.0008	0.0006
SI	0.0016	0.0012
CA	0.0029	0.0022
CR	0.0012	0.0009
FE	0.0074	0.0055
NI	0.0006	0.0004
U235	0.8360	0.6263
U238	116.8000	87.5043
TOTAL	133.4793	100.0000

CAN

Nuclide	COMPOSITION GRAMS WT.	Percentage of weight
H	0.000092	0.0005
C	0.004985	0.0257
AL	0.000185	0.0010
SI	0.120009	0.6182
P	0.003139	0.0162
S	0.000739	0.0038
TI	0.001846	0.0095
CR	3.360261	17.3091
MN	0.197554	1.0176
FE	13.038740	67.1642
NI	1.661668	8.5595
CU	0.294041	1.5146
NB	0.003693	0.0190
MO	0.046157	0.2378
AG	0.680102	3.5033
TOTAL	19.4131	100.0000

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CRIT-BUCK-SPEC-REAC-RRATE

UO23R4.

CORE

Nuclide	COMPOSITION GRAMS WT.	Percentage of weight
H	0.0007	0.0005
C	0.0031	0.0023
O	16.0900	11.8488
AL	0.0020	0.0015
SI	0.0141	0.0104
MN	0.0001	0.0001
FE	0.0016	0.0012
NI	0.0016	0.0012
MO	0.0007	0.0005
U235	0.8500	0.6259
U238	118.8300	87.5076
Total	135.7939	100.0000

CAN

ISOTOPE	COMPOSITION GRAMS	Percentage of weight
H	0.0001	0.0005
C	0.0078	0.0386
SI	0.0916	0.4539
P	0.0549	0.2723
S	0.0058	0.0290
CR	3.6330	18.0110
MN	0.2377	1.1782
FE	13.6399	67.6212
NI	2.5003	12.3953
Total	20.1710	100.0000

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UO24R4. (This is the same as the plate used in the ZEBRA 8 Series. It is the plate with the silver-copper braze material, $71 \pm 1\%$ Ag, $29 \pm 1\%$ Cu.)

CORE

Nuclide	COMPOSITION GRAMS WT.	Percentage of weight
H	0.0005	0.0004
C	0.008	0.0060
O	15.847	11.8513
SI	0.008	0.0060
FE	0.008	0.0060
U234	0.006	0.0045
U235	0.838	0.6267
U238	117.000	87.4991
Total	133.7155	100.0000

CAN

Nuclide	COMPOSITION GRAMS	Percentage of weight
H	0.000089	0.0005
C	0.008931	0.05
SI	0.087529	0.49
P	0.003573	0.02
S	0.003573	0.02
CR	3.286777	18.40
MN	0.275089	1.54
FE	12.393330	69.38
NI	1.804159	10.10
CU	0.265086	1.484
AG	0.682008	3.818
TOTAL	18.810100	105.3025 *

- Note: The percentage weights given in the ZEBRA Database are in two parts, the steel part and the silver-copper braze part. The hydrogen was also added later, hence the percentage total figure of 105.3025.

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CRIT-*BUCK*-SPEC-REAC-RRATE

UO2DP4 Depleted UO2 plate

Nuclide	COMPOSITION GRAMS	Percentage of weight
H	0.00008	0.00005
C	0.0048	0.0030
O	19.0310	11.85785
SI	0.0112	0.0070
CR	0.0128	0.0080
MN	0.0019	0.0012
FE	0.0241	0.0150
NI	0.0112	0.0070
U235	0.2834	0.1766
U238	141.1110	87.9243
TOTAL	160.49148	100.00000

Note: This plate does not have a can

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

Natural Uranium Metal Components

Blanket Region Natural Uranium Components

Plate	Thickness (cm)	Width (cm)	Volume (cm ³)
U8	0.317	5.067	8.1388
U2	1.2723	5.067	32.6657

	Plate U8		Plate U2	
Nuclide	Weight (g)	Percent weight	Weight (g)	Percent weight
H	0.0006	0.0004	0.0024	0.0004
C	0.0800	0.0536	0.3000	0.0492
SI	0.0800	0.0536	0.3000	0.0492
FE	0.0800	0.0536	0.3000	0.0492
U235	1.0600	0.7097	4.3300	0.7106
U238	148.0600	99.1291	604.1099	99.1414
Total	149.3606	100.0000	609.3423	100.0000

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CRIT-BUCK-SPEC-REAC-RRATE

Sodium Plates

NASTDL4.

CORE

Nuclide	Weight (g)	Percentage of weight
H	0.0003	0.0025
O	0.0020	0.0169
NA	11.8150	99.9518
CA	0.0032	0.0271
FE	0.0002	0.0017
Total	11.8207	100.0000

CAN

Nuclide	Weight (g)	Percentage of weight
H	0.0001	0.0005
C	0.0142	0.0802
SI	0.0690	0.3899
P	0.0041	0.0232
S	0.0043	0.0243
CR	3.0975	17.5016
MN	0.3009	1.7002
FE	12.4100	70.1194
NI	1.6815	9.5009
NB	0.1168	0.6599
Total	17.6984	100.0000

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NASTDM4.

CORE

Nuclide	Weight (g)	Percentage of weight
H	0.00031	0.0026
O	0.0020	0.0170
NA	11.8150	99.9517
CA	0.0032	0.0270
FE	0.0002	0.0017
Total	11.82071	100.0000

CAN

Nuclide	Weight (g)	Percentage of weight
H	0.00009	0.0005
C	0.01062	0.0600
SI	0.09027	0.5100
P	0.00407	0.0230
S	0.00212	0.0120
CR	3.38424	19.1200
MN	0.28320	1.6000
FE	11.90590	67.2645
NI	1.89036	10.6800
NB	0.12921	0.7300
Total	17.70008	100.0000

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NASTBR4 (This sodium plate was also used in the ZEBRA 8 Series of measurements)

CORE

Nuclide	NASTBR4 Weight (g)	Percentage Of weight
H	0.000047	0.0004
LI	0.000059	0.0005
B	0.000034	0.0003
O	0.000710	0.0060
NA	11.790000	99.9760
K	0.000410	0.0034
CA	0.001530	0.0130
FE	0.000047	0.0004
TOTAL	11.792837	100.0000

CAN

Nuclide	NASTBR4 Weight (g)	Percentage of weight
H	0.000088	0.0005
C	0.010608	0.06
SI	0.068952	0.39
P	0.003536	0.02
S	0.003536	0.02
CR	3.180625	18.0
MN	0.242216	1.37
FE	12.317650	69.6695
NI	1.736173	9.82
NB	0.114920	0.65
Total	17.678304	100.0000

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CRIT-*BUCK*-SPEC-REAC-RRATE

NAJI4

CORE

Nuclide	Weight (g)	Percentage Of weight
H	0.00027	0.0024
O	0.00176	0.0156
NA	11.24840	99.9635
CA	0.00183	0.0163
FE	0.00025	0.0022
Total	11.25251	100.0000

CAN

Nuclide	Weight (g)	Percentage of weight
H	0.000120	0.0005
C	0.014382	0.06
SI	0.117453	0.49
P	0.007191	0.03
S	0.002397	0.01
CR	4.547097	18.97
MN	0.381122	1.59
FE	16.263610	67.8395
NI	2.509656	10.47
NB	0.129438	0.54
Total	23.9724	100.0000

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-*BUCK*-SPEC-REAC-RRATE

NAJII4

CORE

Nuclide	Weight (g)	Percentage Of weight
H	0.00027	0.0024
O	0.00176	0.0156
NA	11.24840	99.9635
CA	0.00183	0.0163
FE	0.00025	0.0022
Total	11.2525	100.0000

CAN

Nuclide	Weight (g)	Percentage of weight
H	0.000120	0.0005
C	0.016779	0.0700
SI	0.093483	0.3900
P	0.006712	0.0280
S	0.005753	0.0240
CR	4.271445	17.8200
MN	0.393107	1.6400
FE	16.759310	69.9175
NI	2.308308	9.6300
NB	0.115056	0.4800
Total	23.970	100.0

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

Stainless Steel Plates

STSTBR8 (This is the Stainless Steel "Bright" plate also used in the ZEBRA-8 Series)

Nuclide	Weight (g)	Percent weight
H	0.0003	0.0005
C	0.1268	0.2000
AL	0.0635	0.1000
SI	0.5074	0.8000
TI	0.1903	0.3000
CR	11.4821	18.1000
MN	0.6977	1.1000
FE	44.0116	69.3995
NI	6.1513	9.7000
CU	0.0635	0.1000
MO	0.1268	0.2000
Total	63.4213	100.0000

STSTD8 (This is the Stainless Steel "Dull" plate also used in the ZEBRA-8 Series)

Nuclide	Weight (g)	Percent weight
H	0.0003	0.0005
C	0.1286	0.2000
AL	0.0643	0.1000
SI	0.5143	0.8000
TI	0.1929	0.3000
CR	11.6380	18.1000
MN	0.7071	1.1000
FE	44.6100	69.3995
NI	6.2350	9.7000
CU	0.0643	0.1000
MO	0.1285	0.2000
Total	64.2833	100.0000

Note: these two plates have the same composition but slightly different masses.

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The 40% Stainless Steel Plate, STSTF8.

Nuclide	Weight (g)	Percent weight
H	0.0001	0.0004
C	0.0057	0.0231
AL	0.0173	0.0700
SI	0.1210	0.4899
P	0.0067	0.0271
S	0.0025	0.0101
TI	0.0642	0.2599
CR	4.4710	18.1012
MN	0.4446	1.8000
FE	16.7141	67.6684
NI	2.7910	11.2996
CU	0.0173	0.0700
NB	0.0025	0.0101
MO	0.0420	0.1700
Total	24.7000	100.0000

Mild Steel Plates and the Steel Bar

Weight (g)

Nuclide	MST1	MST2	MST3	MST8
H	0.00295	0.00157	0.00842	0.00053
C	0.6646	0.3311	1.9890	0.0812
AL	0.4090	0.2038	1.2240	0.0500
TI	0.2045	0.1019	0.6120	0.0250
CR	0.1534	0.0764	0.4590	0.0188
MN	1.9428	0.968	5.8140	0.2375
FE	507.1599	252.69	1517.7600	62.0000
NI	0.3068	0.1528	0.9180	0.0375
CU	0.3068	0.1528	0.9180	0.0375
MO	0.1022	0.0509	0.3060	0.0125
TOTAL	511.2520	254.7292	1530.0070	62.50046

Percentage by weight.

Nuclide	MST1	MST2	MST3	MST8
H	0.0006	0.0006	0.0006	0.0008
C	0.1300	0.1300	0.1300	0.1300
AL	0.0800	0.0800	0.0800	0.0800
TI	0.0400	0.0400	0.0400	0.0400
CR	0.0300	0.0300	0.0300	0.0300
MN	0.3800	0.3800	0.3800	0.3800
FE	99.1994	99.1994	99.1994	99.1992
NI	0.0600	0.0600	0.0600	0.0600
CU	0.0600	0.0600	0.0600	0.0600
MO	0.0200	0.0200	0.0200	0.0200
Total	100.0000	100.0000	100.0000	100.0000

These four mild steel components have essentially the same composition. The hydrogen fraction is a nominal one.

MST9F10 (The Steel Bar used as a radial reflector)

(Weight in g per 1 cm length) Total length ~3 m

Nuclide	Weight (g)	Percentage of weight
H	0.0020	0.0010
C	0.3550	0.1798
SI	0.3750	0.1900
P	0.0570	0.0289
S	0.0510	0.0258
MN	1.6780	0.8500
FE	194.8830	98.7244
Total	197.4010	100.0000

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Graphite Plates.

Square section plates of width 5.067 cm

Plate	GI8		GII8		GIII8	
Nuclide	Weight (gms)	Weight percent.	Weight (gms)	Weight percent.	Weight (gms)	Weight percent
H	0.0007	0.005	0.0003	0.002	0.00026	0.002
C	13.2580	99.920	13.8470	99.984	13.64100	99.985
S	0.0053	0.040	0.0005	0.004		
FE	0.0046	0.035	0.0014	0.010	0.00180	0.013
TOTAL	13.2686	100.000	13.8492	100.000	13.64306	100.000
Thickness	0.318cm		0.31775cm		0.319cm	

Plate	G13		G3	
Nuclide	Weight (gms)	Weight percent.	Weight (gms)	Weight percent.
H	0.369	0.025	0.319	0.1
C	1477.500	99.975	318.750	99.9
TOTAL	1477.869	100.000	319.069	100.0
Thickness	33.3375cm		7.62 cm	

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Aluminium Plates.

Plate	ALG8		ALSC3	
Nuclide	COMPOSITION GRAMS WT.	Percentage of weight	COMPOSITION GRAMS WT.	Percentage of weight
AL	9.7377	99.670	417.1504	99.847
SI	0.0039	0.040	0.0418	0.010
MN	0.0005	0.005	0.0167	0.004
FE	0.0274	0.281	0.5431	0.130
CU	0.0004	0.004	0.0376	0.009
	9.7699	100.000	417.7893	100.000

AL2O34

Nuclide	COMPOSITION GRAMS WT.	Percentage of weight
H	0.0014	0.0023
B10	0.0012	0.0020
B11	0.0049	0.0081
O	28.6050	47.0786
AL	32.1476	52.9090
TOTAL	60.7601	100.0000

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CRIT-*BUCK*-SPEC-REAC-RRATE

93% Enriched Uranium Plate

PLATE IDENTITY 93U516

Nuclide	COMPOSITION GRAMS WT.	Percentage of weight
H	0.0003	0.0004
C	0.018	0.0245
O	0.039	0.0530
AL	0.007	0.0095
SI	0.011	0.0149
FE	0.025	0.0340
U235	68.27	92.7578
U238	5.23	7.1059
Total	73.6003	100.0000

Absorber Plates used in Small Sample Perturbation Measurements

TA8

Nuclide	COMPOSITION GRAMS WT.	Percentage of weight
TA	134.05	100%

B4CNAT4

CORE

Nuclide	COMPOSITION GRAMS WT.	Percentage of weight
H	0.0005	0.003
B10	2.8230	14.517
B11	12.5050	64.307
C	4.0510	20.832
SI	0.0390	0.201
CA	0.0058	0.030
FE	0.0214	0.110
Total	19.4457	100.000

CAN

Nuclide	COMPOSITION GRAMS WT.	Percentage of weight
H	0.000088	0.0005
C	0.010620	0.06
SI	0.090270	0.51
P	0.004071	0.023
S	0.002124	0.012
CR	3.384236	19.12
MN	0.283200	1.6
FE	11.905900	67.265
NI	1.890358	10.68
NB	0.129210	0.73
Total	17.7	100.0000

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Sheath Material.

(Weight in g per unit cm.)

SHEATH (Stainless Steel) (This sheath is also used in the ZEBRA-8 Series)

Nuclide	GRAMS WT.	Percent of weight
H	0.00006	0.0005
C	0.0245	0.2
AL	0.0245	0.2
SI	0.0736	0.6
TI	0.0368	0.3
V	0.0123	0.1
CR	2.1950	17.9
MN	0.1716	1.4
FE	8.2880	67.5995
NI	1.3850	11.3
CU	0.0123	0.1
MO	0.0368	0.3
TOTAL	12.26046	100.0000

MSHTH (Mild Steel)

Nuclide	Weight.	Percent weight
H	0.00068	0.006
C	0.0098	0.085
SI	0.0034	0.03
P	0.0010	0.01
S	0.0039	0.034
MN	0.0396	0.345
FE	11.4140	99.49
TOTAL	11.47238	100.000

Mild Steel Cylindrical Spacer Material, MSTST3 and MSTST12 used Above and Below the Plenum Region.

Weight per 1 cm length: 33.23 g

Superlattice Mild Steel Plates

The mild steel superlattice grids are of width 0.25 cm, and are situated in a gap of 0.2665 cm between the groups of 5x5 elements. The composition is assumed to be that of the mild steel element sheath MSHTH.

Control Rod Materials

All plates are nominally 4.318 cm square.

PUIVC4 (The mixed uranium-plutonium oxide control rod plate)

CORE

Nuclide	Weight, g	Weight %
O	10.831	11.827
U235	0.429	0.468
U238	59.861	65.367
NP237	0.001	0.001
PU239	18.078	19.741
PU240	2.029	2.216
PU241	0.205	0.224
PU242	0.087	0.095
AM241	0.006	0.007
C	0.01	0.011
AL	0.01	0.011
SI	0.01	0.011
FE	0.01	0.011
NI	0.01	0.011
Total	91.577	100.001

CAN

Nuclide	Weight, g	Weight %
H	0.000064	0.0005
C	0.0064	0.05
SI	0.0524	0.41
P	0.0026	0.02
S	0.0026	0.02
CR	2.2864	17.90
MN	0.1903	1.49
FE	8.8734	69.47
NI	1.2760	9.99
NB	0.0830	0.65
Total	12.773164	100.0005

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Plutonium metal control rod plates

PUIIC8

CORE

Nuclide	Weight, g	Weight %
H	0.00007	0.00014
C	0.0068	0.01340
AL	0.0068	0.01340
SI	0.0068	0.01340
FE	0.0068	0.01340
NI	0.0068	0.01340
GA	0.8942	1.76237
NP237	0.0161	0.03173
PU239	47.149	92.92573
PU240	2.452	4.83263
PU241	0.134	0.26410
AM241	0.0590	0.11628
Total	50.73837	99.99998

CAN

Nuclide	Weight, g	Weight %
C	0.0082	0.07
SI	0.040	0.34
P	0.0024	0.02
S	0.0024	0.02
CR	2.128	18.14
MN	0.110	0.94
FE	8.359	71.26
NI	1.080	9.21
Total steel	11.73	100.00
Steel %		74.904
Cu	3.93	
Cu %		25.096
Grand total	15.66	100.000

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PUIHC8

CORE

Nuclide	Weight, g	Weight %
GA	0.85	1.678
PU239	43.947	86.764
PU240	5.111	10.091
PU241	0.521	1.029
PU242	0.045	0.089
AM241	0.1773	0.350
Total	50.6513	100.001

CAN

Nuclide	Weight, g	Weight %
C	0.0081	0.07
SI	0.0395	0.34
P	0.0023	0.02
S	0.0023	0.02
CR	2.105	18.14
MN	0.109	0.94
FE	8.269	71.26
NI	1.069	9.21
Total	11.6042	100.00
Steel %		74.904
Cu	4.071	25.096
Grand total	15.6752	100.00

UO₂C₄R₄ The control rod natural uranium oxide plate

CORE

Nuclide	Weight, g	Weight %
H	0.00037	0.0004
C	0.0056	0.0059
SI	0.0056	0.0059
FE	0.0056	0.0059
O	11.1554	11.8513
U234	0.0042	0.0045
U235	0.59	0.6268
U238	82.3612	87.4992
Total	94.12797	99.9999

CAN

Nuclide	Weight, g	Weight %
H	0.000065	0.0005
C	0.0065	0.05
SI	0.064	0.49
P	0.0026	0.02
S	0.0026	0.02
CR	2.390	18.4
MN	0.200	1.54
FE	9.012	69.38
NI	1.312	10.1
CU	0.230	1.77
AG	0.580	4.465
Total	13.80	106.2355 *

- The weight of the CuAg braze material is not included in the percentage weight figures.

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UC8 The control rod natural uranium metal plate

Nuclide	Weight, g	Weight %
C	0.058	0.054
SI	0.058	0.054
FE	0.058	0.054
U235	0.767	0.710
U238	107.080	99.129
Total	108.021	100.001

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NASTC4 The control rod sodium plate

CORE

Material	Weight, g	Weight %
H	0.000033	0.00040
LI	0.000041	0.00050
B	0.000024	0.00029
O	0.000493	0.00602
NA	8.193000	99.97600
K	0.000285	0.00348
CA	0.001063	0.01297
FE	0.000033	0.00040
Total	8.194966	100.00006

CAN

Material	Weight, g	Weight %
C	0.0078	0.06
SI	0.051	0.39
P	0.0026	0.02
S	0.0026	0.02
CR	2.353	17.99
MN	0.179	1.37
FE	9.113	69.67
NI	1.284	9.82
NB	0.085	0.65
Total	13.078	99.99

STSTC8 The stainless steel control rod plate

Nuclide	Weight, g	Weight %
C	0.0731	0.16
SI	0.4109	0.90
P	0.0183	0.04
S	0.0183	0.04
TI	0.3653	0.80
CR	7.9905	17.50
MN	0.9132	2.00
FE	32.4460	71.06
NI	3.4245	7.50
Total	45.6601	100.00

GC8 The graphite control rod plate

Material	Weight, g	Weight %
H	0.00100	0.01000
B	0.000075	0.00079
C	9.543	99.90520
NA	0.00066	0.00691
AL	0.00048	0.00500
SI	0.00191	0.02000
S	0.00005	0.00052
CA	0.00058	0.00607
V	0.00010	0.00105
MN	0.00015	0.00157
FE	0.00381	0.03989
CU	0.00019	0.00199
ZN	0.00005	0.00052
Total	9.552055	99.99951

ALCG8 The aluminium control rod plate

Material	Weight, g	Weight %
AL	7.0644	99.500
SI	0.0133	0.187
MN	0.00225	0.032
FE	0.01773	0.250
CU	0.00225	0.032
Total	7.1	100.001

B10C2 The enriched boron carbide control rod plate

CORE

Nuclide	Weight, g	Weight %
H	0.0082	0.04
B10	17.90	85.13
B11	1.57	7.47
C	0.3154	1.50
O	0.4333	2.06
AL	0.0841	0.40
SI	0.1577	0.75
K	0.0841	0.40
CR	0.0841	0.40
FE	0.1472	0.70
NI	0.1577	0.75
CU	0.0841	0.40
Total	21.0259	100.00

CAN

Nuclide	Weight, g	Weight %
NI	37.05	100

The enriched boron carbide absorber pins.

The pellets consist of about 2.72 g B10, 0.31 g B11, 1.10 g carbon and 0.02 g aluminium stearate. The weight per unit length (per element) is 6.338 g of B10, 0.722 g of B11, 2.563 g of C and 0.0466 g of aluminium stearate. The densities within the 1.8 cm ID tubes are, 0.8302 g/cc B10, 0.0946 g/cc B11, 0.3357 g/cc C and 0.0061 g/cc of aluminium stearate (assumed to be $\text{Al}(\text{C}_{18}\text{H}_{36}\text{O}_2)_3$ that is, about 0.0002 g/cc Al, 0.0045 g/cc C, 0.00075 g/cc H and 0.00065 g/cc O)).

	Density within the tubes
H	0.00075
B10	0.8302
B11	0.0946
C	0.33645
O	0.00065
Al	0.0002
Total	1.2629

CRSHEATH The control rod sheath

Weight per 1 cm of length

Material	Weight, g	Weight %
H	0.0015	0.00
C	0.05	0.13
SI	0.04	0.11
P	0.01	0.03
S	0.01	0.03
MN	0.22	0.59
FE	36.82	99.11
Total	37.1515	100.00

DCRSHTH The double element control rod sheath (weight per element)

Weight per 1 cm of length

Material	Weight, g	Weight %
H	0.00045	0.001
C	0.06	0.134
SI	0.05	0.112
P	0.01	0.022
S	0.01	0.022
MN	0.27	0.603
FE	44.40	99.106
Total	44.80045	100.00

The Pin Geometry Components.

The mini-calandria, which fit inside the standard element sheaths, contain a 4x4 array of pins. Their length is approximately 1/3 the inner core height, a little under 30 cm. The pin array is similar to that used in the Cadenza experiments (Zebra Assembly 23 - see the document ZEBRA-LMFR-EXP-001). Some details are given in MTN/54 Appendix 1 and are reproduced in Section 1.4.3 describing the reactivity worth measurements. The compositions and dimensions are those of the fuel pin PUPINA and calandria NACLI used in the Cadenza cores (see ZEBRA-LMFR-EXP-001) and this should be taken as the model to be used for calculations, with adjustments for Pu241 decay (and noting the average compositions given in MTN/54 Appendix 1 Table A4, reproduced as Table 1.44 in Section 1.4.3). In this Table the compositions have been averaged and include the contributions of the endplates. In the axial blanket region the uranium oxide pins UO2PINC were used, with the addition of a small plate geometry axial blanket cell to provide the height match with the plate geometry elements.

The calandria were contained in mild steel sheaths.

**APPENDIX to Section 1.1.3: Hypothetical Atom Density
(Contributed by the Internal Reviewer, Atsushi Zukeran)**

The hypothetical atom density defined to unify two sets of atom densities relating to two different dates is theoretically described.

The differential equations governing the atom densities at time t are given by the following simultaneous equations, where $^{241}\text{Am} \alpha$ decay to ^{237}Np is considered as a ^{241}Am loss term,

$$\frac{d}{dt} N^{Pu241}(t) = -\lambda_{Pu241} \cdot N^{Pu241}(t) \quad (1)$$

$$\frac{d}{dt} N^{Am241}(t) = -\lambda_{Am241} \cdot N^{Am241}(t) + \lambda_{Pu241} \cdot N^{Pu241}(t) \quad (2)$$

Under the initial condition of $N^{Pu241}(0) = N_0^{Pu241}$ and $N^{Am241}(0) = 0$ at time $t = 0$, the atom densities as solutions are given by

$$N^{Pu241}(t) = N_0^{Pu241} \cdot \exp(-\lambda_{Pu241} \cdot t) \quad (3)$$

$$N^{Am241}(t) = -\frac{\lambda_{Pu241} \cdot N_0^{Pu241}}{\lambda_{Pu241} - \lambda_{Am241}} \left\{ \exp(-\lambda_{Pu241} \cdot t) - \exp(-\lambda_{Am241} \cdot t) \right\} \quad (4)$$

The initial atom densities $N_{bw}^{Pu241}(0) = N_0^{Pu241}$ and $N^{Am241}(0) = 0$ can be obtained from Eqs. (3) and (4), i.e. null atom density of ^{241}Am as a result of fuel fabrication.

The sum of the atom densities of N^{Pu241} and N^{Am241} can be given by,

$$SumPuAm = -\frac{N_0^{Pu241}}{\lambda_{Pu241} - \lambda_{Am241}} \left\{ \lambda_{Am241} \cdot \exp(-\lambda_{Pu241} \cdot t) - \lambda_{Pu241} \cdot \exp(-\lambda_{Am241} \cdot t) \right\} \quad (5)$$

$$\cong N_0^{Pu241} \dots \text{when } \lambda_{Am241} \cong 0 \text{ missing } \alpha - \text{decay of } ^{241}\text{Am} \quad (6)$$

This implies that the sum of atom densities does not vanish at time $t=0$ but not vanishing at arbitrary time t since atom density of ^{241}Am is missed by α decay to ^{237}Np . However, as an approximation of $\lambda_{Am241} \cong 0$ when α -decay of ^{241}Am is ignored, the sum tends to the initial atom density N_0^{Pu241} .

In order to unify the atom densities fabricated at $t=0$ with the PLATEDATA Databank earlier reference time $-t_0, t_0 > 0$, the fabricated atom densities have to be back-dated to $-t_0$ with the backward (bw) decay calculation which results in the following;

$$N_{bw}^{Pu241}(-t_0) = N_0^{Pu241} \cdot \exp(\lambda_{Pu241} \cdot t_0) \quad (7)$$

$$N_{bw}^{Am241}(-t_0) = -\frac{\lambda_{Pu241} \cdot N_0^{Pu241}}{\lambda_{Pu241} - \lambda_{Am241}} \left\{ \exp(\lambda_{Pu241} \cdot t_0) - \exp(\lambda_{Am241} \cdot t_0) \right\} \quad (8)$$

As evident from the above equations, the ^{241}Pu atom density increases but the density of ^{241}Am is a negative value at $-t_0$ as shown in Figure A1.1. The negative atom density is the “Hypothetical” value which reproduces the fabricated ^{241}Am density ($=0$) when a “forward” decay calculation, as an ordinary chain calculation, is performed under the initial conditions of Eqs. (7) and (8). The atom densities obtained by “forward” calculation are given by;

$$N_{fw}^{Pu241}(t) = N_0^{Pu241} \cdot \exp\{-\lambda_{Pu241} \cdot (t - t_0)\} \quad (9)$$

$$N_{fw}^{Am241}(t) = -\frac{\lambda_{Pu241} \cdot N_0^{Pu241}}{\lambda_{Pu241} - \lambda_{Am241}} \left[\exp\{-\lambda_{Pu241} \cdot (t - t_0)\} - \exp\{-\lambda_{Am241} \cdot (t - t_0)\} \right] \quad (10)$$

These equations reproduce the fabricated atom densities N^{Pu241} and $N^{Am241}(t_0)=0$ at $t=t_0$. Therefore, the “Hypothetical” atom density of ^{241}Am is required so as to reproduce the fabricated (initial) atom density in the forward decay calculation

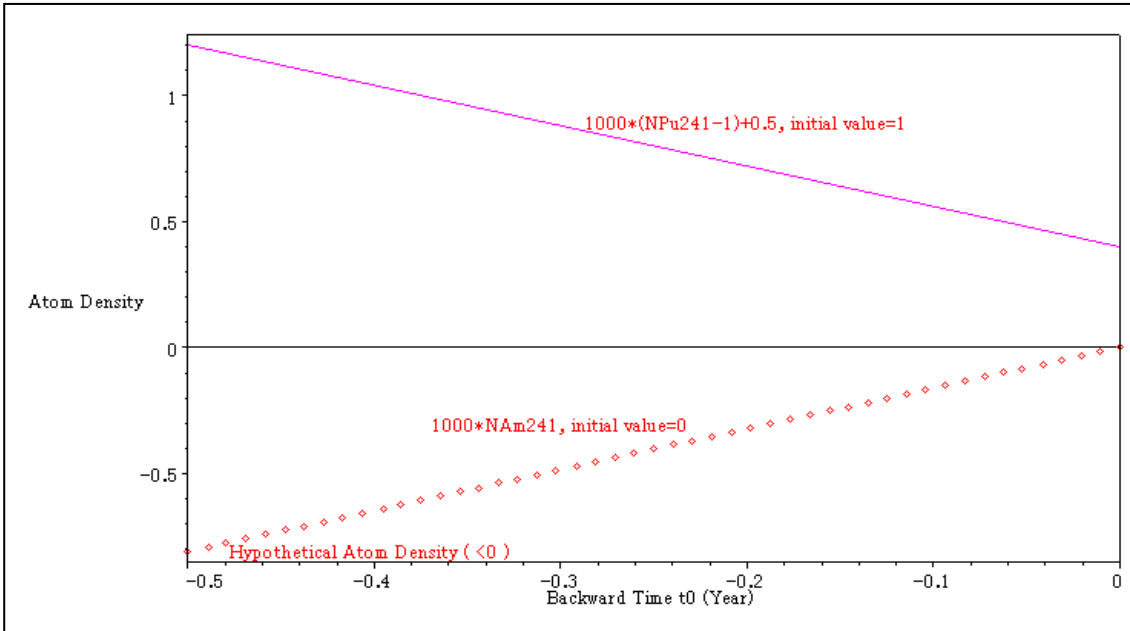


Figure A1.1 Atom Density Variation when data is back-dated to unify the data of newly fabricated data to an older PLATEDATA Database reference date for the material compositions.

1.1.4 Temperature Information.

The values of k_{eff} have been corrected to refer to the ambient temperature in the reactor containment, 23.5°C in the case of MZA and 21.4°C in the case of MZB, the uncertainty in the correction being $\pm 3 \times 10^{-4}$ dk/k in the case of MZA and $\pm 2 \times 10^{-4}$ dk/k in the case of MZB. These uncertainties would also cover the recommended k_{eff} values being equally valid for any temperature in the range 20 to 25°C.

The corrections are based on measurements of the temperature distributions, and the corresponding control rod positions, when the temperatures are varied by varying the cooling air flow.

1.1.5 Additional Information Relevant to Critical Measurements.

None

1.2 Description of Buckling and Extrapolation Length Measurements

1.2.1 Overview of Experiment

In a fast reactor the geometric bucklings derived by fitting to the reaction rate distributions are space and energy dependent. The hypothetical fundamental mode geometric bucklings are defined as the single valued pair of axial and radial geometric bucklings which would produce the same value of k_{eff} as the energy dependent values.

The method which was used to derive the fundamental mode geometric buckling from axial and radial fission rate traverses in MZA is based on that developed by the Cadarache MASURCA group and relies on the fact that a hypothetical detector with an energy-dependence proportional to the asymptotic $D\phi^*$ (that is, the diffusion coefficient multiplied by the fundamental mode neutron importance or adjoint neutron flux) would respond only to the fundamental mode component of the flux distribution. The response of such an "experimental adjoint leakage detector" may be constructed by linear regressions of measured and calculated reaction rates at each position in the scan, the basic detectors selected being U238, Np237, U235, Pu239 fission chambers and U235 and Pu239 foils (see Section 1.7 for details of these measurements).

Because of its low density, the high sodium content of MZA resulted in a slow attenuation of transients and provided a stringent test of the technique for deriving bucklings.

1.2.2A Description of Experimental Configuration.

This is the MZA core described in Section 1.1.2

1.2.2B Methods

Systematic errors were assessed by varying the input data, the fitting range and the calculation method (both diffusion theory and S8 transport theory approximations were used) and noting the consequent effect on the derived buckling values, leading to estimated uncertainties of $\pm 0.05 \text{ m}^{-2}$ in the axial buckling ($\sim 6.35 \text{ m}^{-2}$) and $\pm 0.29 \text{ m}^{-2}$ in the radial buckling ($\sim 15.12 \text{ m}^{-2}$). The overall uncertainty of $\pm 0.30 \text{ m}^{-2}$ is equivalent to an uncertainty of ± 0.004 in k_{eff} and $\pm 6 \text{ mm}$ in the radial reflector savings. The results are presented in MTN/44 and MTN/56, based on an analysis of the measurements made using the six different detectors.

1.2.2C Results

Calculations were made using both diffusion theory and transport theory to compare with the measured distributions and hence to correct the measured scans for modelling approximations and to derive the bucklings.

The analysis of the measured scans made by Franklin and Hardiman (MTN-44) gave the following values:

Axial buckling $6.35 \pm 0.05 \text{ m}^{-2}$
Radial buckling $15.12 \pm 0.29 \text{ m}^{-2}$

Total buckling $21.4 \pm 0.3 \text{ m}^{-2}$

For a core model with a half-height of 0.450 m and a circular radius of 0.4425 m the derived reflector savings are axial $174 \pm 3 \text{ mm}$ and radial $176 \pm 6 \text{ mm}$.

In MTN-56 Nakano carried out an analysis in which the bucklings were derived separately for each of the six different detectors and then averaged, giving a mean total buckling value of $21.6 \pm 0.3 \text{ m}^{-2}$, which is 0.2 m^{-2} higher than the value derived by Franklin and Hardiman, although within the uncertainty range.

Taking the mean of the two analyses results in a recommended value for the total geometric buckling of $21.5 \pm 0.3 \text{ m}^{-2}$. The corresponding uncertainty in k_{eff} is ± 0.004 , much larger than the uncertainty in the criticality for the reference core, ± 0.0016 . Furthermore, if this buckling were to be used in a reactor calculation it would be necessary to include the additional sources of uncertainty in the model, dimensions and composition, although these might well not increase this already large uncertainty. Combining the ± 0.004 with the ± 0.0016 gives ± 0.0043 for the uncertainty in the k_{eff} value calculated using this buckling. Because of the heterogeneity of the core elements and the spaces between the groups of 5x5 elements, the region to which the buckling values apply is not precisely defined. Nevertheless the values are useful, for example, in cell calculations made to provide cell averaged cross-sections for whole reactor calculations or in studies of local effects.

1.2.3 Description of Material Data.

The materials are described in Section 1.1.3, being those used in the standard MZA core.

1.2.4 Temperature

The temperature was not recorded and no temperature corrections were made. The temperature correction to k_{eff} in MZA was $(9.5 \pm 3) \times 10^{-4} \text{ dk/k}$ and the uncertainty in the buckling due to temperature differences from ambient would correspond to $\sim \pm 10 \times 10^{-4} \text{ dk/k}$, or $\sim \pm 0.075 \text{ m}^{-2}$, which is small compared with the quoted uncertainty in the measured value of the buckling.

1.2.5 Additional Information Relevant to the Buckling Measurements

None.

The suitability of this measurement as a benchmark is discussed in Section 2.2.

1.3 Description of Spectral Characteristics Measurements

1.3.1 Overview of Experiments

Central Cell-averaged Reaction Rate Ratio Measurements

Measurements were made of fission in U235, U238, Pu239, Pu240, Pu241 and capture in U238. Measurements were made using several different techniques: foil activation, fission chambers and Solid State Track Recorders, (SSTRs).

Cell-averaged values of the reaction rates were measured using foils of the material, either by situating the foils in special plates of the material for which the reaction rate is required, in such a way as to sample the average reaction rate, or, when this was not practicable, at a single place in the plate or adjacent to the plate containing the material of interest and applying a calculated correction. Figure 1.17B shows the location of foils in the plates of interest.

Neutron Energy Spectrum Measurements.

Proton-Recoil-Counter measurements were made together with Time of Flight measurements made on subcritical MZA cores using extracted beams. Extracted beams were also used for the high energy measurements made using the Beam Proton-Recoil Counter and the Double Scintillation Spectrometer.

1.3.2A Description of Experimental Configurations.

The cores are described in Section 1.1.2

1.3.2B Methods

Reaction Rate Ratio Measurement Techniques

U238 Capture/Pu239 Fission

The Thermal Comparison Technique for U238 capture/Pu239 fission relates the capture and fission activities of foils located in plates in cells in the central region of the core to those in a large graphite thermal column on the source reactor Nestor. U238 capture reactions were measured via the Np239 activity (half-life 2.35 day) induced in natural U or UO₂ foils, the coincidences between the 106 keV gamma-ray and the 104 keV x-ray being counted. Pu239 fission was measured via the gamma-ray activity of fission products in Pu metal or PuO₂/UO₂ foils using NaI detectors with a gamma threshold of 1.28 MeV. In order to take account of any differences in the fission yields between the Zebra and Nestor thermal column spectra, calibration experiments were performed in which a Zebra/Nestor fission ratio was obtained by counting fragments in a parallel-plate Pu239 fission chamber placed in Zebra and in the thermal column, fission foils being irradiated in dummy chambers at the same positions and subsequently counted under the standard conditions.

The Absolute Technique relies on measuring separately the U238 capture rate and the Pu239 fission rate relative to absolute standards of activity. The capture rate is measured by irradiating a thin deposit (1 mg/cm²) of natural uranium on aluminium at the midplane of a modified uranium metal or UO₂ plate, intra-cell distribution measurements with rectangular uranium foils being used to provide the cell-averaging factors. To determine the absolute capture rate per U238 atom, a high-purity Am243 source of the same geometry as the uranium deposit, and calibrated by low-geometry alpha-assay, was counted in the same sequence as the irradiated uranium deposit. The Pu239 fission rate in the plutonium fuel plate was measured by simultaneously irradiating plutonium metal fission foils loaded transversely in the plate and in a dummy fission chamber, the absolute fission rate in the chamber being subsequently determined by counting fragments from a standardised Pu239 deposit with corrections for loss of pulses due to deposit thickness and discriminator threshold (these being less than 0.3%).

Fission Ratios

Foil Measurements of relative fission rates were obtained from the fission product gamma-ray activity induced in rectangular foils of Pu metal and natural, enriched and depleted U and UO₂ located transversely in the appropriate fuel plates to sample the cell average reaction rate. To relate these activity ratios to the required fission-rate ratios, ratios measured using calibrated fission chambers inserted into a cavity in the Zebra core were compared with the gamma-activity ratios of foils irradiated in dummy chambers at the same positions, the foils subsequently being counted using procedures identical to those for the irradiations within the lattice cell. The fission chamber deposits of Pu239 (99%) U235 (93%) and natural uranium were standardised both absolutely and relatively by an extensive series of low-geometry alpha assays, thermal column irradiations and inter-laboratory cross-checks. The design of the parallel plate fission chambers is shown in Figure 1.17A.

The second technique makes use of Solid-State Track Recorders (SSTR) of Makrofol KG 0.06 mm thick, 25 mm diameter irradiated in close contact with thin electro-deposits of natural uranium, U235 and Pu239 on the mid-plane of modified fuel plates and subsequently etched and the tracks counted. The relative masses of the fissile deposits were obtained from similar irradiations in the Nestor thermal column.

Fission rates in Pu240 and Pu241 relative to Pu239 were obtained using alpha-assayed deposits in parallel-plate chambers; the uncertainty associated with the fission chamber cavity was considered acceptable in view of the lower accuracy considered useful for measurements of these.

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

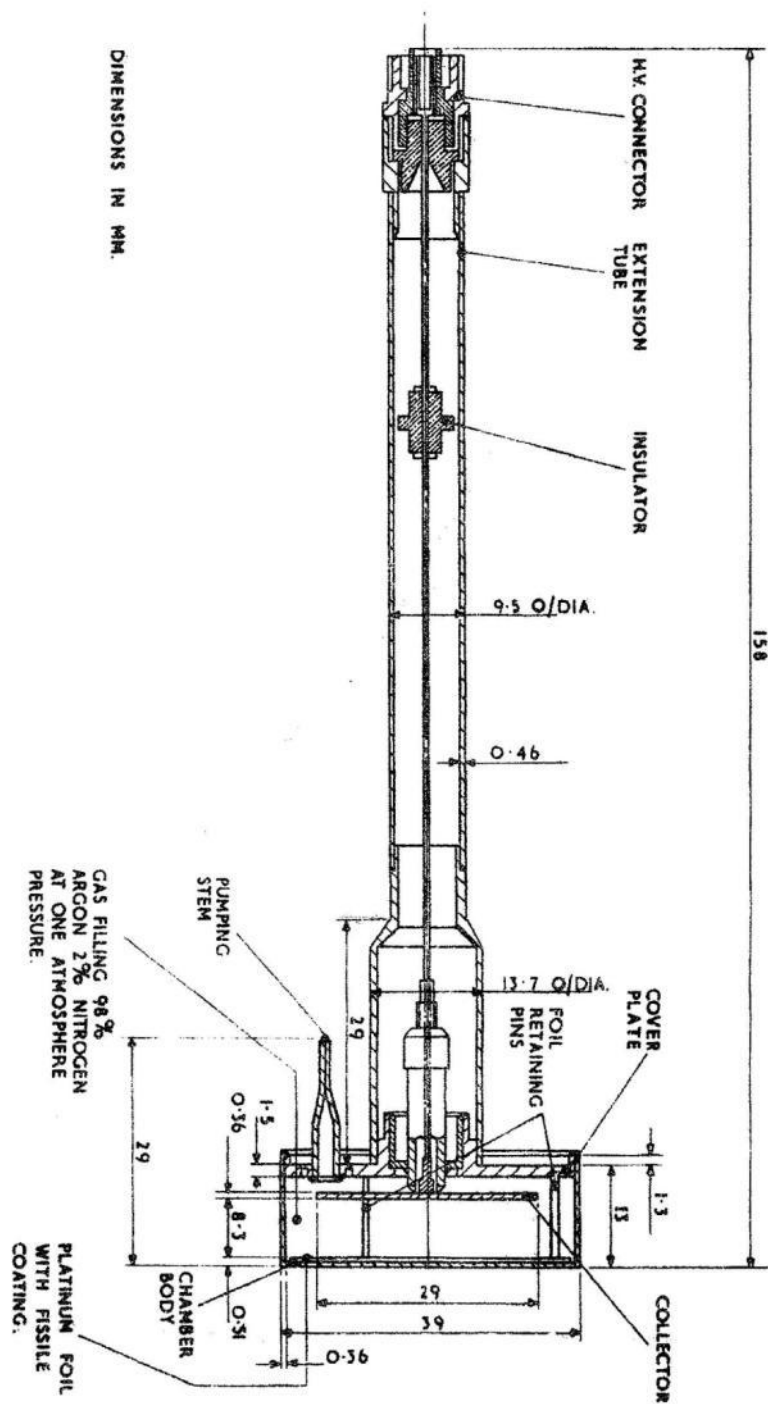


Figure 1.17A Zebra Parallel Plate Fission Chamber.

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

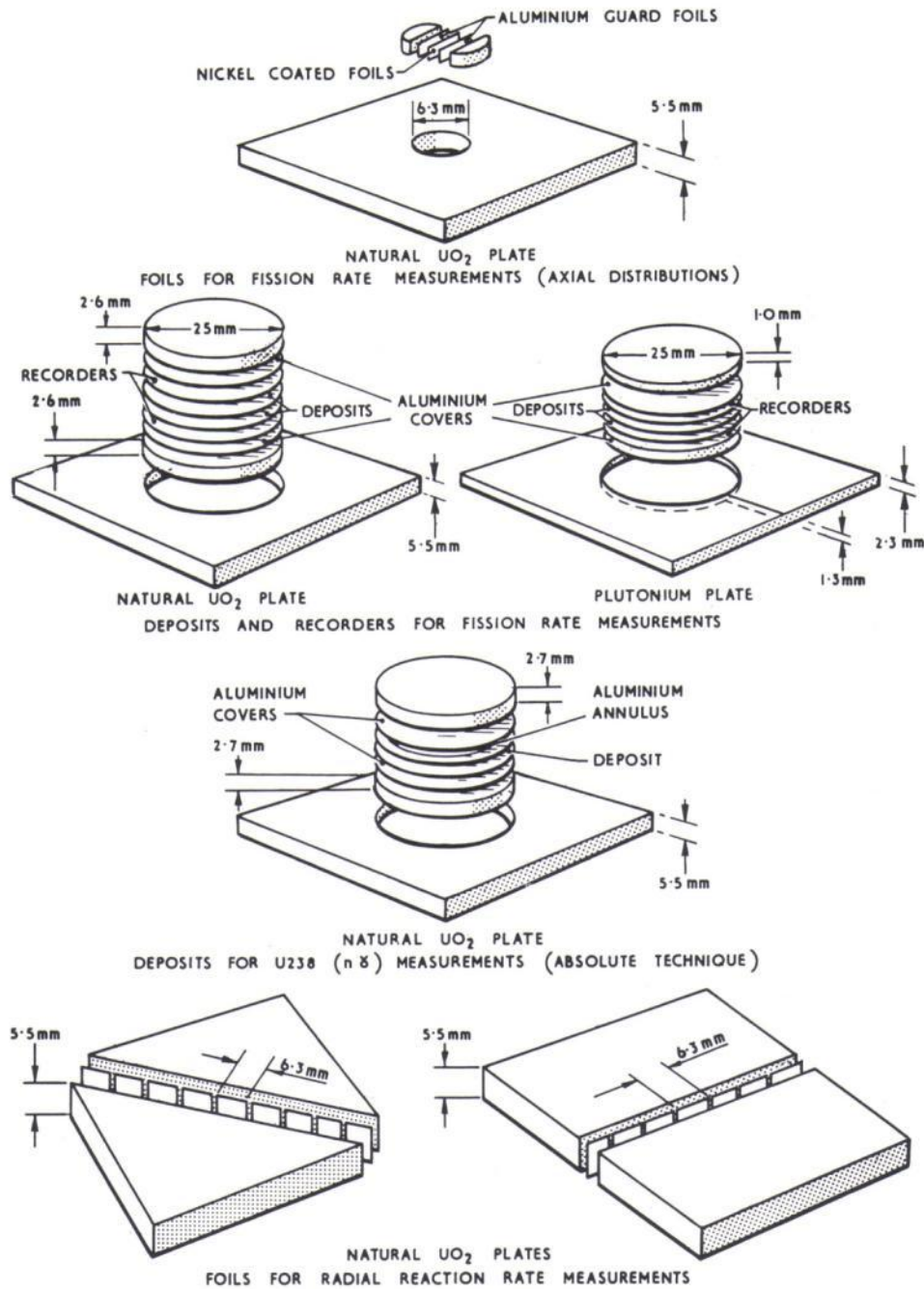


Figure 1.17B Detector locations in Zebra Plates.

Neutron Energy Spectrum Measurements.

In-core measurements were made using Proton-Recoil Counters (PRC). Time of Flight (TOF) measurements were made on subcritical cores using extracted beams. Extracted beams were also used for the high energy measurements made using the Beam Proton-Recoil Counter and the Double Scintillation Spectrometer.

The Time of Flight measurements provided high resolution spectra which are given in graphical form in MTN/11 and Addendum, where comparisons are made with MURAL-FGL5 calculations. These measurements provided valuable data for checking the detailed form of the cross-section data, in particular the representation of resonances in the nuclear data libraries. The energy resolution of the PRC measurements is less detailed and 1/4 lethargy width group representations were obtained. The TOF measurements were also condensed to this 1/4 lethargy group representation and a Gaussian smoothing applied to make the results more consistent with the PRC measurements. The calculated spectra made to compare with the measurements must also have this Gaussian smoothing applied.

Corrections were made to relate extracted beam spectra to in-core cell average spectra (using the codes MURAL-TOFFEE, developed by J D MacDougall, AEEW-M-903, 1969) and for the subcriticality of the system.

Measurements were corrected to give fundamental mode (or critical core) cell averaged flux spectra in 1/4 lethargy width groups and it is these spectra which are given in the MTN documentation.

Proton-Recoil Counter (PRC) Technique

In the PRC measurements neutrons enter a spherical proportional counter containing methane and cause protons to recoil with an energy distribution related to the neutron energy. Efficiency is based on geometry and the hydrogen scattering cross-section; the unfolding of a neutron spectrum from the proton-recoil distribution uses calculated response function shapes modified on the basis of experimental results obtained with mono-energetic neutrons. The lower energy measurements (up to about 2 MeV) are made using chambers located in an empty element near the core centre. For the higher energy range the chambers are located in a beam extracted from the core, the In-Beam-PRC measurements.

The general principles of the PRC method are described by Broomfield and Carter in AEEW-M 905 and the measurements made in MZA are described in MTN/10. The set of SP2 counters (40 mm ID) filled to 1, 3 and 10 atm. pressure of hydrogen had overlapping energy ranges of 40 to 250 keV, 100 to 600 keV and 200 keV to 1.25 MeV. Pulse-rise-time discrimination against gamma events was used with the 3 atm. Counter, allowing detection of neutrons down to about 2 keV. A small addition of helium-3 to the filling gas provided a calibration of the energy scale at 764 keV when counters are placed in a thermal neutron flux. SP2 counters were found to give excessive count-rates in assemblies fuelled with high Pu240 content plutonium, and a smaller version (SP7, 22.6 mm ID) was developed. Counters, surrounded by 4 - 8 mm of lead, were located on the core centre-line in an empty fuel-element sheath. Single-sided delay-line pulse shaping was used with a choice of lengths from 3 to 11 μ secs, together with active base-line restoration and pile-up rejection.

SP2 measurements were made successfully to 2 MeV with a higher stopping power filling of 5 atm. H_2 + 5 atm. argon, while larger counters (ID = 152 mm) with fillings of 2 atm. CH_4 , and 2 atm. CH_4 + 2 atm. argon irradiated in an extracted beam covered overlapping energy ranges of 0.3 to 2.3 MeV and 0.6 to 3.7 MeV respectively. These larger counters had smaller wall corrections and in this way the energy range could be extended upwards. The counters located at 9.7 m from the centre of MZA received neutrons, via the evacuated flight tube, from an 85 mm diameter source area. The apparent energy of oxygen resonances at 442 and 1000 keV and measurements with mono-energetic neutrons indicated a linear relationship between ionisation and energy, with non-zero intercept for methane fillings.

Time-of-Flight (TOF) Technique

The Time-of-Flight equipment on Zebra comprised a 14 MeV electron linac and a D₂O-cooled uranium metal target and is described by Burbidge et al, AEEW-R 646, (1970). Neutron output was 3×10^9 per pulse, 200 pps. The flight-path was up to 200 m long. A lithium glass scintillation detector, 305 mm diameter, containing 14 separate glasses and photomultipliers was mounted inside the flight tube. The probe tube had a 102 mm or 52 mm square section leading to the core centre.

A programme called WINTOF (J Marshall, AEEW-M-897, 1969) was used to unfold the background-corrected time distributions with the measured in-core U238 and U235 fission chamber profiles using an iterative method due to Paterson and Shutler (AWRE O-8/67 1967).

The spectrum of the emergent beam was related to the required in-core cell average scalar flux using the code TOFFEE which took account of the plate structure of the cell and the collimation geometry. The perturbation caused by the insertion of the probe tube was not calculated in detail although various theoretical and experimental estimates showed the effect to be small, at least up to 400 keV. The spectrum in the pulsed subcritical system (a k_{eff} value of between 0.85 and 0.90 was obtained by reducing the core size, giving an effective pulse length of about 7 μsec) was related to the fundamental mode by static source calculations.

Double Scintillator Spectrometer (DSS) Technique

Neutrons in a collimated beam from the core centre were scattered from a hydrogen-containing scintillator, and their initial energy is related to their time-of-flight to a second scintillator. Detector efficiency is based on the hydrogen scattering cross-section and the geometry of the first scintillator, together with measurements of the efficiency of the second detector made with monoenergetic neutrons.

The double-scintillator spectrometer was developed at Aldermaston by Paterson and Redfean. The NE104 scattering scintillator was 75 mm in diameter and for measurements in the energy range above 1 MeV the thickness used was 3 mm. Below 1 MeV, where mean free paths are shorter, a thickness of 1 mm was used to reduce the probability of multiple scattering events. The second detector was a 100 mm diameter by 50 mm thick NE102A disc situated at 45° to the beam line leading to the first scintillator and a distance of 1.28 m from it. The flight times over this distance (53 nsec for a 3 MeV scattered = 6 MeV incident neutron) were measured by a 512 channel analyser.

The efficiency calculation for the thin scattering scintillator was straightforward. The efficiency of the second detector was affected at all neutron energies by its detection threshold and since the effect is difficult to calculate reliably measurements with reproducible thresholds were made. The total resolution of the system (due largely to geometry) rises from 15% at 300 keV to 19% at 6 MeV. The measurements in MZA were made in the neutron beam emerging from the core centre region with the scattering scintillator 9.5 m from the viewed surface.

As in the TOF experiments and beam-geometry PRC (BPRC), the spectrum in the emergent beam was related to the in-core cell average scalar flux by TOFFEE calculations for the appropriate collimation optics.

Lithium-6 Semiconductor Sandwich (LISS) Technique

This was an in-core device in which a neutron interacts with a thin layer of Li-6, and the resulting α -particle and triton are detected by two close-spaced silicon surface-barrier diodes. The efficiency is essentially based on the Li-6 (n, α) cross-section and calculable geometric factors.

The analysis of the sum (alpha + triton) peak distribution gives the spectrum in the range 500 keV - 5 MeV, while by unfolding the triton distribution low resolution data between 10 and 200 keV was obtained. Spectrometers were calibrated with monoenergetic neutrons over the range 300 keV - 5 MeV (providing, in effect, a further measurement of the (n, alpha) cross section). Although the lithium-6 spectrometer provides wide energy coverage in a compact in-core device, its low sensitivity and limited irradiation life, coupled with unfolding problems and inaccuracy of the Li-6 (n, α) cross section data (at the time of the measurements), rendered it of limited value. It was, nevertheless, used as one of the methods for measuring the high energy spectrum.

High-Energy Spectrum Measurements

Three independent experimental techniques were used in MZA to extend neutron spectrum measurements above 1.2 MeV, the upper limit of the Time-of-Flight and in-core Proton Recoil Counter techniques. Full details of these three experiments and their results are given in MTN/40, (Li-6 Spectrometer), MTN/41 (Double Scintillator Spectrometer) and MTN/50 (Proton Recoil Counter in beam). On the basis of these a best high energy spectrum for the energy range to an upper limit near 8 MeV was recommended in MTN/74. The three measurement techniques used were In Beam Proton-Recoil-Counters, the Double Scintillator Spectrometer (DSS) Technique and the Lithium-6 Semiconductor Sandwich (LISS) Technique.

Calculated corrections to the beam PRC measurements were made to convert the measured directed spectrum to a central cell-average spectrum (MTN/50). The correction factors range from 0.938 at 500 keV to 1.093 in the upper energy group at about 3 MeV. The DSS results given in MTN/41 are those for the measured spectrum in the beam, corrected only for scattering by the aluminium windows and air. Before comparison with the other two techniques a correction for the difference between the directed spectrum in the beam and the cell-average spectrum is applied and this was calculated using the program TOFFEE and the then current datasets, FGL4 and FGL5; the correction factors are in the range 0.923 at about 500 keV, to 1.125 at about 5 MeV. The first scintillator was set at 45° to the neutron beam and therefore viewed an elliptical area of the fuel element cell. The minor axis of this ellipse was parallel to the cell height, and an effective detector diameter of 0.707 times the actual diameter was used in the calculation. (If the actual diameter is used, the Beam/In Core correction factor in the highest energy group is increased by only 0.7%).

The high energy spectra measured using the three techniques are combined in MTN/74.

Details of the spectrum measurements made in MZA are given in the following references:

1. Time-of-Flight Spectrum Measurements in Zebra 11 (MZA), and Addendum B M Franklin and J P Hardiman. MTN/11
2. Spectrum Measurements with Proton Recoil Counters in Zebra 11 (MZA) M D Carter and J Samways. MTN/10
3. Lithium - 6 Spectrometer Measurements in Zebra Core 11 (MZA) I C Rickard. MTN/40
4. A Measurement of the Lithium - 6 (n, alpha) cross-section over the Energy Range 150 Kev to 3.9 Mev. P J Clements, I C Rickard. AERE - R7075

1.3.2C Results

Central Cell-averaged Reaction Rate Ratio Measurements in MZA and MZB

The cell averaged reaction rate is the component of the neutron balance for the central cell, for the material and reaction of interest, divided by the numbers of atoms of this material in the cell. For U238 having density $N_{238}(x)$ at position x , and for the reaction with cross-section $\sigma_{238}(E)$, the cell averaged reaction rate is:

$$R_{238} = \left\{ \int_{\text{cell}} \left\{ \int_E N_{238}(x) \cdot \sigma_{238}(E) \cdot \Phi(x,E) \cdot dE \right\} dV \right\} / \left\{ \int_{\text{cell}} N_{238}(x) \cdot dV \right\}$$

where the integration is over the neutron energy, E and the cell volume elements, dV at position x .

Measurements were made of fission in U235, U238, Pu239, Pu240, Pu241 and capture in U238. For simplicity the notation F25, F28, F49, F40, F41 is used to denote the fission rate in U235, U238, Pu239, Pu240 and Pu241 respectively, while C28 denotes capture in U238. Small letters are used to denote gamma-activity rates. From the measurements cell averaged values of the ratios F28/F25, F25/F49 and C28/F49 were derived. F49 is then the average Pu239 fission rate per atom in the plutonium plates and F25 and F28 are averages per atom for the plates containing uranium, weighted with the relative atomic mass of uranium in these regions of the cell.

Measurements were made using several different techniques: foil activation, fission chambers and Solid State Track Recorders, (SSTRs). The results are presented in MTN/14, MTN/30 and MTN/87. Included are the measurements of the variation of the reaction rates through a cell and the factor $P(t)$ required to relate the gamma activities to fission rates.

U238 Capture/Pu239 Fission

The Thermal Comparison Technique for U238 capture/Pu239 fission relates the capture and fission activities of foils located in the constituent plates (see Figure 1.17B) to those in a large graphite thermal column on the source reactor Nestor. U238 capture reactions were measured via the 2.35 day Np239 activity induced in natural UO_2 foils, the coincidences between the 106 keV gamma-ray and the 104 keV x-ray being counted. Pu239 fission was measured via the gamma-ray activity of fission products in nickel coated Pu metal foils irradiated in Zebra and nickel coated Pu/Al foils irradiated at the same time in Nestor, the activity being measured using NaI detectors with a threshold of 1.28 MeV. In order to take account of any differences in the fission product yields, and resulting gamma activity, between the Zebra and thermal column spectra, calibration experiments were performed in which a Zebra/Nestor fission ratio was obtained by counting fragments in a parallel-plate Pu239 fission chamber placed in Zebra and in the thermal column, fission foils being irradiated in dummy chambers at the same positions and subsequently counted under the standard conditions. The largest contribution to the overall error on the thermal comparison results was the $\pm 1.0\%$ uncertainty in the value of the ratio of the Maxwellian-average cross sections for U238 (n,γ) and Pu239 (n,f) used in the interpretation.

The Absolute Technique relies on measuring separately the U238 capture rate and the Pu239 fission rate relative to absolute standards of activity. The capture rate was measured by irradiating a thin deposit (1 mg/cm) of natural uranium on aluminium at the mid-plane of a modified uranium metal or UO_2 plate, intra-cell distribution measurements with rectangular uranium foils being used to provide the cell-averaging factors. To determine the absolute capture rate per U238 atom, a high-purity Am243 source of the same geometry as the uranium deposit and calibrated by low-geometry alpha-assay was counted in the same sequence as the irradiated uranium deposit. The Pu239 fission rate in the plutonium fuel plate was measured by simultaneously irradiating plutonium metal fission foils loaded transversely in the plate and in a dummy fission chamber, the absolute fission rate in the chamber being subsequently determined by counting fragments from a standardised Pu239 deposit with corrections for loss of pulses due to deposit thickness and

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discriminator threshold, these being less than 0.3%.

Fission Ratios

Foil Measurements of relative fission rates were obtained from the fission product gamma-ray activity induced in rectangular foils of Pu metal and natural, enriched and depleted U and UO_2 located transversely in the appropriate fuel plates to sample the cell average reaction rate. The F28/F25 ratio was measured using 93% U235 and 0.04% U235 nickel coated foils and the F25/F49 ratio was measured using 93% U235 and 95% Pu239 foils. To relate these activity ratios to the required fission-rate ratios, ratios measured using calibrated fission chambers inserted into a cavity in the Zebra core were compared with the gamma-activity ratios of foils irradiated in dummy chambers at the same positions, the foils subsequently being counted using procedures identical to those for the irradiations within the lattice cell. The fission chamber deposits of Pu239 (99%), U235 (93%) and natural uranium were standardised both absolutely and relatively by an extensive series of low-geometry alpha assays, thermal column irradiations and inter-laboratory cross-checks. In this way the values of $P(t)$, the factors relating the gamma activities to the fission ratios, were measured.

The second technique used Solid-State Track Recorders (SSTR) of Makrofol KG 0.06 mm thick, 25 mm diameter irradiated in close contact with thin electro-deposits of natural uranium, U235 and Pu239 on the midplane of modified fuel plates and subsequently etched for 18 hours in 6N KOH solution. The relative masses of the fissile deposits were obtained from similar irradiations in the Nestor thermal column. Initially the tracks were counted by eye but later a Quantimet B television image analyser was used for automatic scanning (~ 1000 tracks per minute). At the optimum track density of about 200 per mm, overlap corrections and non-fission background are 5% and 2% respectively. Measurements were made in both dummy fission chambers and in plates in the core cells.

U238/U235 fission ratio measurements by both techniques had then been made in nine Zebra cores. The means of the ratios of SSTR (eye) and SSTR (QM) results to foil activation results are 0.998 ± 0.013 and 1.013 ± 0.013 respectively, showing no significant bias between techniques. A less extensive comparison of U235/Pu239 ratios by the two techniques also shows satisfactory agreement.

The main source of systematic error arises from the Fission Chamber Calibration in the foil activation technique, estimated as 0.95% for U238/U235 and 1.1% for U235/Pu239.

Measurements using absolute fission chambers were made at the centre of the core using an element which was half filled to the midplane, with a sodium plate at the top of the half element. The fission chambers were inserted on a rigid extension via a brass guide-tube and were located 1.0 ± 0.5 mm above the sodium plate.

The sources of uncertainty are discussed in the MTN documents, MTN/14, MTN/30 and MTN/87. By way of illustration the uncertainties in the foil measurements of fission ratios are summarised in Table 1.36A and the SSTR measurements in Table 1.36B. The sources of uncertainty in the measurements of the ratio of U238 capture to Pu239 fission in MZA are summarised in Table 1.37.

Measured values and the averages of measurements made using the different techniques are presented in Tables 1.38 and 1.39.

The measurements made in the later Bizet and Cadenza assemblies, involving the Pu239 fission chamber, were revised in 1980 because of a 1% revision in the Pu239 alpha decay half-life relative to the value used when the fission chambers were calibrated by alpha assay. Ratios to Pu239 fission were reduced by 1%. Both the fission chamber and the foil measurements were revised for these later cores. The half-life value used at the time of the calibration of the chambers was 24.35×10^3 years, see AEEW-R526 (1967), AEEW-R936 (1974) and AEEW-R1090 (1977), (with the uncertainty later increased to $\pm 0.6\%$). The revised value is $(24.11 \pm 0.01) \times 10^3$. As described in MTN87 the alpha calibrations were later revised to take account of a correction to the alpha counting geometry. Thermal spectrum measurements made in the NESTOR graphite thermal column were also used in the calibrations. For the Pu241/Pu239 ratio the thermal spectrum value is in agreement with current nuclear data.

The alpha calibration of the enriched U, natural U and depleted U chambers depends on the decay of U234 and so an accurate knowledge is required of the fraction of U234 in the material, this being determined by mass spectrometry. Thermal spectrum calibration is also used. The alpha decay data which have been used are compared with currently recommended values in Table 1.35. We see that the alpha decay half-life value used for U234 in 1967 was 0.8% higher than the currently recommended value whereas the value being used in 1974 was 0.5% lower. The value used in the recalibration of the chambers at the time of the Mozart programme is assumed to be the 1967 value and so there is a similar discrepancy as for the Pu239 half-life, an overestimate of about 1%.

Because there is a similar discrepancy in the U234 half-life to the discrepancy in the Pu239 half-life (an overestimate by about 1%) no correction is proposed to these ratio measurements but an additional uncertainty of 1% is combined with the published uncertainties.

Table 1.35 Alpha decay half-lives.

Isotope	Alpha decay half-life (years)		
	J M Stevenson and A M Broomfield AEEW-526 (1967)	D W Sweet, AEEW-R 936 (1974) AEEW-R1090 (1977)	Current IAEA
U-234	$0.2475 \times 10^6 \pm 0.6\%$	$0.2442 \times 10^6 \pm 0.6\%^*$	$0.2455 \times 10^6 \pm 0.2\%$
U-235	$0.713 \times 10^9 \pm 0.2\%$	$0.704 \times 10^9 \pm 0.2\%$	$0.7038 \times 10^9 \pm 0.1\%$
U-236	$2.39 \times 10^7 \pm 0.8\%$		2.342×10^7
U-238	$4.50 \times 10^9 \pm 0.2\%$		4.468×10^9
Pu-239	$24.35 \times 10^3 \pm 0.2\%$	$24.35 \times 10^3 \pm 0.2\%$	$24.11 \times 10^3 \pm 0.1\%$
Pu-240	$6.600 \times 10^3 \pm 0.6\%$	$6.600 \times 10^3 \pm 0.6\%$	$6.561 \times 10^3 \pm 0.1\%$
Pu-241	$0.572 \times 10^6 \pm 0.2\%$	$0.572 \times 10^6 \pm 0.2\%$	
Pu-242	$0.376 \times 10^6 \pm 1.1\%$	$0.376 \times 10^6 \pm 1.1\%$	$0.373 \times 10^6 \pm 0.8\%$
Am-241	0.458×10^3	$0.433 \times 10^3 \pm 0.5\%$	$0.4326 \times 10^3 \pm 0.1\%$

*The reference for this revised value for U234 is A Spennol and B Denecke, Proc. BNES Conf. On Chemical Nuclear Data, University of Kent, p199 (1971).

The fission chambers are located in a central core element (position 50-50) loaded up to the core mid-plane and empty above, the top plate in the half element being a sodium plate. The flux they are situated in is an average of the flux emerging from the sodium plate at the top of a core cell and the flux emerging from the edges of plates above the core mid plane and transmitted through the element sheaths. There is the further modifying effect of the transmission through the chamber walls.

To calculate values to compare with the fission chamber measurements it is necessary to make cell calculations to relate the cell averaged values given in the usual core calculation to values measured at the

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upper axial boundary of a core cell, (next to the sodium plate, or within the sodium plate at the end of the cell) averaged with the cell edge fluxes.

**Table 1.36A Components of the Percentage Uncertainties in the Foil Measurements.
Fission ratios in MZA.**

	F28/F25	F25/F49
	(%)	(%)
<u>P(t) measurements.</u> (the relationship between gamma emission rate ratios and fission ratios, time t)		
Relative masses of fission chambers	0.8 systematic	0.9 systematic
Fission chamber counting rates	0.5 random	0.7 random
Statistics of foil counting	0.2 " "	0.05 " "
Mass uncertainties in foil counting	0.04 " "	0.3 " "
Drifts in foil counting	1.2 " "	0.4 " "
Resonance shielding in foils	0.04 " "	0.1 " "
<u>Plate measurements.</u>		
Statistics of foil counting	0.2 " "	0.04 " "
Mass uncertainties in foil counting	0.04 " "	0.2 " "
Drifts in foil counting	0.8 " "	0.6 " "
Macroscopic flux corrections	0.1 " "	0.1 " "
Perturbation produced by the use of 93% U235 foils	0.2 " "	0.2 " "
Radial fine structure variations in F28/F25	0.6 " "	0.4 " "
Cell average correction		0.1 " "
Total (r = random, s = systematic)	1.7% r, 0.8% s	1.2% r, 0.9% s

Fission ratios in MZB.

	F28/F25	F25/F49
	(%)	(%)
<u>P(t) measurements.</u> (the relationship between gamma emission rate ratios and fission ratios, time t)		
Relative masses of fission chambers	0.9 systematic	0.9 systematic
Fission chamber counting rates	0.8 random	0.8 random
Statistics of foil counting	0.1 " "	0.05 " "
Mass uncertainties in foil counting	0.03 " "	0.3 " "
Drifts in foil counting	0.5 " "	0.7 " "
Resonance shielding in foils	0.06 " "	0.2 " "
<u>Plate measurements.</u>		
Statistics of foil counting	0.1 " "	0.1 " "
Mass uncertainties in foil counting	0.03 " "	0.2 " "
Drifts in foil counting	0.3 " "	0.8 " "
Macroscopic flux corrections	0.1 " "	0.1 " "
Perturbation produced by the use of 93% U235 foils	0.2 " "	0.2 " "
Radial fine structure variations in F28/F25	0.6 " "	0.4 " "
Cell average correction		0.1 " "
Total (r = random, s = systematic)	1.1% r, 0.9% s	1.4% r, 0.9% s

Table 1.36B Components of the Percentage Uncertainties in the SSTR Measurements

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MZA	F28/F25
Uncertainties in the counts for a single recorder	
Statistics	0.3 - 0.6
Background	0.4
Overlap	0.8
Etching	0.5
Focus variations	0.5
Instrument drifts	0.8
Systematic to the pair of recorders	
Thermal calibration of deposits (systematic uncertainty)	0.8
Correction for plastic perturbation	0.3
Correction for orientation	0.1
Correction to cell average	0.7
Total for the average random component of the uncertainty	1.7%

MZB	F28/F25	F25/F49
Thermal Calibration		
Statistics	0.3	0.3
Background	0.3	0.3
Etching	0.3	0.3
Overlap	0.3	0.3
Focus variations	0.3	0.3
Instrument drifts	0.4	0.4
Thermal cross-section ratio		0.7
Influence of chamber on ratio		0.3
Total	0.8%	1.1%
Zebra Measurement		
Statistics	0.4	0.6
Background	0.5	0.6
Etching	0.5	0.3
Overlap	0.7	0.3
Focus variations	0.4	0.3
Instrument drifts	0.5	0.4
Correction for plastic perturbation	0.4	0.6
Correction for orientation	0.2	0.1
Correction to cell average	0.7	0.2
Total for average of detectors	1.5%	1.3%

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Table 1.37 Sources of Uncertainty in the Measurements of C28/F49 in MZA.

<u>Source of uncertainty</u>	<u>Thermal method</u>	<u>Absolute method</u>
<u>C28 Measurements;</u>		
Foil and deposit counting	0.3%r	0.5%r, 0.3%s
Macroscopic flux corrections	0.1%r	0.2%r
Axial fine structure correction		0.3%r
Radial fine structure correction	0.4%r	0.4%r
<u>F49 Measurements;</u>		
Zebra/thermal measurement	0.3%r	
R	0.6%r	
Resonance shielding in foils (chamber)	0.1%r	0.1%r
Zebra plate/chamber		0.4%r
Zebra absolute chamber		0.1%r, 1.1%s
Radial fine structure correction	0.4%r	0.4%r
Macroscopic flux corrections	0.1%r	0.1%r
Thermal cross-section C28/F49	1.0%s	
Thermal flux depressions	0.5%s	
Total	0.9%r, 1.1%s	0.9%r, 1.1%s

R is the factor converting the ratio of gamma activity to the ratio of Pu239 fissions in ZEBRA to the Pu239 fissions in the Thermal Column in NESTOR.

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Table 1.38 Summary of Cell Average Reaction Rate Ratio Measurements in MZA and MZB/1

MZA			
Ratio	Value	Uncertainty (%)	
		random	systematic
F28/F25 foils	0.03416	1.7	0.8
F28/F25 SSTR	0.03306	1.7	-
F28/F25 Average	0.03356	1.3	
F25/F49 foils	0.978	1.2	0.9
C28/F49 thermal comparison	0.1297	0.9	1.1
C28/F49 absolute	0.1286	0.9	0.8
C28/F49 Average	0.1291	0.9	
MZB/1			
Ratio	Value	Uncertainty (%)	
		random	systematic
F28/F25 foils	0.02301	1.1	0.9
F28/F25 SSTR	0.02258	1.7	-
F28/F25 Average	0.02283	1.1	
F25/F49 foils	1.067	1.4	0.9
F25/F49 SSTR	1.065	1.7	-
F25/F49 Average	1.066	1.2	
C28/F49 thermal comparison	0.1424	1.0	1.1
C28/F49 absolute	0.1431	1.1	0.8
C28/F49 Average	0.1428	1.2	

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Table 1.39 Summary of Absolute Fission Chamber Measurements (on the mid plane) in MZA, MZB/1 and MZB/3

MZA			
Ratio	Value	Uncertainty (%)	
		random	systematic
F28/F25	0.03348	0.5	0.8
F25/F49	0.9818	0.7	1.3
F40/F49	0.2565	1.1	1.6
F41/F49	1.279	0.9	2.8
MZB/1			
Ratio	Value	Uncertainty (%)	
		random	systematic
F28/F25	0.02256	0.7	0.9
F25/F49	1.054	0.8	1.3
F40/F49	0.2023	1.1	1.6
F41/F49	1.356	0.8	2.9
MZB/3			
Ratio	Value	Uncertainty (%)	
		random	systematic
F28/F25	0.02248	0.7	0.9
F25/F49	1.059	0.8	1.3

The central reaction rate ratio measurements are recommended as suitable for consideration as benchmark measurements and the uncertainties are discussed further in Section 2.

Comparison of Spectrum Measurement Techniques and Construction of the Overall MZA Spectrum

Low Energy Spectrum Measurements

There is satisfactory agreement between the Proton Recoil Counter, PRC, (MTN/10) and Time-of-Flight, TOF, (MTN/11) measurements over a range from about 15 keV to 300 keV. The increasing dispersion below 10 keV is ascribed to the limitations of the PRC technique; the spectrum is steeply falling in this region, rendering results very sensitive to inaccuracies in energy scale. Above 400 keV the comparison reflects the increasing uncertainty in the TOF data due to poorly-known detector efficiency, sensitivity to timing errors and unfolding problems. Results of the high energy measurements on MZA using the extracted Beam PRC (BPRC) and Double Scintillator Spectrometer, DSS, techniques in a neutron beam extracted with the same probe geometry show good agreement from 0.3 to 3 MeV giving confidence in the extrapolation of the DSS data up to 6 MeV. When, however, the BPRC and DSS results are compared with the in-core PRC a significant difference in spectrum shape is seen amounting to a swing of some 10 per cent between 300 and 1200 keV. This coupled with evidence for a probe-tube size-dependence of TOF results above 400 keV suggests that the relationship between the extracted-beam and the scalar-flux spectrum in this energy region is not adequately understood. A systematic uncertainty of 7 per cent has been included in the beam results above 1 MeV when these data are normalised to the in-core data.

Corrections were required to relate the extracted beam spectra to the in-core spectra and for the subcriticality of the core. Also, when comparing with the PRC spectra, a 15% Gaussian smoothing was applied to the measured TOF spectra and the calculated spectra. A final spectrum was synthesised from the various measurement techniques using different normalisation procedures and this is given in Table 1.42. Typical experimental errors on the 1/4 lethargy group fluxes (expressed relative to the total flux) are 5% over the range from 1 keV to 1 MeV and increase outside this energy range.

The improved representation of the cross-section data in the later FGL5 nuclear data library resulted in calculated spectra agreeing much better in the fine detail of the TOF spectra than was obtained with the older FGL4 data set used in the earlier analyses, but still with some discrepancies in overall shape. The TOF spectra are compared with the FGL5 calculated spectrum in MTN/11 Addendum and in Table 1.40. This calculation used the MURAL-TOFFEE code to calculate the directed spectrum in the beam, emerging from the edges of the plates in a core cell. The TOF results obtained using the large probe tube are the ones preferred, with the 200m flight tube results being the more accurate above 1.24 keV and the 50 m flight tube results more accurate below this energy.

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Table 1.40 TOF Spectra and C/E Ratios to FGL5 - TOFFEE Cell Averaged Spectra.

Group	Upper Energy keV	Calculation FGL5 TOFFEE Cell Average Corrected to MURAL	Large Probe Tube					
			200m		50m		C/E FGL5	
			Corr Flux	s.d. %	Corr Flux	s.d. %	200m	50m
9	1353	13.88	13.6	17			1.02	
10	1054	16.01	14.2	10			1.13	
11	821	21.80	20.0	11			1.09	
12	639	27.14	25.7	9			1.05	
13	498	19.90	18.4	7			1.08	
14	389	28.54	26.8	8			1.06	
15	302	28.80	30.0	5			0.96	
16	235	25.97	26.9	6			0.96	
17	183	25.95	27.3	7			0.95	
18	143	26.62	26.9	6			0.99	
19	111	21.79	21.4	5			1.02	
20	86.5	20.70	21.4	4	18.0	12	0.97	1.15
21	67.4	16.28	15.6	5	14.4	7	1.04	1.13
22	52.5	16.12	13.6	5	13.1	6	1.18	1.23
23	40.9	13.02	12.0	4	11.1	6	1.08	1.18
24	31.8	10.02	9.7	4	10.0	5	1.03	1.00
25	24.8	11.52	11.3	4	10.9	4	1.02	1.06
26	19.3	7.926	7.8	4	7.5	6	1.02	1.06
27	15.0	7.341	6.80	4	6.95	5	1.08	1.06
28	11.7	6.145	6.10	4	6.10	5	1.01	1.01
29	9.12	3.815	3.80	5	3.55	6	1.01	1.07
30	7.10	3.930	3.58	5	3.68	5	1.10	1.07
31	5.53	3.043	3.01	6	2.91	5	1.01	1.05
32	4.31	1.821	1.78	6	1.87	5	1.02	0.97
33	3.36	0.498	0.57	13	0.54	13	0.88	0.92
34	2.61	1.311	1.29	8	1.36	7	1.01	0.97
35	2.04	2.465	2.48	7	2.51	7	1.00	0.98
36	1.59	2.348	2.36	7	2.35	7	1.00	1.00
37	1.234	1.643	1.65	7	1.71	6	0.99	0.96
38	0.961	1.259	1.32	8	1.34	6	0.96	0.94
39	0.749	0.907	0.97	9	0.98	6	0.94	0.93
40	0.583	0.561	0.66	10	0.642	7	0.85	0.87
41	0.454	0.356	0.43	14	0.426	7	0.82	0.84
42	0.354	0.203	0.34	18	0.256	7	0.60	0.79
43	0.275	0.158			0.209	7		0.76
44	0.215	0.095			0.129	8		0.74
45	0.167	0.060			0.082	9		0.74
46	0.130	0.034			0.048	14		0.72
47	0.101	0.017			0.023	27		0.75
48	0.079	0.008			0.014	42		0.62
49	0.061	0.004			0			
	0.048							

The recommendation made was to use the 200m flight tube results above 1.234 keV and the 50 m flight tube results below this energy. The original calculation of the spectrum is included because this was used to normalise the measured spectra.

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The shape of the PRC spectrum in the region of the ~30 keV resonance in iron was found to be distorted and so an adjustment was made to the energy scale, as described in MTN/22. The revised Series 1 spectrum ($k_{\text{eff}} = 0.85$) is reproduced in Table 1.41. This improved the agreement with the TOF measurements in the region of the resonance but worsened the agreement with measurements at other energies. MTN/10 includes the Series 2 measurements ($k_{\text{eff}} = 0.96$).

A calculated spectrum which is to be compared with the measured spectrum should have 15% Gaussian smoothing applied.

Table 1.41 Series 1 PRC Spectrum and Energy Scale Adjustment (MTN/22)

Group No.	Lower Energy Boundary (keV)	Unadjusted PRC Series 1 (MTN-10)	Adjusted PRC Series 1	Standard deviation %	TOF/Adjusted PRC
8	1350				
9	1054	14.61	14.65	5	0.96
10	821	14.65	14.74	5	0.962
11	639	21.06	21.11	5	0.973
12	498	25.15	25.20	5	0.990
13	388	22.11	22.16	5	0.861
14	302	26.89	26.95	5	0.978
15	235	28.85	28.91	5	1.029
16	183	26.35	26.41	5	1.050
17	143	27.12	27.18	5	1.003
18	111	26.11	25.90	5	1.026
19	86.5	21.45	21.55	5	1.022
20	67.4	20.79	20.87	5	1.042
21	52.5	16.33	16.80	10	0.980
22	40.9	14.68	14.26	10	0.980
23	31.8	10.28	12.29	10	0.913
24	24.8	11.16	9.732	10	0.944
25	19.3	10.26	11.28	10	0.957
26	15.0	7.648	8.014	10	0.971
27	11.7	7.063	7.186	10	0.882
28	9.12	5.298	5.852	10	0.979
29	7.10	3.346	3.354	15	1.155
30	5.53	3.160	3.167	15	1.091
31	4.31	(2.349)	(2.354)	15	(1.192)
32	3.35	(1.442)	(1.445)	15	(1.240)
33	2.61	(0.813)	(0.815)	15	(1.197)
34	2.03	(1.156)	(1.159)	15	(1.083)

High Energy Spectrum Measurements

Quarter-lethargy group spectra derived from the measured spectra obtained using the BPRC and Li-6 techniques were normalised to the DSS spectrum where they overlap, with a weight assigned to the ratio of each group based on the quoted uncertainties. There is excellent agreement between BPRC and DSS. It is indeed so good over the rest of the energy range that one may conclude that the group between 639 keV and 871 keV is high in the BPRC spectrum by a few percent because of the presence of unwanted counts in the He-3 calibrating peak centred on 764 keV. Uncertainties at the high energy end are largely dominated by those from the BPRC spectrum - based on lack of precision in its energy scale. The good agreement seen suggests that this energy scale has in fact been adequately determined, and that the errors shown may even be a little pessimistic.

The Li-6 results show clearly a systematic tilt relative to the DSS, although no individual ratio when taken with its error is inconsistent with a value of unity. This tilt may be due to uncertainties in the shape of the Li-6 (n, α) cross-section, for which $\pm 10\%$ was assumed for the highest energy group.

The individual spectra from these three techniques are not on an absolute scale, and therefore normalisation is necessary. The method adopted was to normalise the spectra to measurements made by TOF and in-core PRC which, together, cover the energy range from 200 eV to 1.2 MeV (MTN/10 and /11.) The whole experimental spectrum may then be normalised and compared with calculation. Such normalisation presents little problem with the DSS and Beam PRC, where quarter-lethargy group values show only small uncertainties (2.5% to 5%) between 300 KeV and 1.05 MeV. The Li-6 Spectrometer, however, is approaching its poorest accuracy within the 300 keV to 1.05 MeV energy range; the Sum Peak spectrum was normalised using error-weighted ratios through this range, but the normalisation factor itself was found to have an uncertainty of about $\pm 8\%$.

Quarter lethargy group flux values for the three techniques are given in MTN/74, with the Li-6 results normalised in the three possible ways. Agreement between DSS and BPRC was found to be very good, and normalisation to the lower range experimental spectrum presented little problem. These normalised spectra may be combined with weighting related to the estimated uncertainties in the measured values for each group. It should be noted, however, that there appears to be a small but significant difference in shape between the low and high energy spectra where they overlap. This must lead to an uncertainty of about $\pm 2.5\%$ in normalisation factor.

Shape agreement between Li-6 and BDSS is just acceptable, within the estimated group uncertainties, but normalisation presents difficulties. Normalisation down to 30 KeV using the results of triton analysis leads to a systematic difference of about 20% between Li-6 and DSS. Normalisation over the range of sum-peak analysis gives reasonable agreement, though this must be fortuitous, since the normalisation factor itself has an uncertainty of $\pm 8\%$. It was therefore proposed that if the Li-6 data are to be included in the final spectrum, they should first be normalised directly to the DSS measurements over the whole of the range of overlap; Li-6 measurements thus lose some of their independence, but their use was justified by the higher maximum energy reached.

A final recommended quarter lethargy group averaged spectrum has thus been assembled in MTN/74, and is reproduced in Table 1.42 together with the lower energy spectrum based on the TOF and PRC measurements. Each quarter-lethargy group represents a weighted mean, and errors have been assigned accordingly. For comparison with calculation, an overall experimental resolution of 15% was assumed. A cell averaged spectrum calculated using FGL5 data, with 15% Gaussian smoothing, is included for comparison.

Table 1.42 Spectra in 1/4 lethargy width Groups, with 15% Gaussian Smoothing of the Calculated and Low Energy Spectrum.

Group Number	Upper Energy Boundary MeV	MURAL FGL5 Calculated Spectrum (Cell Average) 15% smoothing	MEASURED LOW ENERGY SPECTRUM 15% smoothing Standard deviation $\pm 5\%$	MEASURED HIGH ENERGY SPECTRUM DSS + PRC +Li6 Normalisation: 0.235 TO 1.35 MeV	Standard deviation of High Energy Spectrum (%)
1	10.00				
2	7.79	1.081		1.18	15
3	6.07	2.469		3.07	10
4	4.72	4.281		4.99	7
5	3.68	7.077		7.82	5
6	2.87	10.531		10.93	4.5
7	2.23	11.708		12.46	4.0
8	1.74	13.311		14.15	3.5
9	1.353	13.935	14.86	15.90	2.5
10	1.054	16.330	14.96	16.66	2.5
11	0.821	21.949	21.37	21.87	2.5
12	0.639	26.246	25.69	25.07	3.0
13	0.498	21.271	21.84	21.59	3.5
14	0.388	27.798	27.34	25.49	4.0
15	0.302	28.691	30.21	29.19	4.5
16	0.235	26.293	27.39		
17	0.183	26.027	27.87		
18	0.143	25.701	26.72		
19	0.111	21.932	22.07		
20	0.0865	20.567	21.70		
21	0.0674	16.874	16.69		
22	0.0525	15.700	14.18		
23	0.0409	12.790	11.81		
24	0.0318	10.127	10.56		
25	0.0248	11.645	11.48		
26	0.0193	8.296	8.26		
27	0.0150	7.136	6.88		
28	0.0117	5.981	6.01		
	0.0091				

The spectrum measurements presented in this Table are recommended as suitable for consideration as benchmark spectra for the centre of MZA. Note, however, that there is a possible ambiguity over the corrections which were applied to relate the sub-critical core measurements to the critical core, the uncertainty being over whether this was the fundamental mode spectrum or the critical core spectrum.

PRC Spectrum Measurements in the Blanket and Reflector of MZB/2

These measurements were made in the version of MZB with the depleted uranium oxide blanket sector and are described in MTN/78. The results are given in the following Table 1.43.

Table 1.43 PRC Spectrum Measurements in the Blanket and Reflector Regions of MZB/2.

Group No.	LOWER ENERGY BOUNDARY keV	BLANKET SPECTRUM POSITION 50-32 QUARTER LETHARGY FLUX	Standard Deviation %	REFLECTOR SPECTRUM POSITION 47-28 QUARTER LETHARGY FLUX	Standard Deviation %
7	1740				
8	1350	95.8	10	9.5	10
9	1050	114.2	10	13.0	10
10	821	146.4	15	16.9	15
11	631	270.8	15	34.5	15
12	498	390.0	5	53.5	5
13	388	312.3	5	53.3	5
14	302	414.7	5	82.0	5
15	235	546.0	5	95.2	5
16	183	557.2	5	93.4	5
17	143	623.9	5	123.0	5
18	111	688.7	5	141.6	5
19	86.5	631.2	5	116.1	5
20	67.4	671.3	5	147.3	5
21	52.5	603.3	5	120.6	5
22	40.9	588.5	5	101.9	5
23	31.8	464.7	25	70.8	25
24	24.8	516.9	25	171.4	25
25	19.3	512.5	25	173.3	25
26	15.0	420.1	10	115.1	10
27	11.7	405.8	10	103.3	10
28	9.12	328.1	15	71.0	25
29	7.10	236.1	15	48.7	25
30	5.53	211.5	15	70.3	25
31	4.31	139.9	15	80.9	15
32	3.35	75.7	30	63.5	15
33	2.61	41.9	30	49.4	15
34	2.03	73.2	30	41.5	25
35	1.58	116.1	25	45-9	25
36	1.23	104.0	25		

These PRC spectrum measurements made in the blanket and reflector regions of MZB/2 are recommended as suitable for consideration as benchmark measurements.

Thus the three sets of measurements presented in this section, the central reaction rate ratio measurements in MZA and MZB, the central spectrum measurements made in MZA and the blanket and reflector spectrum measurements made in MZB/2 are recommended as suitable for consideration as benchmark measurements and are discussed further in Section 2.

1.3.3 Description of Material Data.

The materials of the cores are described in Section 1.1.3.

1.3.4 Temperature

The temperature was not recorded and no temperature corrections were made.

1.3.5 Additional Information Relevant to the Spectral Characteristics Measurements

None.

1.4 Description of Reactivity Effects Measurements

1.4.1 Overview of Measurements

Reactivity changes were measured in MZA and MZB relative to the movement of the calibrated control rods, CR7 and FR9, expressed in terms of "standard cms." of movement. These were calibrated by period measurements which were then interpreted using the inhour equation and the chosen set of delayed neutron data to give reactivities in absolute terms. Two different sets of nuclear data were used in the original analyses. The early analysis used the ZEBRA (Stevenson) delayed neutron data, with the FD4 (FGL4) nuclear cross-section library, whereas the later analysis used the Smith-Tomlinson delayed neutron data set (MTN/104) with the FGL5 fine group nuclear cross-section library. This second scale is the reactivity scale adopted in the present document, although it should be noted that the Smith-Tomlinson set is now over 30 years old and there are more recent evaluations of the delayed neutron data and more recent cross-section libraries. Some of the differences between the newer JEFF-3 and the Smith-Tomlinson delayed neutron data are discussed in Section 2.4.1 of Part 2 (the MZC document, ZEBRA-LMFR-EXP-003)

1.4.2A Description of Experimental Configuration.

The critical configurations in which the measurements were made, and the dimensions of the perturbation materials, are described in Section 1.1.2

1.4.2B Methods

The Reactivity Scale Experiment in MZB/4

Three ways to provide a reactivity scale were intercompared in MZB/4, the delayed neutron scale used to calibrate the control rods, the calculated inner core enrichment scale and the calculated edge element worth scale (MTN/52 and analysis in MTN/76). The method used to reduce the core enrichment was to replace the UPuO_2 plate in all the core cells of the central element by a UO_2 plate of the same size. Changes were made to the numbers of elements at the edge of the core. Each of the changes was balanced by movements of the calibrated control rods and the comparison of calculation with measurement made for the enrichment worth and the edge element worth (expressed in terms of the delayed neutron scale).

Sodium voiding measurements in MZA and MZB/2.

The sodium plates in different axial sections of the central nine elements of MZA were replaced by steel rings having a thickness and composition matching that of the sodium cans. The change in reactivity was measured using a calibrated control rod. The results are described in MTN/13 and the analysis in MTN/19, MTN/65 and MTN/103. Three different axial regions in the core section were voided, as well as the axial blanket region. The nine elements were also fully voided.

In MZB/version 2 similar measurements were made in groups of nine elements at different radial positions in the inner core, outer core and sector radial blanket (MTN/54). In addition to the plate geometry elements measurements were also made using pin geometry components.

All components interchanged were weighed and changes in core height were measured. Corrections for differences in core height and the weight of the steel canning material were made to obtain the measured sodium worths.

Central and Distributed Reactivity Perturbation Measurements in MZA and MZB

The experiments are described in MTN/9, /26 and /36 and the analyses in MTN/64, /69 and /96.

The plate samples used in the measurements were as follows:

Plutonium metal: the core plates PUV8 and PUIX8 and the plates PUII, and PUIII which have smaller Pu240 and 241 fractions.

Mixed U-PuO₂: the PUIV plate.

Uranium: 93% U235 metal (93U516); natural and depleted UO₂ (UO24R4 and UO2DP4)

Sodium and steel: NASTBR4 and STSTBR4

Tantalum and enriched boron.

All plates were weighed and thicknesses measured and corrections applied to the measured values for differences between the thickness and steel content of components interchanged. The effects of changes in axial dimensions were measured using steel spacer components.

The worths were measured in terms of the delayed neutron reactivity scale and the results were revised in MTN/96 to use the FGL5 cross-section set and the Smith-Tomlinson delayed neutron data (dating from 1972). The aim in the present document is to include sufficient information about the control rod calibration measurements for them to be recalibrated using current delayed neutron data. The measurements of relative worth (for example worths of a component relative to the worth of a plutonium component) are, of course, independent of the reactivity scale.

The Large Sample Changer element (LSC) was used for the small sample perturbation measurements, with the samples being in plate form and replacing plates (or empty cans or steel spacer plates) in cells of the core elements. This special element was about 4 m. long and took the place of a standard element in the core. It was filled with standard core cells. The element moved vertically between two positions ~1.6 m apart. In both positions, the core cells in the LSC extended beyond the extremes of the axial blanket regions in the adjacent standard elements. The LSC contained no blanket cells. Both end stops were adjusted so that in both positions unit cells in the LSC were aligned with the central unit cell (MZB) or two unit cells (MZA) in the surrounding elements. The cells which were aligned with the central cells when the LSC was in the "Down" position were exposed above the top of the surrounding elements when the LSC was in the "Up" position. By this means the contents of these central cells could be modified, with the reactor at Normal Shut Down.

The difference in reactivity between the Up and Down positions was measured by the compensating change in the position of the regulating control rod as the reactor power was balanced alternately with the LSC in each condition.

The measurements in MZA were made with CR7 and CR8 always at 50.0 cms and 66.5 cms respectively and FR9 near the point of inflexion (the maximum change in reactivity with position). Both these coarse rod positions are a little lower than used in the calibration of FR9 by period measurements, because the LSC was more reactive than a standard element. The check on the effect of this small change on the absolute worth of the standard cm of FR9 in MZA is described in MTN/9.

In MZB/1 CR7 and CR8 were always at 69.0 cms and 76.5 cms respectively and FR9 again near the point of inflexion.

Steps were taken to minimise the effects of introducing cooler sections of the LSC into the hot core (~ 60°C in MZA, ~50°C in MZB/1):-

- (a) the LSC was moved at regular intervals (~ 7 mins.);
- (b) generally three measurements in the Up position and two in the Down position were made and each Down result compared with the mean of the Up results immediately before and after;
- (c) the LSC was left overnight half way between the two positions.

Two or three measurements were made during each day's experiments. The results for each day showed little drift and the variations were taken as a guide to the expected uncertainty in reproducibility of a single

(DOWN-UP) measurement.

A statistical analysis of the results of measurements that were repeated and of the variation of the normal results within a day indicated that a standard error of ~ 0.020 std. cm. FR9 (or $\sim 10^{-6}$ dk/k) on a single determination of a cell perturbation in MZA was appropriate. In MZB/1 this source of uncertainty was smaller, $\sim 5 \times 10^{-7}$ dk/k because of the larger core size. This uncertainty was assumed to apply to each single measurement and the uncertainties on the average of two measurements have in general been reduced correspondingly. (The uncertainty for each of the measurements for the U235 plates in MZA is larger because the difference between two measurements was involved.)

The spontaneous neutron source added with a Mk.V plutonium plate at the centre of a core containing $\sim 5,000$ such plates increases the effective source by less than 0.1%. For a balanced reactor at the same power, the degree of subcriticality must be increased by the same fraction. It was concluded that the degree of subcriticality for the LSC measurements was equivalent to 1.1 std. cm FR9. Hence the error introduced by ignoring the source change is ~ 0.001 std. cm FR9, and is thus negligible compared with the other uncertainties. The effect is even smaller in MZB.

Measurements were made in MZA to check that the worth per compensating standard cm of FR9 was the same in the core configuration used for these experiments as that determined in the rod calibrations.

Corrections were made for any change in the length of the central cells on the substitution resulting in a redistribution of the contents of the LSC, and for the adding or subtracting of structure (such as cans or spacers) not required in the "ideal" experiment. (The "ideal" experiment being that in which a sample (such as a core of a plutonium plate) is added without any change in the can mass or any change in the cell height.)

1.4.2C Results of the Reactivity Effects Measurements

The Reactivity Scale and the Calibration of the Control Rods

Reactivity changes were measured relative to the movement of the calibrated control rods, CR7 and FR9, expressed in terms of standard cms of movement. These were calibrated by period measurements which were then interpreted using the inhour equation and the chosen set of delayed neutron data, the Smith-Tomlinson data set (MTN/104).

The period measurements corresponding to the standard cm of movement of the rods are given for MZA and MZB in Tables 1.47 and 1.48 and are summarised in Table 1.49.

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Table 1.47 Absolute Calibrations of Rods, CR7 and the Fine Rod FR9 in MZA

Rod	No. of Core Elements	Rod Movement (standard cm)	Correction for Drift	Corrected Rod Movement	Period (sec)
FR9	217	3.677	- 0.015	3.662	177.5
		2.676	- 0.039	2.637	257.1
		4.668	- 0.060	4.608	135.5
CR7	217	1.501	- 0.025	1.476	208.0
		0.997	- 0.037	0.960	330.4
		2.226	- 0.051	2.175	132.3
FR9	213	3.970	- 0.016	3.954	164.9
		2.929	- 0.046	2.883	236.7
		4.926	- 0.090	4.836	129.5
CR7	213	1.403	- 0.015	1.388	231.6
		2.384	- 0.025	2.359	125.3

Note: Rod 9 contains 64.05 standard cm and Rod 7 contains 62.74 std. cm.

Table 1.48 Absolute Calibration of Control Rods CR7 and FR9 in MZB/1

Rod	Rod Movement (std. cm)	Correction for Drift	Corrected Rod Movement	Period (secs)
FR9	4.864	- 0.015	4.849	182.6
	3.899	- 0.030	3.869	235.1
	5.856	- 0.053	5.803	148.8
CR7	1.895	- 0.002	1.893	235.8
	2.393	- 0.007	2.386	181.8
	2.888	- 0.015	2.873	145.8

Note: Rod 9 contains 64.7 standard cm, Rod 7 contains 64.1 std. cm.

Table 1.49 Reactivity Worths of Control Rods based on FGL5 cross-section data and the Smith-Tomlinson delayed neutron data (in units of 10^{-4} dk/k per std cm) (MTN/104 Table 7)

Assembly	FR9	CR7
	10^{-4} dk/k per std cm	10^{-4} dk/k per std cm
MZA	0.502 ± 0.025	1.062 ± 0.053
MZB/1	0.383 ± 0.019	0.784 ± 0.039
MZB/2	0.380 ± 0.019	
MZB/3	0.376 ± 0.019	
MZB/4	0.437 ± 0.022	

These reactivity worths have an estimated systematic uncertainty of $\pm 5\%$ arising predominantly from the uncertainty in the delayed neutron data.

This figure is consistent with the uncertainty estimate of 5% for Beta-effective made by the reviewer, Atsushi Zukeran, although it should be noted that the relative contributions of the different fissile isotopes (in particular U238 and Pu239) to the period/reactivity relationship are somewhat different for the period measurements from the relationship for Beta-effective. An analysis of the uncertainties for the calibration based on period measurements is given by Stevenson in a paper to the Specialists Meeting on Delayed Neutron Data (Birmingham University, Sept 1986, p1). His analysis relates directly to the Zebra period measurements and the Smith-Tomlinson delayed neutron data. He assesses the total uncertainty as $\pm 5\%$ (arising from uncertainties in the delayed neutron data and the calculation of relative fission rates and relative neutron importances for prompt and delayed neutrons - in fact all of the nuclear data uncertainties).

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The contributions of the fissile nuclides to the effective delayed neutron fractions calculated for MZA and MZB are given in Tables 1.49A and 1.49B by time group. To recalculate the reactivity scales using different delayed neutron data and cross-sections the reactivity changes which produce the periods given in Tables 1.47 (MZA) and 1.48 (MZB/1) should be calculated using the new data and compared with the value calculated using the data in the tables. This will provide the scaling factors to be applied to the reactivity scales.

Table 1.49A Calculated Values of the 6 Time-group Beta Effective Fractions in MZA
Smith-Tomlinson delayed neutron data and FGL5 cross-sections. (MTN/104)

Calculated β_{eff} values for precursor time-group i	Nuclide Group Yield ($\times 10^{-8}$)					
	U235	U238	Pu239	Pu240	Pu241	Pu242
β_1	643.4	1987	5376	306.3	177	1.802
β_2	3716	21320	40460	3381	4283	89.80
β_3	3234	24900	31000	2279	3195	73.73
β_4	7123	60440	47610	4481	7286	189.4
β_5	2228	34950	14840	1689	3400	100.1
β_6	454	11660	5024	340.7	304.8	4.593
Total contribution for isotope	17398.4	155257	144310	12477	18645.8	459.43

$$\text{MZA } \beta_{\text{eff}} = 0.00349$$

Table 1.49B Calculated Values of the 6 Time-group Beta Effective Fractions in MZB
Smith-Tomlinson delayed neutron data and FGL5 cross-sections. (MTN/104)

Calculated β_{eff} values for precursor group i	Nuclide Group Yield ($\times 10^{-8}$)					
	U235	U238	Pu239	Pu240	Pu241	Pu242
β_1	822.9	2193	5216	231.1	157.3	1.249
β_2	4763	23690	39570	2571	3836	62.73
β_3	4143	27620	30250	1729	2854	51.39
β_4	9130	67150	46570	3407	6524	132.3
β_5	2855	38800	14510	1283	3042	69.88
β_6	581.8	12950	4909	258.8	272.7	3.205
Total contribution for isotope	22295.7	172403	141025	9479.9	16686	320.75

$$\text{MZB } \beta_{\text{eff}} = 0.00362$$

Sodium voiding measurements in MZA.

The sodium plates in four different axial regions of the central nine elements of MZA were replaced by stainless steel rings having a composition similar to the sodium cans. Three equal volume axial regions in the core section were voided, these being the central 4 cells, the intermediate 4 cells and the outer 4 cells in the core, as well as the cells in the axial blanket region. The nine elements were also fully voided. The change in reactivity was measured using the calibrated control rod, FR9. The results are described in MTN/13 (with corrected data in MTN/54 Appendix 3) and the analysis in MTN/19, MTN/65 and MTN/103.

The weight of the steel ring is on average 0.08 g less than that of the average can of a sodium plate but the correction to the reactivity change due to this difference is well within the uncertainty. However, corrections to the observed reactivity changes were required because the average ring thickness is a little greater than that of a sodium plate, producing some axial movement of the contents of the elements. These corrections were obtained from calculations. The resulting measured results for the removal of sodium, corrected for this change, are given in Table 1.50.

Table 1.50 Sodium Voiding Reactivity Changes in the Central 9 Elements of MZA
(MTN/54 Appendix 3, Table A5 with the measured reactivities increased by 1.8%)

Sodium voiding regions (Groups of 4 cells in the core)	Compensating movement of FR9 ($\times 10^{-4}$ dk/k)	Height Correction ($\times 10^{-4}$ dk/k)	Corrected Measured Values ($\times 10^{-4}$ dk/k)
Core Region 1 (0.0 to ~15.02 cm) (24 plates = 2.55 kg Na)	+2.79 $\pm$ 0.06	+0.56 $\pm$ 0.21	+3.35 $\pm$ 0.22
Core Region 2 (~15.02 to ~30.04 cm) (24 plates = 2.55 kg Na).	+0.14 $\pm$ 0.08	+0.40 $\pm$ 0.19	+0.54 $\pm$ 0.20
Core Region 3 (~30.04 to ~45.06 cm) (24 plates = 2.55 kg Na)	-3.18 $\pm$ 0.08	+0.19 $\pm$ 0.15	-2.99 $\pm$ 0.17
Axial Blanket (~45.06 to ~80.10 cm) (64 plates = 6.79 kg Na)	-3.22 $\pm$ 0.08	+0.06 $\pm$ 0.14	-3.16 $\pm$ 0.16
Elements (0.0 to ~80.10 cm) (136 plates = 14.43 kg Na)	-2.95 $\pm$ 0.08	+1.21 $\pm$ 0.42	-1.74 $\pm$ 0.43
Sum of Core 1, 2, 3 and Axial Blanket			- 2.19 $\pm$ 0.38

Corrected results obtained using 0.502×10^{-4} dk/k per std. cm of FR9.

The axial dimensions are the distances from the core mid-plane with the voiding being symmetrical in the upper and lower halves of the reactor.

The $\pm$ 5% systematic uncertainty in the reactivity scale is not included

Sodium voiding measurements in MZB/2.

In MZB/version 2 similar measurements were made in groups of nine elements at different radial positions in the inner core, outer core and sector radial blanket (MTN/54). The positions of the measurements are shown in Figure 1.18 and the measured results for the central and off-central positions in Tables 1.51 and 1.52. Measurements were also made in pin geometry. The group of 9 elements voided of sodium was surrounded by a ring of 16 pin geometry elements to form an array of 5x5 elements.

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Table 1.51 Sodium Voiding in the Central 9 Elements of MZB/2

Geometry	Region Voided in the central 9 elements	Axial Dimensions of Region Voided (cm) (Half-core range)	Mass of Sodium Removed (Kg)	FR9 (std cm)	Measured Reactivity ($\times 10^{-4}$ dk/k)
Pin	Central core calandria	0 – 14.9	2.61	-4.99 ± 0.05	$+1.90 \pm 0.02$
	Edge core calandrias	14.9 – 44.6	5.22	$+0.39 \pm 0.06$	-0.15 ± 0.02
	All core calandrias	0-44.6	7.83	-4.56 ± 0.06	$+1.73 \pm 0.02$
	Axial blanket calandrias	44.6 – 74.3	5.22	$+2.23 \pm 0.04$	-0.85 ± 0.02
	Core plus axial blanket calandrias	0 – 74.3	13.04	-1.94 ± 0.06	$+0.74 \pm 0.02$
Plate	Centre 3 core cells	0 – 12.2	2.23	-4.58 ± 0.06	$+1.74 \pm 0.02$
	Upper 4 and lower 4 core cells	12.2 – 44.6	5.95	-1.46 ± 0.11	0.55 ± 0.04
	All 11 core cells	0 – 44.6	8.19	-6.02 ± 0.14	$+2.29 \pm 0.05$
	Axial blankets	44.6 – 79.5	6.81	$+1.99 \pm 0.07$	-0.76 ± 0.03
	Core plus axial blanket	0 – 79.5	14.99	-3.90 ± 0.15	$+1.48 \pm 0.06$

Corrected results obtained using 0.380×10^{-4} dk/k per std. cm of FR9.

The axial dimensions are the distances from the core mid-plane and apply in each half of the reactor.
The $\pm 5\%$ systematic uncertainty in the reactivity scale is not included

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Table 1.52 Sodium Voiding in Off-central Positions in MZB/2

Geometry	Position (See Figure 1.18)	Region Voided in 9 elements	Axial Dimensions of Region Voided (cm) (half-core range)	Mass of Sodium Removed (Kg)	FR9 (std cm)	Measured reactivity ($\times 10^{-4}$ dk/k)
Pin	4	Full core height	0 – 44.6	7.83	-0.74 ± 0.05	$+0.28 \pm 0.02$
Plate	4	Full core height	0 – 44.6	8.19	-1.30 ± 0.12	$+0.49 \pm 0.05$
	5	Full core height	0 – 45.0	7.66	$+5.15 \pm 0.14$	-1.96 ± 0.05
	6	Oxide radial blanket	0 – 49.6	6.08	$+2.58 \pm 0.05$	-0.98 ± 0.02
	2	Full core height	0 – 45.0	7.66	$+5.24 \pm 0.14$	-1.99 ± 0.05
	1	Inner metal radial blanket	0 – 50.3	6.37	$+3.36 \pm 0.05$	-1.28 ± 0.02

Footnotes:

- 1 Corrected results obtained using 0.380×10^{-4} dk/k per std. cm of FR9.
- 2 *The experimental errors do not include the systematic error from the reactivity scale ($\pm 5\%$)*
- 3 **The axial dimensions are the distances from the core mid-plane and apply in each half of the reactor.**

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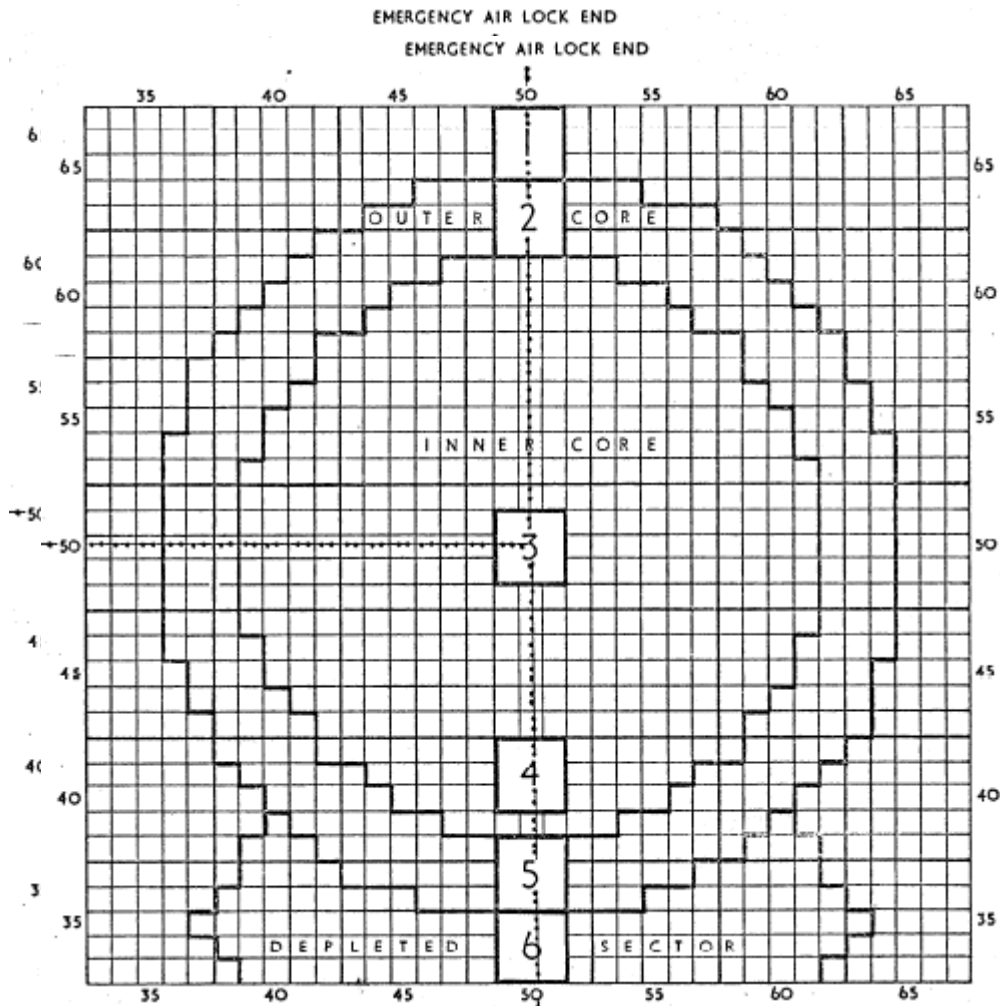


Figure 1.18 Locations of the Sodium Voiding Measurements in MZB/2

Reactivity Differences between Pin and Plate Elements

The change in reactivity resulting from replacing the central 25 plate geometry elements by 25 pin geometry elements was measured in MZB/2 at the core centre and near the inner core boundary. After making a correction for the extra core element present when the pin geometry sodium voiding measurements were made the pin geometry elements were measured to be less reactive by $+7.3 \pm 1.0$ std cm FR9 at the core centre and by 3.8 ± 1.0 std cm FR9 at the inner core boundary. In MZB/2, 1 std. cm is equal to $0.380 \pm 0.019 \times 10^{-4}$ dk/k and so these differences in reactivity are 2.8×10^{-4} dk/k and 1.4×10^{-4} dk/k, with an uncertainty of $\pm 0.4 \times 10^{-4}$ dk/k

Details of the elements interchanged are given in MTN/54 Appendix 2.

Central and Distributed Reactivity Perturbation Measurements in MZA and MZB

The measurements are summarised in MTN/96 and compared there with FGL5 calculations. More details of the samples and the calculations are given in MTN/64. The experimental results are based on the standard cm worth determined by period measurements, and do not include the systematic uncertainty in this worth. The reactivity scale was renormalised to the FGL5 cross-section set calculations of relative fission rates and the Smith-Tomlinson delayed neutron data, increasing the worths measured in MZA by 1.9% and in MZB by 3.3%.

All components were weighed and thicknesses measured and corrections were made for differences between the measured weights of steel and dimensions and the Database values.

The replacement of the steel frames by the steel plates added 372.3 g steel (and a negligible change in cell length) and produced an increase in the FR9 position in MZA of:

$$1.006 \pm 0.014 \text{ std cm FR9 i.e. } 0.00270 \pm 0.00004 \text{ std cm FR9/g steel in MZA.}$$

and in MZB/1:

$$0.541 \pm 0.014 \text{ std cm FR9 i.e. } 0.00145 \pm 0.00004 \text{ std cm FR9/g steel in MZB.}$$

These results were then used to correct for the steel mass changes (made in similar positions in the cell). Hence the effect of the change in thickness was deduced.

In MZA a 1.12 mm thickness increase resulting from adding steel shims produced a change of:

$$(+0.118 \pm 0.020) - 0.00270 \times 22.0 = +0.059 \pm 0.020 \text{ std cm FR9 in MZA}$$

and a 1.06 mm thickness decrease between the two types of frames produced a change of:

$$(-0.059 \pm 0.020) - 0.00270 \times 7.1 = +0.040 \pm 0.020 \text{ std cm FR9 in MZA}$$

These two results correspond to 0.053 ± 0.018 and 0.038 ± 0.019 std cm FR9 per mm increase in thickness in MZA. A figure of $+0.045 \pm 0.015$ std cm FR9/mm thickness increase was used in making the corrections to the MZA measurements.

In MZB/1 a 1.12 mm thickness increase of adding the steel shims produced a change of:

$$(+0.049 \pm 0.014) - 0.00145 \times 22.0 = +0.017 \pm 0.014 \text{ std cm FR9}$$

and the 1.07 mm thickness decrease between the two types of frames produced a change of:

$$(-0.049 \pm 0.014) + 0.00145 \times 7.1 = -0.039 \pm 0.014 \text{ std cm FR9.}$$

These two results correspond to 0.015 ± 0.013 and 0.036 ± 0.014 std cm FR9 per mm increase in thickness. A figure of $+0.026 \pm 0.013$ std cm FR9/mm thickness increase was used in making the corrections to the MZB/1 measurements.

Thus most of the corrections for thickness changes were small.

In MZB/1 the steel worth obtained from the 16 steel plates versus 8 UO₂ dummies, when 873.8 g steel was added, gave, after a small correction for the height change, a value of:

$$+0.00129 \text{ std cm FR9/g steel.}$$

A mean value of $+0.00137$ std cm FR9/g steel added, with an uncertainty of $\pm 15\%$, was taken to correct for

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changes in the weight of all types of steel and in all positions in a cell. An uncertainty of $\pm 15\%$ was also adopted for the corrections in MZA, based on intercomparisons of different steels made in the Zebra 8G experiments.

Calculations showed that all steels in the assembly have the same worth/unit mass within a range of 3% and therefore only corrections for changes in the total weight of steel were made.

Corrections for copper (and brass, assumed to be equal to copper) were calculated (relative to the PUII plutonium plate) and found to be:

+0.0073 std cm FR9/g Cu in MZA

+0.0042 std cm FR9/g Cu in MZB/1

Uncertainties of one third were assumed for this correction.

The only impurity to be allowed for is the gallium in the plutonium metal plates. The light atom impurities in the samples were considered to be insignificant.

The results for the “ideal” perturbations, after these corrections have been applied for differences in canning material weights and plate thicknesses from the Database values, are given in Tables 1.53, and 1.54. The results of Perturbation measurements made over the whole core height at four radial positions in MZB are given in Tables 1.55, 1.56, 1.57 and 1.58.

A problem in the original analysis of MTN/9 and MTN/26 was that the importance of the silver-copper braze material present on the UO_2 plates which have the 4 rounded corners (the UO24R4 plates) was not recognised. (The braze material was $71 \pm 1\%$ Ag and $29 \pm 1\%$ Cu.) This was corrected for in an addendum to MTN/26. Measurements were also made using the UO_2 plates with the three rounded corners (the UO23R4 plates) which do not use this braze material, and so a comparison can be made.

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Table 1.53 Central Perturbation Measurements in MZA

Measurement (corrected for changes in weights and sample thickness)	Position in cell (numbered upwards)	Measured value $\times 10^{-4}$ dk/k
<u>MZA</u>		
PUV8 plate replacing can	4	2.959 ± 0.010
PUIII8 plate replacing can	4	2.976 ± 0.010
PUII8 plate replacing can	4	3.119 ± 0.010
2 x 93% U235 plates added	4	4.265 ± 0.013
Adding unit cell (plates only)	1 cell	4.486 ± 0.018
Adding unit cell (plates + sheath)	1 cell	4.362 ± 0.035
4 x nat UO2 plates replacing cans	1 cell	-0.939 ± 0.016
4 x dep UO2 plates added	1 cell	-1.181 ± 0.015
12 Na plates replacing cans	2 centre cells	-0.229 ± 0.011
372 g steel added	12, 14, 15, 17	-0.506 ± 0.007
1 Ta plate added (134.2g)	14	-1.276 ± 0.011
2 Ta plates added (266. 5g)	14	-2.359 ± 0.012
0.681 g B10 added	14	-0.468 ± 0.011
1.388 g B10 added	14	-0.914 ± 0.012
2.421 g B10 added	14	-1.557 ± 0.010

*It is recommended that an additional 1% random uncertainty be added.
The $\pm 5\%$ systematic uncertainty in the reactivity scale is not included*

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Notes:

1 PUV8 and PUIX8 plates contain about 76 g plutonium (~18% Pu240), PuIII8 and PuII8 plates contain about 71 g plutonium (~10% and 5% Pu240 respectively).

The 93% U235 plates contain 74 g uranium, and the canned natural UO₂ and the uncanned depleted UO₂ plates contain about 135 and 160 g UO₂ respectively.

The PUIV plate contains about 131 g PuO₂/UO₂ including some 86 g natural uranium and 29 g plutonium (~10% Pu240).

2 The positions in the cell refer to the particular cell (Figure 1.19) and are those positions nearest the core mid-plane. There were 12 core cells in a MZA core element, and 11 in a MZB inner core element. For the plutonium and U235 samples in MZB/1 position 4 was used in each of two cells. The positions "1 cell" or "2 cells" refer to a complete cell or cells centred on the core centre line, (not necessarily corresponding to the usual cell boundaries) with the plates added in their usual positions in these cells. Depleted UO₂ plates were placed in the natural UO₂ plate positions. Numbers greater than 14 refer to the next cell above. The plate samples correspond in thickness to the plate normally in the position except for the B10 samples which were only 1.5 mm thick and together with steel frames replaced the sodium plate indicated. The steel additions were by replacing frames by plates.

3 The experimental results are based on the standard cm worths determined by period measurements, and the uncertainties do not included the systematic uncertainty of $\pm 5\%$ in these worths.

PLATE NUMBER		PLATE NUMBER		PLATE NUMBER	
14	NA	14	NA	8	UO ₂
13	UO ₂	13	UO ₂	7	NA
12	NA	12	NA	6	UO ₂
11	PuO ₂ /UO ₂	11	Pu METAL	5	NA
10	NA	10	C	4	UO ₂
9	UO ₂	9	UO ₂	3	UO ₂
8	S. STEEL	8	NA	2	NA
7	NA	7	NA	1	UO ₂
6	UO ₂	6	UO ₂		
5	NA	5	S. STEEL		
4	Pu METAL	4	Pu METAL		
3	NA	3	NA		
2	UO ₂	2	UO ₂		
1	NA	1	NA		

INNER CORE CELL OUTER CORE CELL

NATURAL UO₂ RADIAL
BLANKET CELL MZB(1)

The MZB outer core cell is the same as the MZA core cell.

Figure 1.19 Plate Numbering in the MZB Inner Core and Outer Core Cells (also the MZA Cell) and Radial Blanket

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Table 1.54 Central Perturbation Measurements in MZB/1

Corrected measured value	Position in cell	Measured value $\times 10^{-4}$ dk/k
<u>MZB/1</u>		
2 PUIX8 plates replacing cans	4	2.332 ± 0.004
2 PUIII8 plates replacing cans	4	2.346 ± 0.005
2 PUII8 plates replacing cans	4	2.463 ± 0.005
2 x 2 x 93% U235 plates added	4	3.702 ± 0.008
2 PUIV4 plates replacing cans	11	0.732 ± 0.004
Adding unit cell (plates only)	1 cell	0.810 ± 0.009
Adding unit cell (plates + sheath)	1 cell	0.758 ± 0.015
8 nat UO2 plates added	2 cells	-0.969 ± 0.006
8 dep UO2 plates added	2 cells	-1.223 ± 0.012
7 Na plates replacing cans	1 cell	-0.062 ± 0.005
372g steel added	5, 7, 10, 12	-0.208 ± 0.005
874 g steel added	UO2 positions in two cells	-0.430 ± 0.005
0.68l g B10 added	7	-0.209 ± 0.006
1.388 g B10 added	14	-0.914 ± 0.012
2.421 g B10 added	14	-1.557 ± 0.010

*It is recommended that an additional 1% random uncertainty be added.
The $\pm 5\%$ systematic uncertainty in the reactivity scale is not included*

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Table 1.55 Full Element Perturbations at the Core Centre of MZB

Corrected Cell Perturbation	Position in cell	Number of cells	Experimental value $\Delta k/k \times 10^{-4}$
PUIX8 plate replacing can	4	6	4.703 ± 0.024
PUIII8 plate replacing can	4	6	4.747 ± 0.024
PUII8 plate replacing can	4	6	4.979 ± 0.024
93% U235 plate added	4	6	3.815 ± 0.029
PUIV8 plate replacing can	11	11	3.035 ± 0.015
PUIV8 plate core replacing UO2 plate core	11	11	3.808 ± 0.017
Nat. UO2 plate replacing can	2,6,9,13	11	-3.082 ± 0.019
Dep. UO2 plate added	2,6,9,13	11	-3.937 ± 0.032
Nat. B4C plate replacing can	7	6	-3.441 ± 0.015
Ta plate added (134 g)	7	6	-2.141 ± 0.014
109.1 g steel added	7	6	-0.144 ± 0.014

Footnotes:

- 1 When the number of cells is 6 only alternate core cells were perturbed, when 11, all core cells were perturbed. The plate samples correspond in thickness to the position except for the U235 and Ta plates when the thickness was made up with steel plates.
- 2 The steel addition was achieved by replacing a sodium dummy by two steel plates.
- 3 The Nat. B4C plate (B4CNAT4) is canned and contains 2.82 g B10

*It is recommended that an additional 1% random uncertainty be added.
The $\pm 5\%$ systematic uncertainty in the reactivity scale is not included*

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Table 1.56 Worths of Full Element Perturbations at the Inner Core Boundary of MZB/2

Corrected Perturbation	Position in Cell	Number of Cells	Experimental value
PUIX plate replacing can	4	6	2.090 ± 0.010
PUIII plate replacing can	4	6	2.095 ± 0.010
PUII plate replacing can	4	6	2.216 ± 0.010
93% U235 plate added	4	6	1.628 ± 0.012
PUIV plate replacing can	11	11	1.419 ± 0.010
PUIV plate core replacing UO2 plate core	11	11	1.670 ± 0.010
Nat UO2 plate replacing can	2,6,9,13	11	$- 1.054 \pm 0.011$
Dep UO2 plate added	2,6,9,13	11	$- 1.422 \pm 0.019$
Nat B4C plate replacing can	7	6	$- 1.463 \pm 0.010$
Ta plate added (134 g)	7	6	$- 0.940 \pm 0.010$
109.1 g steel added	7	6	$- 0.051 \pm 0.010$

*It is recommended that an additional 1% random uncertainty be added.
The $\pm 5\%$ systematic uncertainty in the reactivity scale is not included*

Table 1.57 Worth of Full Element Perturbations at the Outer Core Boundary of MZB/2

Ideal Cell Perturbation	Position in Cell	Number of Elements	Experimental value $dk/k \times 10^{-4}$
Pu XII plate replacing can	4	1	2.062 ± 0.013
Pu III plate replacing can	4	1	2.056 ± 0.013
Pu II plate replacing can	4	1	2.163 ± 0.013
93% U235 plate added	4	1	1.680 ± 0.009
Nat. UO2 plates replacing cans	2, 6, 9, 13	2	0.407 ± 0.019
Dep. UO2 plates added	2, 6, 9, 13	2	0.347 ± 0.024
Nat B4C plate replacing can	7	2	2.459 ± 0.011
Ta plate added	7	2	$- 1.484 \pm 0.010$
109.1 g steel added	7	2	0.195 ± 0.010

Notes:

- 1 Each core cell was perturbed. Single element perturbations were carried out in lattice position (50,36) only, two element perturbations in (50,36) plus (51,36).
- 2 *The $\pm 5\%$ systematic uncertainty in the reactivity scale is not included*
- 3 *It is recommended that an additional 1% random uncertainty be added.*

Table 1.58 Worths of Plutonium in the Natural Uranium Oxide Sector of MZB/1

Perturbation	Position in Cell	No of Cells	Element Positions	dk/k x 10 ⁻⁴
PUIV plate replacing UO ₂ plate	6	18	(49,35) (50,25) (51,25)	2.869 ± 0.009
PUIV plate replacing UO ₂ plate	6	18	(49,33) (50,33) (51,33)	1.095 ± 0.008

A mixed oxide plate replaced a UO₂ plate in 6 cells in 3 elements.

It is recommended that an additional 1% random uncertainty be added.

The ± 5% systematic uncertainty in the reactivity scale is not included

In conclusion, the measurements of sodium voiding reactivities in pin and plate geometry and the material worth measurements described in this section are recommended as suitable for consideration as benchmark measurements.

1.4.3 Description of Material Data.

The core and perturbation materials are described in Section 1.1.3. In addition to the standard plate geometry components some special components were used in the perturbation measurements and these are described in the appropriate sections.

Pin Geometry Materials

In addition to the plate geometry elements measurements were made using pin geometry, or mini-calandria components. Details of these are given in MTN/54 Appendix 1. The mini-calandrias are similar to those used in the ZEBRA Cadenza cores (ZEBRA-LMFR-EXP-001) and are contained in mild steel sheaths. Three mini-calandrias were present in the core section of an element with axial blanket calandrias (containing UO₂ pins) above and below these. The Pu/(U + Pu) enrichment of the core region pins was 0.163.

A detailed description of the layout of a mini-calandria containing a 4x4 array of oxide pins is given in the description of the Cadenza Cores (ZEBRA-LMFR-EXP-001). The mini-calandria were contained in standard Zebra sheaths. Spacer discs were placed at the end of the pellet stack which became the top end of the pin in the calandria. (Encapsulated fuel pins were not used). The mini-calandria length was chosen to be very close to one third of the core height of an inner core element and the overall composition of a sodium filled calandria and the mixed oxide pins was designed to be as close as possible to that of the plates in an inner core cell of MZB. The model used to represent the mini-calandrias should be based on the fuel pin PUPINA in a NACL mini-calandria, as described in ZEBRA-LMFR-EXP-001, (with the Am241 composition modified to be consistent with the earlier date - i.e. set to zero and the Pu241 composition adjusted correspondingly). The same design was used with natural uranium oxide pins in the axial blankets (to be modelled on UO₂PINC). One mini-calandria in the axial blanket was therefore 5.1 cm shorter than four B12-30G cells in a plate axial blanket and a special cell with a composition similar to that of a B12-30G cell was added beyond the calandria in each axial blanket, (Cell B12-50). This cell was not voided in the sodium removal measurements in the axial blankets.

The homogeneous compositions of the mini-calandria with mixed oxide and uranium oxide pins in both mild steel and stainless steel sheaths are given in Table 1.44 together with the homogeneous composition of the C12-38 and B12-30G plate cells in mild steel sheaths. The calculated core compositions apply to a core height of 89.20 cm. The axial blanket composition for the pin system is for a calandria height of 29.73 cm and for the plate system is for a region height of 34.94 cm. The nine elements in the pin voiding experiments were type C12-45 in mild steel sheaths, whereas the surrounding sixteen pin elements were type C12-45S in stainless steel sheaths.

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Comparison of the compositions of the calandria with mixed oxide pins in a mild steel sheath and the corresponding C12-38 plate cell shows:-

- (a) The Pu239 densities agree very closely.
- (b) The higher plutonium isotope contents of the plate cell differ because of the presence of the PUIV4 plate which has only ~10% Pu240 in the plutonium compared with the ~18% Pu240 in the PUIX8 plate and in the mixed oxide pellets.
- (c) The uranium densities in the plate cell are about 3% higher than in the pin cell.
- (d) The oxygen density in the plate cell is lower because of the use of the PUIX8 metal plate whereas the plutonium and uranium are in oxide form in the pin geometry elements.
- (e) The sodium density of the calandria is about 4% less than in the plate cell.
- (f) The steel (plus copper) densities are best compared by total masses of the constituent materials when it is found that the density in the pins plus mini-calandrias plus sheath is 2% less than for the plates plus sheath.

In summary, these comparisons demonstrate acceptable agreement between the two core region compositions.

For the axial blanket compositions:-

- (a) The U235 densities were well matched, and the U238 content of the plate cell was 3% higher;
- (b) The sodium density in the plate cell was about 10% higher than in the pin cell;
- (c) Oxygen was not present in the axial blanket plate cell but was simulated by carbon.
- (d) The total steel content of the plate cell was just over 2% higher than in the pin cell.

The Axial Blanket Cell (B12-50) for Calandria Element Extremes (above the upper axial blanket calandria and below the lower axial blanket calandria) is as follows:

NASTDM4
GIII8
U8
NASTDM4
STSTBR8
GIII8
U8
STSTBR8
NASTDM4
U8
GIII8
NASTDM4

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Data for Pins and Calandria

Average weight of:	column of pellets in a $\text{PuO}_2\text{-UO}_2$ pin (29.69 cm)	171.61g
	column of pellets in a UO_2 pin (see UO2PINC)*	174.80 g
	steel in a PuO_2/UO_2 or UO_2 pin (see PUPINA and UO2PINC).	27.60 g
	steel in an empty calandria (No Na) (see VCLI)*	661.0 g
	steel in a Na filled calandria (see NACLI)*	653.9 g
	sodium in a filled calandria (see NACLI)*	289.8 g

* See ZEBRA-LMFR-EXP-001 for details of the compositions of these components

Weight ratio of Pu/(Pu + U) in the mixed oxide		0.1630
Oxygen to heavy atom ratio in the mixed oxide		2.00
Plutonium composition in May 1972 (fractions by weight) *	Pu239	0.7867
(The fractions sum to 0.9988. The remaining fraction of 0.0012	Pu240	0.1787
could be Am241, this being 4% of the Pu241 content)	Pu241	0.0288
	Pu242	0.0046
Uranium composition in mixed oxide (fractions by weight)	U234	0.00006
	U235	0.00701
	U238	0.99293
Oxygen to heavy atom ratio in the UO_2 pellets		2.00
Uranium composition in UO_2 (fractions by weight)	U234	0.00006
	U235	0.00732
	U238	0.99262

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Table 1.44 Atomic Compositions of Plate versus Pin/Mini-Calandria Cells
(from MTN/54 Appendix 1).

Material	Plate Cell C12-38(MS)	PUO2/UO2 Pin/Calandria (M S Sheath)	PUO2/UO2 Pin/Calandria (S S Sheath)	Plate Cell B12-30G(MS)	UO2 Pin/Calandria (M S Sheath)	UO2 Pin/Calandria (S S Sheath)
Pu239	0.0008945	0.0008939	0.0008939	-	-	-
Pu240	0.0001796	0.0002021	0.0002021	-	-	-
Pu241	0.0000274	0.0000324	0.0000324	-	-	-
Pu242	0.0000041	0.0000052	0.0000052	-	-	-
U235	0.0000431	0.0000416	0.0000416	0.0000528	0.0000528	0.0000528
U238	0.005945	0.005817	0.005817	0.007285	0.007073	0.007073
O	0.01259	0.01400	0.01400	0.000002	0.01425	0.01425
C	0.000081	0.000067	0.000067	0.01083	0.000052	0.000077
Na	0.00908	0.00867	0.00867	0.00963	0.00867	0.00867
Fe	0.01344	0.01345	0.01231	0.01375	0.01345	0.01231
Cr	0.002689	0.002747	0.003611	0.002771	0.002747	0.003611
Ni	0.001394	0.001299	0.001782	0.001340	0.001299	0.001782
Mn	0.000205	0.000243	0.000292	0.000200	0.000243	0.000292
P	-	0.000006	0.000006	-	0.000006	0.000006
S	-	0.000003	0.000003	-	0.000003	0.000003
Si	0.000156	0.000138	0.000190	0.000223	0.000150	0.000202
Al	0.000009	0.000003	0.000022	0.000016	0.000007	0.000026
Ca	0.000001	0.000002	0.000002	0.000001	0.000004	0.000004
Mo	0.000003	-	0.000008	0.000009	-	0.000008
Ti	0.000010	-	0.000016	0.000028	-	0.000016
V	-	-	0.000005	-	-	0.000005
Nb	0.000028	-	-	0.000026	-	-
Cu	0.000229	-	0.000004	0.000007	-	0.000004
H	0.000033	0.000039	0.000026	0.000033	0.000039	0.000026
Ga	0.000046	-	-	-	-	-

Components used in Perturbation Measurements.

In addition to the standard plate components measurements are made using B10 and Tantalum absorber plates. These are shown in Table 1.45. A set of steel plates and "Dummy" plates are used when the measurement is aimed at determining the reactivity worth of the plate core material and these are listed in Tables 1.45 and 1.46. These have been used in deriving the corrections for differences in canning material weights and thicknesses which have already been applied to the measurements presented in the Tables of results.

Table 1.45 Absorber Plates used in the Reactivity Worth Measurements, and associated Dummy Plates.

Identifier	Thickness (cm)	Weight of Absorber (g) *	Weight of Can (g) (Material)
B10 No. 2	1.27	0.681 *	15.77 (Brass)
B10 No. 3	1.70	1.388 *	18.04 (Brass)
B10 No. 4	1.57	2.421 *	12.65 (Brass)
B10 Dummy	1.67		12.47 (Brass)
TA (1)	3.15	134.2	
TA (2)	3.12	132.3	
TA Dummy (1)	3.15		17.0 (Steel)
TA Dummy (2)	3.17		16.9 (Steel)

Note *: The weights of Absorber in the B10 plates are the weights of B10

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Table 1.46 "Dummy" Plates. (Plates used to replace normal plates in reactivity worth measurements.)

Identifier	Thickness (cm)	Weight (g) (Steel)
UO2 Dummy	2.540	61.77
Na Dummy	7.480	210.7
Dummy for PuIV	0.625	35.48/2
Dummy for Pu metal plates	0.325	14.63 + 5.79 (Cu)
Second dummy for Pu metal plates	0.323	14.84 + 5.76 (Cu)
8 steel plates	~2.52	508.0
8 steel frames	~2.52	135.7
Steel shims	0.112	22.0
2 thin steel frames	0.523	26.7
MZA Unit Cell	7.51	
MZA Unit Cell Spacer	7.51	81.13
MZB Unit Cell	8.09	
MZB Unit Cell Spacer	8.09	85.42

1.4.4 Temperature

The temperature was not recorded for individual measurements and no temperature corrections were applied. The temperature during the measurements was up to $\sim 60^{\circ}\text{C}$ in MZA and $\sim 50^{\circ}\text{C}$ in MZB.

1.4.5 Additional Information Relevant to the Reactivity Measurements

None.

1.5 Description of Reactivity Coefficient Measurements

There were no benchmark measurements.

1.6 Description of Kinetics Measurements

There were no benchmark measurements.

1.7 Description of Reaction-Rate Distribution Measurements

1.7.1 Overview of the Reaction rate distribution measurements.

Axial and radial measurements were made in MZA and MZB using both fission chambers (MTN/29, MTN/33, MTN/80, MTN/94) and foils (MTN/24, MTN/75) and included U235 fission, Pu239 fission, U238 fission and U238 capture, and the threshold reactions Ni58 (n,p) and A127 (n, α). The distributions were measured through the sector radial blankets of MZB.

The results of the analyses are given in a number of MTNs (MTN/38, /45, /57, /63, /70, /71, /72, /105). For the analysis of the radial scan measurements in MZB models of the sector radial blanket and the steel and graphite reflector regions were required.

For the studies on shields the shielding stack adjacent to the graphite reflector must be modelled. This is not treated in the present document.

1.7.2A Description of Experimental Configurations.

The cores are described in Section 1.1.2 with the following modifications:

The MZA core loading was reduced from the standard loading of 213 elements to 209 elements in order to enable the reactor to be made critical with all of the rods excepting the Rod 9 to be fully raised, Rod 9 being at about 50 cm (see Figure 1.20).

A symmetrical loading of core elements was used for the reaction rate scan measurements made in the three versions of MZB, having 413 inner core and 260 outer core elements, four elements less than the standard critical loading (see Figure 1.21). The control rods 7 and 8 were fully raised and rod 9 was positioned at about 75 cm in MZB/1, with the depleted uranium oxide sector, and at about 50 cm in MZB/2, with the natural uranium oxide sector.

The control rods are situated away from the line of the reaction rate measurements and it was considered sufficient to represent just the absorber sections of the rods in the models used for calculations, this being required to reproduce the effect on the axial reaction rate scans (also affected by the axial asymmetry of the core cells).

For the analysis of the radial scan measurements in MZB the representation of the sector radial blanket and the steel and graphite reflector regions is required. The outlines of the different regions, the sector blanket, steel reflector and graphite reflector, were the same in all three versions of MZB, except that the natural uranium oxide sector in MZB-1 contained two regions and one less element. It was proposed in MTN-43 that this difference in the number of elements be ignored in calculations. The assembly loading for MZB Version 1 is detailed in Figure 1.10 and the regions are outlined in Figure 1.21.

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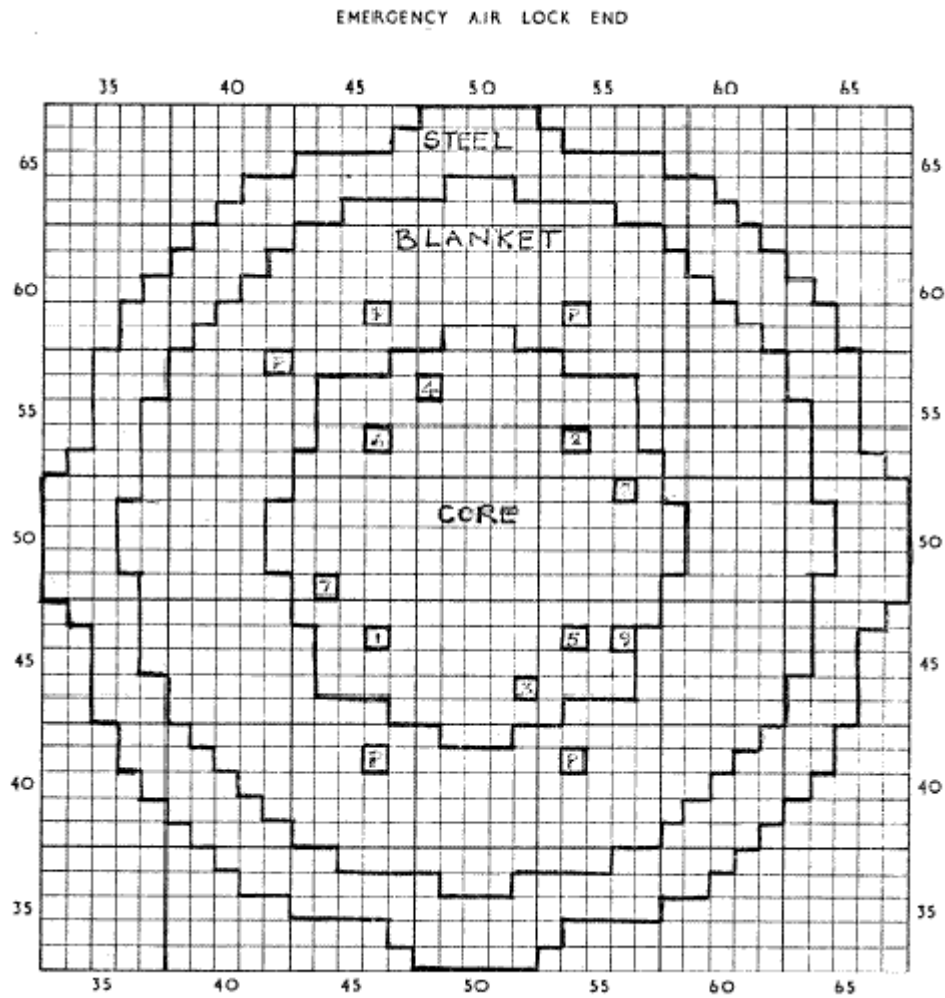


Figure 1.20 The 209 Core Element Loading of MZA used for the Reaction Rate Scan Measurements.

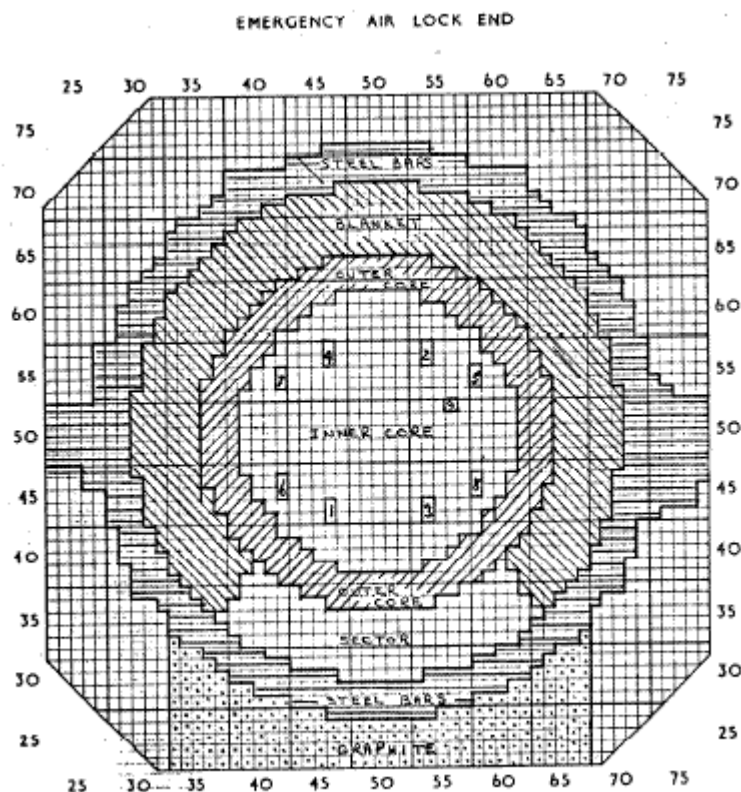


Figure 1.21 The MZB Symmetrical Core Loading used for Reaction Rate Scan Measurements.

(413 inner core elements and 260 outer core elements)

More details of the Blanket Sector and the Graphite Reflector are shown in Figure 1.10. In MZB Version 1 the sector contains the two types of natural uranium oxide blanket element, B12-30 (Central cell B12-31) and an outer ring of elements B12-30A (Central cell B12-31A). The Blanket Sector of MZB Version 2 contains the depleted uranium oxide element B12-32 (Central cell B12-32) (see Table 1.15 for a description of the blanket element loadings).

The graphite reflector sector consists of elements B12-33 in the central section of the sector and B12-31 in the left and right sections of the graphite sector (see Figure 1.10) (see Table 1.16 for a description of the element loadings).

Scans in the Shield Room direction go through the sector blanket, (from bottom to top of the core plan), with the positive distances (measured from the core centre) being in the upper half. That is the elements have X coordinate 50 and are positive for Y coordinates greater than 50. The Flight Tube (or Probe Tube) direction is at right angles to this with the positive distances being on the right hand side, that is they are along the line of elements with Y=50 and are positive for X greater than 50.

1.7.2B Methods

Measurements were made using both fission chambers and foils.

In MZA the fission chamber measurements comprised U235, U238, Pu239, Pu240 and Np237. The foil measurements used uranium foils to measure fission in U235 and U238 and capture in U238. Foils were also used to measure the threshold reactions Al27(n, α) and Ni58(n,p). The detector foils were wrapped in aluminium foil to protect them from contamination.

In MZB fission chambers were used to make measurements for U235, U238, Pu239 and Pu240 and uranium foils to measure fission in U235 and U238 and capture in U238.

In making the calculations to compare with the axial measurements account should be taken of the departure from axial symmetry in the plate geometry cells and the boron shut-down sections of the control rods in the upper axial breeder region. It should be noted that it was found necessary to make cell calculations using energy dependent bucklings recycled from whole reactor calculations to get accuracy in the condensing spectra used to calculate the distributions. The relationship between the foil measurements and the cell averaged values in the breeder regions also required a sophisticated treatment.

1.7.2C Results of the Reaction Rate Distribution Measurements

The positions given for the axial scan measurements are relative to the mid-plane of the element in which measurements were made and the element might be displaced axially relative to its neighbours, in which case a correction is proposed. Positions are given as positive below the mid plane and negative above (the distance being measured from above the core).

Radial scan measurements are described as being in the Shield Room direction or in the Flight Tube (or Probe Tube) direction. Tables 1.80 and 1.81. show the relationship between the measured radial positions and the element coordinates in the Shield Room direction. The Shield Room direction is through the sector blanket, (from bottom to top of the core plans, such as Fig 1.21), with the positive distances (measured from the core centre) being in the upper half of the plans. That is the elements have X coordinate 50 and are positive for Y coordinates greater than 50. The Flight Tube direction is at right angles to this with the positive distances being on the right hand side, that is they are along the line of elements with Y=50 and are positive for X greater than 50.

Foil measurements in MZA

The measurements were made using foils placed horizontally in the mid plane of the plate in the case of the disc shaped foils, and vertically across the thickness of the plate in the case of the rectangular shaped foils used to measure the U235 fission rate in the UO₂ plates in the core. The foils are summarised in Table 1.59. The locations of the plates in which the measurements were made and the orientation of the foils are detailed in MTN-24. Using the plate numbering given in Tables 1.1, 1.2 and 1.4 for the core cells, axial blanket cells and radial blanket cells the positions of the foils are as shown in Table 1.60.

All the foils loaded in plates were wrapped in Al foil 0.02 mm thick to protect them from contamination. In the radial F25, F28 and C28 scans foils were irradiated in a central cell of each element in the core and blanket from position (50,64) to (50,36). The same procedure was followed for the Al and Ni radial scans except that measurements were made in alternate blanket elements only. In the axial scans foils were irradiated in each cell in the core and axial blankets. Because of the number of foils involved the core and blanket scans were made separately with a pair of overlapping foils in each irradiation for normalisation (i.e. 4 common points for each scan direction). In addition, because of the possible influence of the relatively large U235 foils on threshold reactions in the blanket the measurements in the blanket were divided into two, one irradiation being made with only U235 present and one with depleted uranium, aluminium and nickel foils present.

The F28, F25 and C28 reaction rates were measured in the same way as the central reaction rate ratios. The Al27 (n, α) and Ni58 (n,p) reaction rates were measured using a similar gamma counter to that used for F28 and F25, but with the acceptance level set at 0.64 MeV instead of 1.28 MeV.

The means used to locate the foils in the plates were dictated by the need to use large foils to obtain acceptable counting statistics and the need to remove a large number of foils quickly from the reactor. However, from the point of view of calculation it would have been desirable to locate the foils in such a way that they sampled the cell average reaction rate, as in the central reaction rate ratio measurements. A number of spot checks were made on the differences between the variation in cell average reaction rates across the reactor and the variations measured with the large horizontal foils. It was considered that it was most important to check this for C28, although the same foils were counted for fission activity, so providing information for F28. It was assumed that any differences in the variation for F25 would be small and would be calculated sufficiently accurately. The locations of the foils for these measurements are also shown in Table 1 and Figures 2 and 3 of MTN24.

The fission rate scans assume that there are no changes in the gamma-activity per fission across the reactor. Again a number of spot checks were made on the reliability of this assumption. In these measurements half-elements, similar to that used in the central reaction rate fission chamber measurements, were installed at the core centre and at two radial positions (50,43) at the outer edge of the core and (50,40) in the radial blanket. Depleted and enriched uranium foils were simultaneously irradiated in these 3 positions in dummy fission chambers and the activities compared with fission rates measured using a natural and enriched uranium chamber. Because of the large radial gradients in the two off-centre positions it was important to locate the chambers in an accurately reproducible way. The uncertainty in the radial positioning was less than ± 0.25 mm, which corresponds to an error in the foil/chamber comparison of less than $\pm 0.3\%$ in the worst case. To compensate for possible radial variations in fission chamber deposit thicknesses and to eliminate the gradient across the foils both were rotated through 180° halfway through the measurement.

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Table 1.59 Types of Foil used

Reactor region	Reaction Rate	Location Plate Type	Foil Size (mm)	Foil Type
Core	F25	UO2	6.35 x 5.51 x 0.076 thick	93% U235 Metal
	F28, C28	UO2	25.4 dia., 0.076 thick	0.04% U235 Metal
	Al(n,a)	UO2	25.4 dia, 2.54 thick	Al Metal
Axial and Radial Blanket	F25	U metal	25.4 dia., 0.076 thick	93% U235 Metal
	F28, C28	U metal	25.4 dia., 0.076 thick	0.04% U235 Metal
	Al(n,a)	U metal	25.4 dia, 2.54 thick	Al Metal

The plates in which measurements were made are detailed in MTN-25. Measurements were made to relate the reaction rates in the foils to the average values in the plates and hence to the cell average value.

Table 1.60 Locations of Foils.

Reactor region	Reaction Rate	Plate Type	Plate No.
Core	F25	UO2	13
	F28, C28	UO2	9
	Al(n,a)	UO2	2
	Ni(n,p)	UO2	6
Axial Blanket	F25	U metal	15
	F28, C28	U metal	11
	Al(n,a)	U metal	2
	Ni(n,p)	U metal	6
Radial Blanket	F25	U metal	5/3
	F28,C28	U metal	5/2
	Al (n,a)	U metal	15/2
	Ni (n,p)	U metal	15/2

The plate numbering is given in Tables 1.1, 1.2 and 1.4. (5/3 denotes measurements in both plates 5 and 3.) Plate number 15 in the radial blanket is plate number 5 in the cell above the cell on the mid-plane, the numbering being continuous across the mid-plane and there being 10 plates in a radial blanket cell.

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Table 1.61 Typical Uncertainties Associated with the Foil Measurements

Reaction Rate	Position	Percentage Uncertainties						
		Foil Position	Foil Counting	Foil Mass	Other Isotopes	Resonance Shielding	Gammas per Fission	Total
F25	Outer blanket	0.6	0.3	0.1		0.9	3.0	3.3
	Inner blanket	0.4	0.3	0.1		0.5	0.4	0.8
	Outer core	0.3	0.3	0.1		0.1	0.2	0.5
	Core centre		0.3	0.1				0.3
F28	Outer blanket	1.2	3.2	0.1	1.0		3.0	4.7
	Inner blanket	1.2	2.1	0.1	0.3		1.1	2.7
	Outer core	0.4	0.8	0.1			0.6	1.1
	Core centre		1.1	0.1				1.1
C28	Outer blanket	0.6	0.8	0.1				1.0
	Inner blanket	0.4	0.7	0.1				0.8
	Outer core	0.2	0.3	0.1				0.4
	Core centre		0.3	0.1				0.4
Ni(n,p)	Outer blanket	1.3	0.8	0.1				1.6
	Inner blanket	1.8	0.4	0.1				1.9
	Outer core	0.5	0.1	0.1				0.5
	Core centre		0.2	0.1				0.2
Al(n, α)	Outer blanket	0.9	1.2	0.1				1.5
	Inner blanket	1.5	0.5	0.1				1.6
	Outer core	0.5	0.2	0.1				0.5
	Core centre		0.2	0.1				0.2

Scans

The results of the scans are shown in Tables 1.62 to 1.65 and a typical break-down of the uncertainties is shown in Table 1.61. The convention adopted for defining the position of the foils in these tables (and in those for the fission chambers) is to call those distances on the shield-room and top-shield door sides of the core centre minus. The radial positions given in the Tables are those given in the MTN documentation and were calculated using a fuel element pitch within a group of 25 of 5.372 cm (the value given in Section 1.1.2 being 5.3721 cm) and a matrix plate gap of 0.264 cm (the value given in Section 1.1.2 being 0.2665 cm). The axial positions were calculated using the measured data for all the plates except sodium, which was deduced from the measured average core height of 89.97 cm and the measured average axial blanket height of 34.98 cm, (the average sodium plate thickness found in this way being 0.6166 cm, which compares with the database value of 0.616 cm).

The uncertainties in the foil positions were estimates based on the dimensional uncertainties of the reactor components. They essentially comprise two components, firstly the uncertainty in the position of the foil in an element and secondly the uncertainty in the position of the element relative to the physical centre of the core. Both axially and radially the uncertainties are about ± 1 mm. For convenience the positional errors were translated into reaction rate uncertainties using the measured scans.

The F25 and F28 results were corrected for fission in other isotopes. The correction is small for F25 but increases to 20% for F28 at the outer edge of the blanket. The corrections were calculated from the f28/f25 gamma-ratio measured in the central cell in the central reaction rate ratio measurements and the radial variations measured in the scan measurements. The major uncertainty in this correction arises from the uncertainty in the U235 content of the depleted foils, which was assumed to be $\pm 5\%$. No correction has been applied to the C28 values to allow for fission product activity contributing to the coincidence count rate as it is small compared with the overall accuracy of the measurements (i.e. at the core centre, where it is largest, it is about $\pm 0.2\%$).

All the radial scan results were corrected back to the horizontal core centre plane using calculated reaction rates from a 2D SCRAMBLE diffusion theory calculation. The calculation predicted similar axial variations in reaction rates throughout the core and blanket, so that the correction merely reflects the difference between the axial positions of the foils in the core and in the blanket. The corrections used were 1.2% for Al, 0.6% for Ni, 0.2% for F25 and 0.0% for F28 and C28. It was assumed that the uncertainties associated with these corrections are negligibly small compared with the other sources.

The F25 scans were corrected for resonance shielding in the foils. These corrections are needed because the resonance shielding in the enriched uranium foils is greater than in the natural uranium plates and it is the value for the plates which is required for comparison with calculation. The corrections were calculated to be $(1.4 \pm 0.9)\%$ at the outer edge of the radial breeder and $(0.7 \pm 0.5)\%$ at the inner edge of the radial breeder. The corrections were $(1.0 \pm 0.4)\%$ at the outer edge and $(0.3 \pm 0.1)\%$ at the inner edge of the axial breeder.

The method used was to calculate the resonance shielding in the uranium plates and in the uranium foil and to assume that the correction was given by the difference between these values. The resonance shielding in the foils at the extremes of the blanket were calculated using SCRAMBLE fluxes and FD4 cross-section data (i.e. infinite dilution U235 fission data and the corresponding data shielded appropriate to the foil). The ratio of the resonance shielding in the plates to that in the foil was obtained from a MURAL collision probability cell calculation (using fine group plus sub-group nuclear data to represent the resonance structure) by comparing U235 reaction rates in the uranium plates with those obtained using the uranium plate fluxes and cross-section data for the foil. It was then assumed that this ratio remained constant throughout the blanket to obtain the resonance shielding in the plates at the extremes of the blanket. In the radial blanket, for example, the resonance shielding in the foil was calculated to be 2.46% at the outer edge and 1.24% at the inner edge. The MURAL calculation gave 0.84% for the resonance shielding in the plates and 1.87% for the foil, leading to values of 1.11% and 0.56% for the plate at the extremes of the blanket. The corrections were then taken as $(2.46 - 1.11)\% = 1.35\%$ and $(1.24 - 0.56)\% = 0.68\%$. To cover uncertainties arising from the various

approximations made, a 30% uncertainty was assumed for each calculated resonance shielding correction.

It is of interest to note that there is a slight tendency for the radial scans to be asymmetrical, the results being marginally lower on the shield room side of the scan; although this is barely significant within the accuracy of the measurements. Asymmetries could arise due to the concrete shield being further away from the assembly on the shield-room side or they could arise due to Control Rod FR9 not being fully raised.

Axially there are significant asymmetries in several of the scans. In particular for F25 and C28 the reaction rates are about 3% higher at the bottom of the core than at the top and this difference approaches 10% at the extremes of the blanket. The asymmetries obtained are consistent with the scans being influenced by the control rods with their upper absorber sections.

Radial Variation in Gammas per Fission

F25 and F28 measurements were made to investigate whether there were significant variations in the gamma activity per fission across the reactor, the variation in the $P(t)$ value. The results were corrected for resonance shielding in the U235 foils, $(0.13 \pm 0.04)\%$ at (50,50), $(0.23 \pm 0.07)\%$ at (50,43) and $(1.24 \pm 0.37)\%$ at (50,40), and also corrected for fission in other isotopes. The results are given in MTN/24. To within the accuracy of the measurements, up to 0.4% for F25 and up to 1.1% for F28, there was no significant variation in the gammas per fission as F28/F25 varied from 0.0335 at the core centre to 0.0076 in the inner blanket. This differs from the results found for the versions of Zebra Core 8 with a relatively large proportion of low energy neutrons, i.e. Cores 8A and 8F, which had spectra similar to the blanket of MZA, and where the $P(t)$ values obtained for F28/F25 were about 5% to 7% larger than those observed in the present core (or in the other versions of Core 8). In view of this apparent anomaly, where no measurements of the consistency of the gammas per fission for F25 and F28 had been made, i.e. in the outer blanket, the uncertainties have been increased to $\pm 3\%$.

Cell Average Scans

The C28 results obtained with foils sampling the average reaction rates through the uranium plates in a cell relative to those obtained with the large horizontal foils are shown in MTN/24 Tables 9 and 10 (and the MURAL calculations are given in Table 13 of MTN/24). Radially the results shown are a direct comparison of the cell average foil results and the foil scan results; axially the foil scan results are compared with foil scan results which have been interpolated and averaged over the uranium in the cell.

As might be expected, because of the different fine structure in the core and blanket uranium there are significant differences in the cell average scans and the scans with horizontal foils, i.e. the measurements described in MTN/24 show that the C28 results obtained using horizontal foils in the radial blanket should be increased by $(7.0 \pm 1.3)\%$ for comparison with calculations made using cell averaged cross-sections and those in the axial blanket should be increased by $(4.9 \pm 1.3)\%$. These values are in agreement with those obtained from MURAL cell calculations for the core and blanket cells, i.e. 7.9% for the radial blanket and 6.1% for axial blanket.

It is also of interest to note that the measurements indicate that there is a change in fine structure in the outer regions of the core, i.e. the C28 values in this region (given in MTN/24 in Tables 2 and 4) should be reduced by $(2.1 \pm 0.5)\%$.

No measurements were made of the radial fine structure variation in C28 across plates in the blanket. The differences between the core and blanket should be small and it is considered adequate to increase the uncertainty on the blanket results by $\pm 0.7\%$ since within this standard deviation the correction has been found to be essentially the same in previous Zebra cores. Thus the overall correction factors for C28 become $(7.0 \pm 1.5)\%$ and $(4.9 \pm 1.5)\%$ respectively for the radial and axial blanket regions, to obtain the values to be compared with calculations made using cell averaged nuclear data.

The foils used for the C28 measurements were also counted for F28. However, the activity of these foils was low and the statistical accuracy obtained poor. In addition, difficulties with the foil counting equipment resulted in only one set of measurements in the axial and radial directions. (The correction factors obtained after correction for fission in U235 are given in MTN/24 Tables 11 and 12.) Because of the problems encountered in the measurements it was difficult to draw any firm conclusions from these tables. The results suggest that, within the accuracy of the measurements, i.e. about $\pm 3\%$ in the inner blanket and about $\pm 14\%$ in the outer blanket, there is no correction. However, surprisingly, one set of results indicates a 6% correction at the edge of the core. MURAL calculations of these corrections suggest that they are small, 1.1% for the radial blanket and 0.4% for the axial blanket. However, it must be remembered that a MURAL cell calculation ignores the contribution the core makes to F28 in the blanket and so might not be sufficiently accurate close to the core.

In the light of the evidence available it was recommended that no correction should be applied to the F28 results to relate them to cell average values, but that the uncertainty in the results in the outer region of the core and in the axial and radial blankets should be increased by $\pm 3\%$.

In the case of the F25 results it was considered reasonable to apply no correction but to increase the uncertainty in outer region of the core and in the axial and radial blankets by $\pm 0.5\%$.

In summary, the accuracies of the foil measurements in MZA

- for F25 they ranged from 0.3% at the core centre to 3% at the outer edge of the blanket,
- for F28 they ranged from 1% to 5%
- for C28 from 0.4% to 1% (0.4% to 2% when corrected to a cell average C28 scan)
- for Ni(n,p) they ranged from 0.2% to 2%
- and for Al(n, α) they ranged from 0.2% to 2%

There were significant asymmetries in the axial scans, differences of about 3% for F25 and C28 at the outer edges of the core and about 10% at the outer edges of the blanket, indicating the need to model axial variations in the assembly in the calculations made to compare with these scans.

The scans are presented in Tables 1.62 to 1.65.

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Table 1.62 Radial Scans using Uranium Foils in MZA

Distance from Core Centre (mm)	F28		F25		C28	
	Fission Rate Relative to Centre	s.d. (%)	Fission Rate Relative to Centre	s.d. (%)	Capture Rate Relative to Centre	s.d. (%)
- 760.0	0.0101	4.7	0.1564	3.3	0.1000	1.0
- 706.3	0.0176	4.2	0.1996	3.3	0.1404	0.9
- 649.9	0.0280	4.0	0.2578	3.3	0.1913	0.9
- 596.2	0.0474	4.0	0.3312	3.3	0.2537	0.8
- 542.5	0.0844	2.7	0.4081	0.8	0.3327	0.8
- 488.8	0.1675	2.0	0.4771	0.7	0.4007	0.7
- 435.0	0.3724	1.4	0.5247	0.5	0.5206	0.6
- 378.7	0.5139	1.2	0.5951	0.5	0.6013	0.4
- 325.0	0.6387	1.0	0.6780	0.5	0.6820	0.4
- 271.2	0.7434	0.8	0.7662	0.4	0.7538	0.4
- 217.5	0.8308	0.8	0.8432	0.4	0.8416	0.4
- 163.8	0.9106	0.8	0.9046	0.3	0.9153	0.4
- 107.4	0.9555	1.2	0.9589	0.3	0.9575	0.4
-53.72	0.9895	1.1	0.9930	0.3	0.9780	0.4
0.00	1.0000	1.1	1.0000	0.3	1.0000	0.4
53.72	1.0043	1.1	0.9931	0.3	1.0014	0.4
107.4	0.9581	0.9	0.9613	0.3	0.9643	0.4
163.8	0.9118	0.8	0.9110	0.3	0.9011	0.4
217.5	0.8425	0.8	0.8482	0.3	0.8478	0.4
271.2	0.7454	0.8	0.7660	0.4	0.7790	0.4
325.0	0.6434	0.8	0.6808	0.4	0.6887	0.4
378.7	0.5161	1.1	0.5982	0.5	0.5939	0.4
435.0	0.3741	1.3	0.5284	0.5	0.5292	0.6
488.8	0.1687	2.0	0.4782	0.7	0.4117	0.7
542.5	0.0863	2.7	0.4089	0.8	0.3358	0.8
596.2	0.0475	4.0	0.3338	3.3	0.2618	0.8
649.9	0.0290	4.0	0.2570	3.3	0.1970	0.9
706.3	0.0175	4.2	0.2031	3.3	0.1417	0.9
760.0	0.0105	4.7	0.1608	3.3	1.1037	1.0

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Table 1.63 Radial Scans using Nickel and Aluminium Foils in MZA

Distance From Core Centre (mm)	Ni58 (n,p)		A127 (n, α)	
	Capture Rate Relative to Centre	s.d. (%)	Capture Rate Relative to Centre	s.d. (%)
- 760.0	0.0105	1.6	-	-
- 706.3	-		0.0262	1.3
- 649.9	0.0271	1.2	-	-
- 596.2	-	-	0.0572	1.2
- 542.5	0.0792	1.9	-	-
- 488.8	-	-	0.1699	1.4
- 435.0	0.3692	0.8	0.3769	0.9
- 378.7	0.5077	0.5	0.5168	0.5
- 325.0	0.6308	0.4	0.6382	0.4
- 271.2	0.7395	0.3	0.7426	0.3
- 217.5	0.8268	0.2	0.8278	0.3
- 163.8	0.8910	0.2	0.9005	0.2
- 107.4	0.9492	0.2	0.9502	0.2
- 53.72	0.9893	0.2	0.9883	0.2
0.00	1.0000	0.2	1.0000	0.2
53.72	0.9849	0.2	0.9966	0.2
107.4	0.9547	0.2	0.9529	0.2
163.8	0.9046	0.2	0.9077	0.2
217.5	0.8338	0.2	0.8315	0.3
271.2	0.7391	0.3	0.7445	0.3
325.0	0.6452	0.4	0.6385	0.4
378.7	0.5144	0.5	0.5183	0.5
435.0	0.3718	0.9	0.3803	0.7
488.8	0.1609	1.5	-	-
542.5	-	-	0.0947	1.6
596.2	0.0453	1.4	-	-
649.9	-	-	0.0387	1.2
706.3	0.0171	1.5	-	-
760.0	-	-	0.0186	1.5

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Table 1.64 Axial Scans using Uranium Foils in MZA

F28			C28		F25		
Distance from Core Centre (mm)	Fission Rate Relative to Centre	s.d. (%)	Capture Rate Relative to Centre	s.d. (%)	Distance from Core Centre (mm)	Fission Rate Relative to Centre	s.d. (%)
-757.5	0.0142	4.2	0.1468	1.0	-776.2	0.1539	3.2
-670.0	0.0327	4.0	0.2280	0.9	-688.7	0.2365	3.2
-582.6	0.0715	3.9	0.3418	0.9	-601.3	0.3425	3.2
-495.2	0.1776	1.7	0.4657	0.6	-513.8	0.4639	0.7
-421.7	0.4378	1.0	0.5636	0.6	-440.5	0.5360	0.5
-346.7	0.6216	0.8	0.6722	0.4	-365.6	0.6333	0.4
-271.7	0.7710	0.7	0.7764	0.4	-290.6	0.7467	0.4
-196.7	0.8809	0.5	0.8700	0.4	-215.6	0.8481	0.2
-121.8	0.9549	0.4	0.9555	0.4	-140.6	0.9318	0.3
-46.79	0.9962	0.5	0.9804	0.4	-65.67	0.9816	0.2
28.19	1.0001	0.5	1.000	0.4	9.31	1.000	0.2
103.2	0.9724	0.4	0.9669	0.4	84.28	0.9803	0.2
178.1	0.9099	0.6	0.9099	0.4	159.3	0.9232	0.3
253.1	0.8084	0.6	0.8206	0.4	234.2	0.8410	0.2
328.1	0.6728	0.7	0.7049	0.4	309.2	0.7326	0.4
403.1	0.4979	0.9	0.5907	0.6	384.2	0.6175	0.4
492.0	0.1910	1.6	0.4778	0.5	473.3	0.5172	0.6
579.4	0.0755	4.0	0.3591	0.9	560.7	0.4110	3.2
666.9	0.0350	4.2	0.2540	0.9	648.2	0.2994	3.2
754.3	0.0163	4.1	0.1641	1.0	735.6	0.2061	3.2

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Table 1.65 Axial Scans using Nickel and Aluminium Foils in MZA

Ni58 (n,p)			Al27 (n, α)		
Distance from Core Centre (mm)	Capture Rate Relative to Centre	s.d. (%)	Distance from Core Centre (mm)	Capture Rate Relative to Centre	s.d. (%)
-735.6	0.0162	1.5	-719.9	0.0269	1.4
-648.2	0.0352	1.1	-632.5	0.0513	1.0
-560.7	0.0810	1.2	-545.0	0.1047	1.3
-473.3	0.2182	1.1	-457.6	0.2809	0.9
-403.1	0.4881	0.6	-384.2	0.5466	0.5
-328.1	0.6673	0.3	-309.2	0.7047	0.3
-253.1	0.8000	0.2	-234.2	0.8257	0.2
-178.1	0.8984	0.2	-159.3	0.9208	0.2
-103.2	0.9712	0.2	-84.28	0.9756	0.2
-28.18	1.0000	0.2	-9.30	1.0000	0.2
46.80	1.0096	0.2	65.67	0.9893	0.2
121.8	0.9624	0.2	140.6	0.9442	0.2
196.8	0.8992	0.2	215.6	0.8618	0.2
271.7	0.7874	0.2	290.6	0.7453	0.3
346.7	0.6479	0.3	365.6	0.5961	0.4
421.7	0.4514	0.6	440.6	0.3755	0.7
513.8	0.1379	1.4	529.5	0.1216	1.4
601.3	0.0554	1.1	617.0	0.0584	1.0
688.7	0.0251	1.0	704.4	0.0315	1.1
776.2	0.0118	1.5	791.9	0.0180	1.3

Fission Chamber Measurements in MZA.

The fission chambers were standard 20th Century Type FC 11 and had a cylindrical body with a hemispherical end 0.85 cm in diameter with a total length of 4.7 cm. The fissile material was deposited on the inside surface of the body including the hemispherical end and had a total length of 4.1 cm. Details of the coatings are given in Table 1.66 and details of the constructional materials in Table 1.67. The gas filling was Argon + 2% Nitrogen at 3.5 Atm. pressure.

Table 1.66 Chamber Coating Details

Principal Isotope	Nominal Mass	Isotopic Analysis - Atoms %						
		U235	U238	Pu239	Pu240	Pu241	Pu242	Np237
U235	2 mg	93.0	7.0					
Pu239	1 mg			99.3	0.7			
U238	10 mg	0.036	99.964					
Pu240	2 mg			0.258	99.280	0.300	0.162	
Np237	10 mg			0.0003				100

Table 1.67 Dimensions of Additional Components

Component	Material	O.D (mm)	I.D (mm)	Wall Thickness (mm)	Length (mm)
Chamber Body	St. Steel	9.5	8.5	0.5	47
Chamber Central Electrode	St. Steel	5.2	4.24	0.48	40
F/C Extension	Brass	9.6	8.8	0.4	1905
Conductor Wire	Copper	0.9	-		
Guide Tube (all scans)	St. Steel	10.9	10.4	0.25	-
Lead Liner (axial scans)		23.6	11.6	12.0	-

Scanner Mechanism

The fission chamber was connected to a brass extension tube 1.9 m in length with a wire along its centre (spaced by PTFB insulators 0.8 cm long and at 15 cm intervals) acting as a signal lead, see Table 1.67 for details.

A short section (46 cm long) similar in construction was also attached in front of the fission chamber as a nose-piece. Measurements with and without this nose-piece showed that it had no influence on the U235 and U238 scans and indicated that neutron streaming effects were negligible, confirming calculations of the effect.

The brass extension was connected to a mechanical scanner by a rigid aluminium tube carrying a standard coaxial signal cable along its centre. This tube was clamped into a carriage which could be moved along a programme bar having 25 machined slots at 4 cm intervals by signals from push buttons on a control unit situated in the Control Room. A second set of slots, also at 4 cm intervals but displaced by 2 cm, could be used by turning the programme bar through 180° so that measurements could be made every 2 cm.

For the scans 2 cm intervals were used in the core region and 4 cm in the two blanket regions, except in the case of Pu240 where the spacing was 4 cm throughout core and blanket.

The total carriage travel was 98 cm and to extend the scan through both blanket regions (a total of 1.6 m) it was necessary to move the tube in the carriage and reclamp. The first two scans (in the flight tube direction) were made in two halves with a small overlap region in the centre. However in order to avoid introducing additional positional uncertainties in the data used for buckling analysis and to minimise the uncertainty associated with matching each section of the scan, all subsequent scans were made in three sections, one through the entire core region and the others through each blanket section with a small overlap region to facilitate matching.

Element Modifications for the Fission Chamber Scan Measurements.

For the radial scans the two central sodium coupons in each element along the scan line in the core region were replaced with special aluminium bridge pieces having a 1.27 cm hole to allow a stainless steel guide tube (details in Table 1.67) to be inserted. In the blanket region the graphite coupon at the cell boundary was moved above the adjacent sodium coupon to bring the two sodium coupons to the centre line before replacing with the aluminium bridge pieces (see MTN/29 Figs 13 and 14).

The axial scans were made in a central element which was similar to the normal C11 - 1A element except for a central hole, 2.36 cm in diameter. This contained a lead liner with a central 1.16 cm diameter hole to allow insertion of the stainless steel guide tube as used in the radial scans, see Table 1.67. One further difference from the normal C11 - 1A cell pattern was the use of Mk II Pu instead of Mk V.

Measurements with and without the lead liner at points near the core centre and at points near the core/blanket boundary showed no significant effect on the relative reaction rates for U238 and U235. Removal of the lead however increased the U238/U235 fission ratio by $(3.3 \pm 1.5)\%$. The influence of the lead was also checked by calculations which predicted a consistent change of 4% in the U238/U235 fission ratio over the whole length of the scan.

Analysis of Results

The on-line analysis of the results checked the consistency of the monitors and then evaluated the dead-time corrected values normalised to the monitors. The remaining analysis of the results comprised correcting for fission in the other isotopes present, establishing the centre of symmetry and estimating the associated uncertainties.

All the scans were corrected for fission in other isotopes using the appropriate fission chamber scan and values of the central fission ratios measured by parallel plate chambers at the core centre. To cover the differences in environment between the two sets of fission chamber measurements a $\pm 1\%$ uncertainty was assumed in the core centre fission ratio. Apart from U238 and Pu240 the correction for fission in other isotopes was barely significant. For U238 it varied from 1.5% at the core centre to 20% at the outer edge of the blanket, while for Pu240 the corresponding variation was 2.5% to 18%. Since no U235 scan was available in the radial flight tube direction the U238 scan in this case was corrected using the U235 scan in the shield room direction.

Although the relative positions of points in a scan, dictated by the accurately machined programme bar in the scanner, are known to ± 0.25 mm, because of the uncertainty in the position of the effective centre of the chamber and the problems associated with establishing the position of the scanner mechanism relative to the core centre, it was difficult to define the absolute position of a point in the scan to better than ± 3 mm. In view of this the procedure adopted to establish the centre of the core was the same as that in Zebra Cores 9 and 10. Each scan was fitted to a symmetrical even order, degree 4 polynomial over a number of ranges from ± 200 mm to ± 500 mm (relative to the estimated core centre) and the best fit, assessed in terms of the minimum chi-squared, obtained by moving the core centre. Examination of these results indicated that the centre of symmetry, and consequently the core centre, could be established in this way to within ± 1.0 mm. In general, the centres so found agreed well with those determined by physical measurement except in the case

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of the axial scans. By comparison with the U233 and U235 foil scans it was found that the centres of these scans were displaced by approximately 6 mm from that found in the fitting procedure and all axial scans have had their centres lowered by this amount, with an additional uncertainty of 1 mm.

A typical breakdown of the uncertainties associated with the fission chamber scans is shown in Table 1.68.

The Tables 1.69 to 1.72 give the U235 and U238 chamber fission rate scans compared with the foil measurements. More comprehensive measurements are given in MTN/29 together with radial scans in the Flight Tube direction. (Corrections were subsequently made to the U238 scan measurement results given in MTN/29 and the revised values are given in MTN/94.) The Pu239, Pu240 and Np237 fission chamber scans are given in Tables 1.73 to 1.77. In MTN/29 an additional radial scan measurement is also given for Pu239 in the Flight Tube direction.

Table 1.68 Summary of Uncertainties in the MZA Fission Chamber Measurements

Isotope	Position	% Uncertainty				
		Counting s.d. (1)	Dead - Time (2)	Other Isotopes (3)	Position (4)	Total
Pu239	Outer Blanket	0.5	0.2		0.4	0.7
	Core/Blanket Boundary	0.3	0.1		0.1	0.4
	Core Centre	0.2				0.2
U235	Outer Blanket	0.3	0.7		0.5	0.9
	Core/Blanket Boundary	0.2	0.4		0.1	0.5
	Core Centre	0.2				0.2
U238	Outer Blanket	2.2	0.1	1.4	1.9	3.2
	Core/Blanket Boundary	0.4	0.1	0.1	1.4	1.5
	Core Centre	0.3				0.3
Pu240	Outer Blanket	1.9	0.1	0.9	1.4	2.6
	Core/Blanket Boundary	0.5	0.1	0.1	1.0	1.1
	Core Centre	0.3				0.3
Np237	Outer Blanket	1.0	0.7		1.2	1.7
	Core/Blanket Boundary	0.3	0.4		1.2	1.3
	Core Centre	0.2				0.2

1 Counting uncertainties comprise the statistical accuracy of counting and the stability of counting channels (this was found to be about + 0.2%)

2 The dead-time was measured by counting at different power levels for all chambers and was found to be 1.8 μ secs for the Pu239 chamber, 0.5 μ secs for the Np237 chamber and 1.3 μ secs for the other three. An uncertainty of 0.5 μ secs was assumed for each. The maximum corrections were approximately 1.8% for U235, 0.8% for Np237 and Pu239 and 0.25% for U238 and Pu240.

Since the results are expressed relative to the core centre the uncertainties associated with these corrections are systematic to all the measurements in the core and so in common with other systematic uncertainties (i.e. position of core centre and the correction for other isotopes) it has been assumed that these uncertainties apply to the blanket when expressed relative to the core centre.

3 The uncertainty in the correction for other isotopes arises from the $\pm 4\%$ uncertainty in the central fission ratio and from the uncertainty in the isotopic analysis which was assumed to be $\pm 3\%$ for the ratio of the number of U235 atoms/number U238 atoms (N5/N8) in the U238 chamber and $\pm 1\%$ for the ratio of the number of Pu240 atoms/number of Pu239 atoms and the ratio of the number of Pu240 atoms/number of Pu241 atoms (N0/N9 and N0/N1) in the Pu240 chamber.

4 The positional uncertainty is made up of three components:-

- The points relative to each other (0.25 mm)
- The error due to changing the extension (0.5 mm) which applies in the two blanket regions and
- The uncertainty in the position of the core centre (1.0 mm for the radial scans and an additional 1.0 mm for the Axial scans).

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Table 1.69 Comparison of Radial U238 Foil and Fission Chamber Scans in MZA
(Revised values from MTN/94)

Dist (mm)	Foil	s.d. (%) on Foil	Chamber	s.d. (%) on Chamber	Chamber/ Foil	s.d. (%)
-760.0	0.0101	4.7	0.0104	3.2	1.030	5.6
-706.3	0.0176	4.2	0.0172	2.4	0.977	4.8
-649.9	0.0280	4.0	0.0297	2.0	1.061	4.5
-596.2	0.0474	4.0	0.0514	2.0	1.084	4.5
-542.5	0.0844	2.7	0.0934	2.0	1.107	3.4
-488.8	0.1675	2.0	0.1895	1.8	1.131	2.7
-435.0	0.3724	1.4	0.3667	0.9	0.985	1.7
-378.7	0.5139	1.2	0.5053	0.6	0.983	1.3
-325.0	0.6387	1.0	0.6315	0.5	0.989	1.1
-271.2	0.7434	0.8	0.7400	0.4	0.995	0.9
-217.5	0.8308	0.8	0.8290	0.4	0.998	0.9
-163.8	0.9106	0.8	0.9014	0.3	0.990	0.8
-107.4	0.9555	1.2	0.9618	0.3	1.007	1.2
- 53.72	0.9895	1.1	0.9925	0.3	1.003	1.1
0	1.0000	1.1	1.0000	0.3	1.000	1.1
53.72	1.0043	1.1	0.9909	0.3	0.987	1.1
107.4	0.9581	0.9	0.9566	0.3	0.998	0.9
163.8	0.9118	0.8	0.8973	0.3	0.984	0.8
217.5	0.8425	0.8	0.8274	0.4	0.982	0.9
271.2	0.7454	0.8	0.7403	0.4	0.993	0.9
325.0	0.6434	0.8	0.6286	0.5	0.977	0.9
378.7	0.5161	1.1	0.5059	0.6	0.980	1.2
435.0	0.3741	1.3	0.3586	1.1	0.959	1.7
488.8	0.1687	2.0	0.1841	1.8	1.091	2.7
542.5	0.0863	2.7	0.0927	2.0	1.074	3.4
596.2	0.0475	4.0	0.0489	1.9	1.029	4.4
649.9	0.0290	4.0	0.0292	2.0	1.007	4.5
706.3	0.0175	4.2	0.0175	2.4	1.000	4.8
760.0	0.0105	4.7	0.0103	3.3	0.981	5.7

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Table 1.70 Comparison of Axial U238 Foil and Fission Chamber Scans in MZA

Dist (mm)	Foil	s.d. (%) on Foil	Chamber	s.d. (%) on Chamber	Chamber/ Foil	s.d. (%)
-757.5	0.0142	4.2	0.0151	2.8	1.063	5.0
-670.0	0.0327	4.0	0.0335	2.0	1.024	4.5
-582.6	0.0715	3.9	0.0768	2.0	1.074	4.4
-495.2	0.1776	1.7	0.1924	1.7	1.083	2.4
-421.7	0.4378	1.0	0.4223	1.1	0.965	1.5
-346.7	0.6216	0.8	0.6183	0.6	0.995	1.0
-271.7	0.7710	0.7	0.7593	0.4	0.985	0.8
-196.7	0.8809	0.5	0.8714	0.4	0.989	0.6
-121.8	0.9549	0.4	0.9546	0.3	1.000	0.5
- 46.8	0.9962	0.5	0.9976	0.3	1.001	0.6
28.2	1.0001	0.5	1.0000	0.3	1.000	0.6
103.2	0.9724	0.4	0.9695	0.3	0.997	0.5
178.1	0.9099	0.6	0.9120	0.4	1.002	0.7
253.1	0.8084	0.6	0.8093	0.4	1.001	0.7
328.1	0.6728	0.7	0.6752	0.6	1.004	0.9
403.1	0.4979	0.9	0.5015	0.9	1.007	1.3
492.0	0.1910	1.6	0.2053	2.0	1.075	2.6
579.4	0.0755	4.0	0.0812	2.0	1.075	4.5
666.9	0.0350	4.2	0.0362	2.1	1.035	4.7
754.3	0.0163	4.1	0.0167	2.8	1.024	4.9

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Table 1.71 Comparison of Radial U235 Foil and Fission Chamber Scans in MZA

Position (mm)	Foil	s.d. (%) on Foil	Chamber	s.d. (%) on Chamber	Chamber/Foil	s.d. (%)
-760.0	0.1564	3.3	0.1864	0.8	1.192	3.4
-706.3	0.1996	3.3	0.2295	0.8	1.150	3.4
-649.9	0.2578	3.3	0.2922	0.8	1.133	3.4
-596.2	0.3312	3.3	0.3676	0.8	1.110	3.4
-542.5	0.4081	0.8	0.4432	0.6	1.086	1.0
-488.8	0.4771	0.7	0.5024	0.5	1.053	0.9
-435.0	0.5247	0.5	0.5348	0.4	1.019	0.6
-378.7	0.5951	0.5	0.6013	0.4	1.010	0.6
-325.0	0.6780	0.5	0.6813	0.4	1.005	0.6
-271.2	0.7662	0.4	0.7660	0.3	1.000	0.5
-217.5	0.8432	0.4	0.8454	0.3	1.003	0.5
-163.8	0.9046	0.3	0.9115	0.2	1.008	0.4
-107.4	0.9589	0.3	0.9619	0.2	1.003	0.4
- 53.72	0.9930	0.3	0.9953	0.2	1.002	0.4
0	1.0000	0.3	1.0000	0.2	1.000	0.4
53.72	0.9931	0.3	0.9922	0.2	0.999	0.4
107.4	0.9613	0.3	0.9633	0.2	1.002	0.4
163.8	0.9110	0.3	0.9110	0.2	1.000	0.4
217.5	0.8482	0.3	0.8476	0.3	0.999	0.4
271.2	0.7660	0.4	0.7660	0.3	1.000	0.5
325.0	0.6808	0.4	0.6820	0.4	1.002	0.6
378.7	0.5982	0.5	0.5995	0.4	1.002	0.6
435.0	0.5284	0.5	0.5366	0.4	1.016	0.6
488.8	0.4782	0.7	0.5039	0.5	1.054	0.9
542.5	0.4089	0.8	0.4425	0.6	1.082	1.0
596.2	0.3338	3.3	0.3675	0.7	1.101	3.4
649.9	0.2570	3.3	0.2946	0.8	1.146	3.4
706.3	0.2031	3.3	0.2337	0.8	1.151	3.4
760.0	0.1608	3.3	0.1891	0.8	1.176	5.4

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Table 1.72 Comparison of Axial U235 Foil and Fission Chamber Scans in MZA

Position (mm)	Foil	s.d. (%) on Foil	Chamber	s.d. (%) on Chamber	Chamber/Foil	s.d. (%)
-776.2	0.1539	3.2	0.1716	1.0	1.115	3.4
-688.7	0.2365	3.2	0.2531	0.9	1.070	3.3
-601.3	0.3425	3.2	0.3621	0.8	1.057	3.3
-513.8	0.4639	0.7	0.4806	0.6	1.036	0.9
-440.5	0.5360	0.5	0.5480	0.5	1.022	0.7
-365.6	0.6333	0.4	0.6386	0.5	1.008	0.6
-290.6	0.7467	0.4	0.7512	0.4	1.006	0.5
-215.6	0.8481	0.2	0.8550	0.3	1.008	0.4
-140.6	0.9318	0.3	0.9345	0.3	1.003	0.4
-65.67	0.9816	0.2	0.9889	0.2	1.007	0.3
9.31	1.000	0.2	1.0047	0.2	1.005	0.3
84.28	0.9803	0.2	0.9877	0.2	1.008	0.3
159.3	0.9232	0.3	0.9314	0.2	1.009	0.4
234.2	0.8410	0.2	0.8489	0.3	1.009	0.4
309.2	0.7326	0.4	0.7413	0.4	1.011	0.6
384.2	0.6175	0.4	0.6311	0.5	1.022	0.6
473.3	0.5172	0.6	0.5354	0.5	1.035	0.6
560.7	0.4110	3.2	0.4356	0.7	1.060	3.3
648.2	0.2994	3.2	0.3234	0.8	1.080	3.3
735.6	0.2061	3.2	0.2282	0.9	1.107	3.3

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Table 1.73 Pu239 Radial Fission Chamber Scan in MZA (Shield Room Direction).

Position (mm)	Normalised Count rate	s.d. (%)		Position (mm)	Normalised Count rate	s.d. (%)
-791.148	0.17581	0.71		769.852	0.19028	0.71
-751.148	0.19626	0.69		729.852	0.21389	0.67
-711.148	0.22322	0.69		689.852	0.24229	0.67
-671.148	0.25706	0.71		649.852	0.27881	0.68
-631.148	0.30226	0.68		609.852	0.32463	0.66
-591.148	0.34949	0.62		569.852	0.37597	0.59
-551.148	0.39867	0.56		529.852	0.42234	0.52
-511.148	0.44443	0.50		489.852	0.46476	0.46
-486.848	0.47002	0.39		473.152	0.47868	0.37
-471.148	0.47795	0.38		449.852	0.48972	0.38
-446.848	0.48882	0.37		433.152	0.50066	0.39
-426.848	0.51304	0.40		413.152	0.52621	0.40
-406.848	0.53357	0.41		393.152	0.55367	0.45
-386.848	0.56476	0.46		373.152	0.58602	0.46
-366.848	0.60030	0.44		353.152	0.62199	0.46
-346.848	0.63107	0.43		333.152	0.65964	0.41
-326.848	0.66638	0.42		313.152	0.68626	0.40
-306.848	0.70038	0.40		293.152	0.72357	0.39
-286.848	0.73438	0.41		273.152	0.75328	0.36
-266.848	0.76743	0.35		253.152	0.78927	0.36
-246.848	0.79462	0.33		233.152	0.82107	0.36
-226.848	0.82579	0.34		213.152	0.84730	0.31
-206.848	0.85682	0.31		193.152	0.87066	0.30
-186.848	0.88194	0.29		173.152	0.89923	0.30
-166.848	0.89627	0.29		153.152	0.91908	0.28
-146.848	0.92331	0.29		133.152	0.93538	0.28
-126.848	0.94324	0.28		113.152	0.95535	0.26
-106.848	0.96455	0.26		93.152	0.97048	0.26
-86.848	0.97792	0.26		73.152	0.98097	0.25
-66.848	0.98540	0.25		53.152	0.98630	0.26
-46.848	0.99474	0.24		33.152	0.99962	0.24
-26.848	1.00135	0.24		13.152	0.99932	0.24
-6.848	1.00497	0.24				

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Table 1.74 Pu239 Axial Fission Chamber Scan in MZA

Position (mm)	Normalised Count rate	s.d. (%)		Position (mm)	Normalised Count rate	s.d. (%)
-812.187	0.14315	0.81		750.113	0.20437	0.75
-772.187	0.16363	0.78		710.113	0.23601	0.70
-732.187	0.19267	0.81		670.113	0.27226	0.68
-692.187	0.23172	0.77		630.113	0.31450	0.67
-652.187	0.27255	0.70		590.113	0.36697	0.61
-612.187	0.31610	0.69		550.113	0.41495	0.52
-572.187	0.37280	0.62		528.913	0.43586	0.49
-532.187	0.42099	0.55		508.913	0.46294	0.48
-492.187	0.47356	0.49		488.913	0.48520	0.40
-451.087	0.51511	0.43		468.913	0.50535	0.39
-431.087	0.53741	0.42		448.913	0.52531	0.39
-411.087	0.56355	0.42		428.913	0.54509	0.42
-391.087	0.59071	0.42		408.913	0.57638	0.43
-371.087	0.62122	0.41		388.913	0.60865	0.43
-351.087	0.64920	0.42		368.913	0.63844	0.43
-331.087	0.69029	0.42		348.913	0.67728	0.40
-311.087	0.72245	0.38		328.913	0.70385	0.39
-291.087	0.75259	0.36		308.913	0.73935	0.37
-271.087	0.76350	0.33		288.913	0.76836	0.36
-251.087	0.81125	0.32		268.913	0.79832	0.33
-231.087	0.83795	0.31		248.913	0.82626	0.33
-211.087	0.86116	0.33		228.913	0.85809	0.30
-191.087	0.88436	0.30		208.913	0.87598	0.29
-171.087	0.90964	0.28		188.913	0.89954	0.29
-151.087	0.92241	0.28		168.913	0.92092	0.28
-131.087	0.94965	0.27		148.913	0.93778	0.27
-111.087	0.96100	0.26		128.913	0.95096	0.22
-91.087	0.97741	0.25		108.913	0.97432	0.26
-71.087	0.97903	0.25		88.913	0.98099	0.25
-51.087	0.99569	0.25		68.913	0.98978	0.25
-31.087	0.99937	0.25		48.913	1.00039	0.28
-11.087	0.99827	0.25		28.913	0.99957	0.25
				8.913	1.00241	0.25

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Table 1.75 Np237 Axial Fission Chamber Scan in MZA

Position (mm)	Normalised Count rate	s.d. (%)		Position (mm)	Normalised Count rate	s.d. (%)
-803.952	0.01864	1.72		794.048	0.02186	1.69
-763.952	0.02522	1.65		754.048	0.02933	1.68
-723.952	0.03452	1.64		714.048	0.04076	1.56
-683.952	0.04800	1.58		674.048	0.05476	1.49
-643.952	0.06677	1.50		634.048	0.07664	1.47
-603.952	0.09169	1.46		594.048	0.10456	1.45
-563.952	0.12855	1.45		554.048	0.14665	1.42
-523.952	0.18183	1.39		515.348	0.20393	1.19
-483.952	0.25604	1.37		495.348	0.24261	1.22
-464.652	0.30882	1.23		474.048	0.29361	1.22
-443.952	0.37025	1.09		455.348	0.34805	1.15
-424.652	0.42898	0.93		435.348	0.40983	1.03
-404.652	0.48396	0.81		415.348	0.47370	0.85
-384.652	0.53862	0.71		395.348	0.52650	0.72
-364.652	0.58515	0.61		375.348	0.57619	0.65
-344.652	0.62464	0.54		355.348	0.62118	0.56
-324.652	0.66635	0.52		335.348	0.66381	0.51
-304.652	0.71353	0.43		315.348	0.70404	0.46
-284.652	0.74062	0.40		295.348	0.74379	0.40
-264.652	0.77867	0.37		275.348	0.77381	0.37
-244.652	0.80696	0.34		255.348	0.80883	0.36
-224.652	0.84376	0.30		235.348	0.84248	0.30
-204.652	0.86667	0.28		215.348	0.86361	0.30
-184.652	0.89237	0.27		195.348	0.89232	0.27
-164.652	0.91006	0.23		175.348	0.91402	0.23
-144.652	0.93379	0.23		155.348	0.93464	0.23
-124.652	0.94829	0.23		135.348	0.95320	0.23
-104.652	0.96392	0.23		115.348	0.96718	0.18
-84.652	0.98235	0.19		95.348	0.97783	0.19
-64.652	0.99067	0.19		75.348	0.99291	0.19
-44.652	0.99372	0.23		55.348	0.99252	0.23
-24.652	1.00070	0.19		35.348	0.99761	0.19
-4.652	1.00760	0.19		15.348	1.00785	0.19

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Table 1.76 Pu240 Radial Fission Chamber Scan in MZA (Shield Room Direction).

Position (mm)	Normalised Count rate	s.d. (%)		Position (mm)	Normalised Count rate	s.d. (%)
-747.070	0.02751	2.29		771.830	0.02310	2.55
-707.070	0.03819	1.88		731.830	0.03244	2.04
-667.070	0.05149	1.67		691.830	0.04261	1.86
-627.070	0.06938	1.58		651.830	0.06035	1.68
-587.070	0.09716	1.51		611.830	0.08278	1.57
-547.070	0.13812	1.44		571.830	0.11757	1.46
-507.070	0.19826	1.42		531.830	0.16656	1.43
-466.070	0.29300	1.11		491.830	0.24274	1.19
-426.070	0.41018	0.81		451.830	0.35001	0.94
-386.070	0.49623	0.64		413.930	0.44485	0.67
-346.070	0.59242	0.55		373.930	0.53507	0.56
-306.070	0.67091	0.48		333.930	0.62248	0.49
-266.070	0.75422	0.42		293.930	0.70058	0.45
-226.070	0.81675	0.37		253.930	0.77820	0.40
-186.070	0.87429	0.33		213.930	0.83884	0.36
-146.070	0.92341	0.32		173.930	0.89076	0.33
-106.070	0.95801	0.30		133.930	0.93171	0.32
-66.070	0.98231	0.30		93.930	0.96807	0.30
-26.070	0.99969	0.33		53.930	0.98442	0.29
				13.930	1.00032	0.29

Table 1.77 Pu240 Axial Fission Chamber Scan in MZA

Position (mm)	Normalised Count rate	s.d. (%)		Position (mm)	Normalised Count rate	s.d. (%)
-771.516	0.03451	1.73		786.184	0.03352	1.72
-731.516	0.04718	1.52		746.184	0.04485	1.56
-691.516	0.06218	1.49		706.184	0.05926	1.53
-651.516	0.08341	1.49		666.184	0.08075	1.43
-611.516	0.11127	1.43		626.184	0.10560	1.33
-571.516	0.14706	1.38		586.184	0.14094	1.35
-531.516	0.20254	1.30		506.184	0.25573	1.13
-491.516	0.27448	1.22		466.184	0.35017	1.06
-453.816	0.37344	0.99		426.184	0.47034	0.85
-413.816	0.49452	0.79		386.184	0.57880	0.56
-373.816	0.58887	0.53		346.184	0.66915	0.46
-333.816	0.66782	0.45		306.184	0.74563	0.39
-293.816	0.74440	0.40		266.184	0.80658	0.35
-253.816	0.80950	0.38		226.184	0.86527	0.33
-213.816	0.86215	0.32		186.184	0.91083	0.30
-173.816	0.90862	0.31		146.184	0.94642	0.29
-133.816	0.95006	0.29		106.184	0.97252	0.28
-93.816	0.97397	0.28		66.184	0.99047	0.27
-53.816	0.99129	0.31		26.184	1.00509	0.27
-13.816	1.00361	0.27				

Fission chamber measurements in MZB.

Measurements of U235, U238 and Pu239 fission rates were made along the radial centre line through the core and blanket sectors in MZB, in both the natural uranium oxide and the depleted uranium oxide sector versions (MTN/33) and in the uniform uranium metal fuelled blanket version, MZB/3 (MTN/80), including, in this case, Pu240 scans. The scanner which was used enabled measurements to be made in the same radial positions as the foil scans, facilitating comparisons between the two techniques. The scanner also made it possible to investigate in detail the variations in reaction rates across the inner/outer core boundary and the outer core/sector boundary. Axial scans at the core centre, at the middle of the outer core and in the centre of the radial breeder were also measured in MZB/3.

It should be noted that subsequent to MTN/33 being issued thermal column measurements indicated that the U235 content of the U238 chamber was 0.041 %, which is 14 % higher than the value quoted in MTN/33. This implies that the U238 fission rates in the outer breeder regions given in MTN/33 have been overestimated by about 3 per cent. It is the revised results given in MTN/94 which are reproduced here.

Axial scans in MZB/3.

The axial scans were made in elements with normal cell patterns but containing plates with a central hole 2.36 cm in diameter as in MZA. The scans were made inside a lead-liner with a central 1.16 cm diameter hole, which fitted into the hole through the plates.

Radial scans in MZB.

The fission chamber was connected to a PTFE insulated, double screened, coaxial cable with an additional outer PTFE sheath. The chamber positioning was extremely versatile (increments as small, as 0.1 mm were possible) facilitating matching scan intervals to cell or element pitches, thus minimising fine structure effects and eliminating the need to interpolate when comparing results.

The chamber bodies were 2.3 cm long and had flat ends. The material components are summarised in Table 1.78. The fissile coatings were short cylinders situated at the centre of the body length on the inside surface. For U235 and Pu.239 they were 0.4 cm long and for U238 the coating was 1 cm long. The effective length of the coatings was considerably more than their physical length. For instance, in this geometry, 90% of the count rate came from a region approximately 3 cm long. The masses of the coatings were 0.5 mg for U235 (7% U238) and Pu239 (0.7% Pu240) and 2.5 mg for U238 (0.036% U235). The gas filling was argon, 2% nitrogen, at 3.5 atm. pressure. Details of the chambers can be found in MTN/33.

The nose-piece was designed to maintain a symmetrical environment around the chamber and was sufficiently large to minimise streaming effects. Checks were made of streaming effects using a modified nose-piece.

Sources of uncertainty in the measurements are summarised in Table 1.79.

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Table 1.78 Dimensions of Fission Chamber Structural Components

Component	Material	O.D. (mm)	I.D. (mm)	Length (mm)
Chamber Body	St Steel	9.5	8.5	26
Chamber Central Electrode	St Steel	5.2	4.24	20
F/C Extn. nose-piece extensions	Brass	10.0	6.4	110
Conductor Rail	Copper	0.9	-	100
Guide Tube	St Steel	11.4	10.9	-

In the core region, pairs of sodium plates were replaced with special aluminium bridge pieces having a central 1.27 cm hole to accept the 1.0 mm diameter stainless steel guide tube. To achieve this in the inner core the cell above the centre line was rearranged slightly.

In the sector blanket region the central UO_2 plates were replaced with two 1.27 cm thick blocks of UO_2 separated by 1.27 cm, to allow the guide tube to pass through. The natural UO_2 blocks were canned in stainless steel, whilst the depleted UO_2 blocks were built up from 0.624 cm thick pieces and were uncanned.

The positions of the measurements in relation to the core elements are presented in Tables 1.80 to 1.82.

Table 1.79 Illustrative Summary of Percentage Uncertainties in the Radial Scan Chamber Measurements in MZB.

(the uncertainties tabulated with the measured values were calculated as a function of position)

Isotope	Position	Counting s.d. (%)	Correction for other isotopes (%)	Positional s.d. (%)	Total s.d. (%)
U235	Outer Blanket	0.4		0.4	0.5
	Centre of Outer Core	0.3		0.2	0.4
	Core Centre	0.2			0.2
U238	Outer Blanket	2.2	0.6	1.0	2.5
	Centre of Outer Core	0.3	0.1	0.3	0.4
	Core Centre	0.3	0.1		0.3
Pu239	Outer Blanket	0.5		0.4	0.6
	Centre of Outer Core	0.3		0.2	0.4
	Core Centre	0.2			0.2

Notes:-

1. The counting uncertainties quoted above include statistical errors, stability of counting channels (better than 0.2%) and dead time uncertainties (less than 0.2 %)
2. The positional uncertainty of 1.0 mm is discussed in MTN/33 section 3.3.
3. The data for MZB/3 are discussed in MTN/80 and are summarised in MTN/80 Table 1.

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Table 1.80 Scanner Positions and Corresponding Core Positions in the MZB/1 and /2 Scans in the Sector Blanket Direction (also called the Shield Room Direction)

Distance from Core Centre (mm)	Element Position	Core Position	
706.3	50-63	centre of outer core	
488.8	50-59	core centre line	Inner Core
325.0	50-56		
163.8	50-53		
0.0	50-50		
-163.8	50-47		
-325.0	50-44		
-488.8	50-41		
-574.7 -585.5 -596.2 -606.7 -617.7	50-39		Outer Core
-628.4 -639.2 -649.9 -660.7 -671.4	50-38		
-706.3	50-37	centre of outer core	
-738.5 -749.3 -760.0 -770.7 -781.5	50-36		
-792.2 -803.0 -813.7 -824.5 -835.2	50-35		Breeder
-867.4	50-34		
-921.1	50-33		
-977.5	50-32		
-1031.2	50-31		
-1085.0	50-30		
-1138.7	50-29		Steel
-1248.8	50-27		
-1356.2	50-25		Graphite
-1463.6	50-23		

The radial scan at right angles to this is called the Flight Tube direction

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Table 1.81 Scanner Positions and Corresponding Core Positions in the MZB/3 Scans in the Shield Room Direction, for Positive Distances (upper half on the core plans)

Distance from Core Centre (mm)	Element Position	Core Position	
+1138.7	50-71		Steel
1085.0	50-70		Radial Blanket
1031.2	50-69		
977.5	50-68		
921.1	50-67		
867.4	50-66		
813.7	50-65		
760.0	50-64		Outer Core
706.3	50-63		
649.9	50-62		
596.2	50-61		Inner Core
542.5	50-60		
488.8	50-59		
435.0	50-58		
325.0	50-56		
217.5	50-54		
107.4	50-52		
0.0	50-50		

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Table 1.82 Scanner Positions and Corresponding Core Positions in the MZB/3 Scans in the Shield Room Direction, for the Negative Distances (lower half on the core plans)

0.0	50-50	Core centre	Inner Core
-107.4	50-48		
-217.5	50-46		
-325.0	50-44		
-435.0	50-42		
-488.8	50-41		
-542.5	50-40		
-574.7 -585.5 -596.2 -606.7 -617.7	50-39		
-628.4 -639.2 -649.9 -660.7 -671.4	50-38		
-706.3	50-37	centre of outer core	
-738.5 -749.3 -760.0 -770.7 -781.5	50-36		
-792.2 -803.0 -813.7 -824.5 -835.2	50-35		Breeder
-867.4	50-34		
-921.1	50-33		
-977.5	50-32		
-1031.2	50-31		
-1085.0	50-30		
-1138.7	50-29		Steel

The scans in the probe tube (or flight tube) direction have 50 as the Y coordinate and are negative on the probe tube side, with X coordinate greater than 50.

Note:- Because of motor over-run the actual position of a point in the scan may differ by up to 0.3mm from the values quoted above. For the purposes of comparing reaction rates the error introduced by using the demanded position instead of the actual position is small compared with the overall uncertainties on the measurements. For example, the steepest gradient encountered in the scans is that for U238 fission in the breeder and at this position 0.3 mm corresponds to less than 0.5% in the reaction rate.

Results of the Radial Fission Chamber Scans.

The results of the radial measurements are presented in Tables 1.83 to 1.89. In the core region away from the uranium oxide sectors the measured values in MZB/1 and MZB/2 are in good agreement for all three isotopes. There is a tendency for all three reaction rates in the natural uranium sector to be higher by about 1%, while in the depleted uranium sector they are lower by 2% to 3%, relative to the uranium metal fuelled blanket region.

Table 1.83 MZB/1 and MZB/2 U235 Radial Fission Chamber Scans through the Sector Blanket.
(Shield Room axis)

MZB/1, natural uranium sector				MZB/2, depleted uranium sector		
Position (mm)	Normalised Count rate	s.d. (%)		Position (mm)	Normalised Count rate	s.d. (%)
-1138.9	0.1709	0.40		-1138.8	0.1779	0.43
-1085.2	0.1526	0.40		-1085.0	0.1666	0.43
-1031.6	0.1766	0.45		-1031.3	0.1891	0.51
-977.7	0.2214	0.43		-977.6	0.2306	0.52
-921.3	0.2793	0.42		-921.2	0.2816	0.50
-867.7	0.3467	0.37		-867.5	0.3437	0.46
-835.4	0.3863	0.34		-835.3	0.3795	0.41
-824.7	0.3990	0.34		-824.6	0.3902	0.39
-813.9	0.4130	0.33		-813.7	0.3996	0.40
-803.2	0.4253	0.29		-803.0	0.4134	0.41
-792.4	0.4337	0.29		-792.3	0.4243	0.35
-781.8	0.4459	0.29		-781.6	0.4303	0.35
-770.9	0.4564	0.27		-770.8	0.4413	0.38
-760.3	0.4675	0.29		-759.9	0.4545	0.39
-749.6	0.4818	0.28		-749.3	0.4667	0.37
-738.7	0.4918	0.27		-738.5	0.4779	0.37
-706.4	0.5307	0.27		-706.3	0.5172	0.35
-671.6	0.5695	0.26		-671.4	0.5536	0.34
-660.8	0.5840	0.26		-660.7	0.5674	0.36
-650.2	0.5973	0.26		-649.9	0.5822	0.34
-639.4	0.6136	0.25		-639.3	0.5942	0.33
-628.6	0.6249	0.24		-628.4	0.6074	0.34
-617.8	0.6382	0.24		-617.7	0.6222	0.32
-607.1	0.6508	0.24		-606.9	0.6323	0.31
-596.4	0.6682	0.21		-596.2	0.6445	0.32
-585.8	0.6762	0.20		-585.4	0.6593	0.32
-575.0	0.6906	0.22		-574.7	0.6709	0.30
-489.0	0.7784	0.19		-488.6	0.7610	0.27
-325.2	0.9010	0.16		-324.9	0.8903	0.25
-164.0	0.9767	0.16		-163.8	0.9770	0.27
-0.3	1.0000	0.15		0.0	1.0000	0.23
706.4	0.5316	0.24		706.2	0.5349	0.34
488.6	0.7674	0.20		488.8	0.7723	0.27
324.8	0.8968	0.17		325.1	0.8973	0.24
163.6	0.9732	0.16		163.8	0.9763	0.23

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Table 1.84 MZB/1 and MZB/2 Pu239 Radial Fission Chamber Scans through the Sector Blanket (Shield Room axis)

MZB/1, natural uranium sector				MZB/2, depleted uranium sector		
Position (mm)	Normalised Count rate	s.d. (%)		Position (mm)	Normalised Count rate	s.d. (%)
				-1765.7	1.2117	0.47
				-1678.5	1.6806	0.33
				-1570.9	1.9841	0.25
				-1463.6	1.9655	0.24
				-1356.2	1.3532	0.44
-1165.8	0.2239	0.65		-1248.7	0.5206	1.53
-1139.0	0.1961	0.73		-1138.6	0.2078	1.06
-1112.1	0.1664	0.68				
-1085.3	0.1578	0.38				
-1058.1	0.1613	0.55		-1065.0	0.1774	0.73
-1031.5	0.1696	0.61		-1031.2	0.1872	0.74
-977.8	0.2099	0.62		-977.4	0.2210	0.72
-921.4	0.2639	0.58		-921.2	0.2645	0.69
-867.6	0.3253	0.53		-867.4	0.3217	0.65
-835.5	0.3674	0.51		-835.1	0.3638	0.60
-824.5	0.3826	0.51		-824.7	0.3735	0.57
-814.0	0.3980	0.48		-813.6	0.3853	0.60
-803.3	0.4118	0.47		-802.9	0.4014	0.58
-792.6	0.4270	0.45		-792.2	0.4124	0.53
-781.8	0.4397	0.41		-781.5	0.4218	0.53
-771.0	0.4517	0.44		-770.7	0.4335	0.55
-760.3	0.4689	0.44		-760.0	0.4488	0.56
-749.6	0.4829	0.43		-749.2	0.4634	0.54
-738.8	0.5004	0.42		-738.5	0.4782	0.53
-706.5	0.5403	0.37		-706.2	0.5200	0.40
-671.8	0.5836	0.35		-671.3	0.5580	0.39
-661.0	0.5967	0.34		-660.6	0.5739	0.40
-650.3	0.6090	0.36		-649.6	0.5881	0.37
-639.7	0.6265	0.34		-639.2	0.6001	0.36
-628.9	0.6366	0.31		-628.4	0.6119	0.39
-618.0	0.6470	0.31		-617.6	0.6292	0.38
-607.1	0.6592	0.32		-606.9	0.6392	0.36
-596.5	0.6726	0.33		-596.2	0.6530	0.36
-585.9	0.6877	0.24		-585.5	0.6644	0.35
-575.1	0.6947	0.28		-574.6	0.6745	0.34
-489.1	0.7769	0.27		-488.7	0.7640	0.34
-379.0	0.8679	0.24				
-325.3	0.9015	0.23		-324.9	0.8891	0.31
-164.1	0.9781	0.22		-163.8	0.9637	0.33
-0.4	1.0000	0.21		0.0	1.0000	0.32

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Table 1.84 continued

706.4	0.5426	0.23		705.9	0.5405	0.38
488.5	0.7731	0.27		488.9	0.7718	0.34
378.2	0.8610	0.25				
325.1	0.8983	0.24		325.0	0.8986	0.31
163.4	0.9749	0.22		163.9	0.9730	0.33

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Table 1.85 MZB/1 and MZB/2 U238 Fission Chamber Scans through the Sector Blanket
(Shield Room axis) Revised data from MTN-94.

MZB/1, natural uranium sector				MZB/2, depleted uranium sector		
Position (mm)	Normalised Count rate	s.d. (%)		Position (mm)	Normalised Count rate	s.d. (%)
-1138.9	0.0084	3.37		-1138.8	0.0072	2.33
-1085.1	0.0175	2.48		-1085.1	0.0135	1.69
-1031.3	0.0280	2.17		-1031.3	0.0237	1.59
-977.6	0.0468	1.78		-977.6	0.0408	1.56
-921.4	0.0791	1.54		-921.2	0.0735	1.58
-867.5	0.1448	1.43		-867.5	0.1330	1.49
-835.4	0.2085	1.08		-835.3	0.1943	1.43
-824.5	0.2367	1.49		-824.6	0.2230	1.44
-813.8	0.2749	1.04		-813.8	0.2532	1.48
-803.2	0.3166	1.03		-803.1	0.2936	1.51
-792.4	0.3622	1.34		-792.3	0.3393	1.31
-781.6	0.4095	1.23		-781.6	0.3784	1.32
-770.9	0.4592	1.05		-770.8	0.4362	1.22
-760.2	0.5037	0.65		-760.1	0.4811	0.93
-749.5	0.5441	0.55		-749.4	0.5162	0.76
-738.6	0.5748	0.46		-738.6	0.5459	0.68
-706.5	0.6490	0.38		-706.4	0.6275	0.45
-695.7	0.6722	0.43				
-685.0	0.6844	0.40				
-678.3	0.6951	0.43				
-671.6	0.7075	0.30		-671.6	0.6823	0.39
-660.9	0.7206	0.30		-660.8	0.6975	0.36
-650.0	0.7325	0.27		-650.0	0.7084	0.33
-639.4	0.7372	0.26		-639.2	0.7141	0.31
-628.6	0.7362	0.26		-628.5	0.7129	0.31
-617.9	0.7377	0.24		-617.8	0.7142	0.31
-607.0	0.7364	0.25		-607.0	0.7167	0.31
-596.3	0.7347	0.23		-596.3	0.7170	0.31
-585.7	0.7407	0.23		-585.6	0.7190	0.31
-574.9	0.7439	0.24		-574.8	0.7241	0.32
-489.0	0.7946	0.25		-488.9	0.7822	0.33
-325.2	0.9119	0.23		-325.1	0.8996	0.31
-163.9	0.9791	0.23		-163.9	0.9714	0.32
-0.2	1.0000	0.22		-0.1	1.0000	0.31
706.3	0.6478	0.24		706.2	0.6517	0.34
488.6	0.7912	0.24		488.7	0.8009	0.33
324.8	0.9003	0.24		324.9	0.9078	0.33
163.6	0.9776	0.23		163.7	0.9754	0.32

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Table 1.86 MZB/3 Radial Fission Chamber Scans along the Shield Room Axis
(negative direction)

POSITION	Pu239		POSITION	U238	
(mm)	Count Rate	s.d. (%)	(mm)	Count Rate	s.d. (%)
-1785.8	0.7069	0.69			
-1678.6	1.4364	0.36			
-1571.0	1.8994	0.26			
-1463.6	1.9655	0.25			
-1356.2	1.8980	0.33			
-1248.6	0.5404	1.05			
-1192.5	0.2838	0.79			
-1138.8	0.2539	0.62	-1138.8	0.0085	2.41
-1085.1	0.2469	0.62	-1085.1	0.0173	1.80
-1031.3	0.2691	0.61	-1031.3	0.0287	1.71
-977.6	0.3068	0.56	-977.6	0.0455	1.51
-921.2	0.3656	0.54	-921.2	0.0774	1.26
-867.5	0.4140	0.50	-867.5	0.1378	1.12
-835.2	0.4420	0.49	-835.3	0.2009	1.03
-824.6	0.4547	0.48	-824.6	0.2299	1.10
-813.8	0.4615	0.47	-813.7	0.2704	1.07
-803.1	0.4689	0.46	-803.1	0.3109	0.99
-792.3	0.4687	0.46	-792.3	0.3555	0.95
-781.5	0.4690	0.32	-781.6	0.4048	0.86
-770.8	0.4739	0.33	-770.8	0.4529	0.73
-760.1	0.4834	0.34	-760.1	0.4977	0.69
-749.4	0.4919	0.36	-749.4	0.5312	0.63
-738.6	0.5046	0.36	-738.6	0.5659	0.59
-706.4	0.5403	0.34	-706.3	0.6423	0.52
-671.5	0.5755	0.33	-671.5	0.6891	0.46
-660.8	0.5867	0.33	-660.9	0.7013	0.49
-650.0	0.6009	0.33	-650.0	0.7145	0.48
-639.3	0.6104	0.35	-639.3	0.7176	0.47
-628.5	0.6297	0.35	-628.5	0.7197	0.47
-617.8	0.6407	0.34	-617.8	0.7201	0.47
-607.0	0.6528	0.33	-607.0	0.7175	0.47
-596.3	0.6602	0.33	-596.3	0.7219	0.47
-585.6	0.6769	0.34	-585.6	0.7240	0.47
-574.8	0.6917	0.33	-574.8	0.7238	0.47
-542.6	0.7230	0.31	-542.6	0.7456	0.44
-488.9	0.7737	0.33	-488.9	0.7859	0.46
-435.1	0.8202	0.32	-435.1	0.8215	0.43
-325.1	0.8964	0.30	-325.1	0.8968	0.45
-217.6	0.9551	0.33	-217.6	0.9481	0.44
-107.5	0.9882	0.32	-107.5	0.9843	0.44
-0.1	1.0000	0.32	0.0	1.0000	

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Table 1.87 MZB/3 Radial Fission Chamber Scans along the Shield Room Axis
(negative direction)

U235			Pu240		
POSITION (mm)	Count Rate	s.d. (%)	POSITION (mm)	Count Rate	s.d. (%)
-1138.8	0.2096	0.76	-1138.8	0.0256	1.72
-1085.2	0.2155	0.75	-1085.1	0.0379	1.44
-1031.3	0.2479	0.72	-1031.2	0.0554	1.29
-977.6	0.2973	0.68	-977.6	0.0837	1.20
-921.2	0.3631	0.62	-921.2	0.1252	1.11
-867.5	0.4228	0.57	-867.5	0.1925	0.96
-813.8	0.4627	0.54	-813.8	0.3045	0.68
-760.0	0.4820	0.37	-760.1	0.4713	0.52
-706.4	0.5296	0.38	-706.4	0.5914	0.41
-650.0	0.5055	0.39	-650.0	0.6669	0.29
-596.3	0.6528	0.37	-596.3	0.7028	0.37
-542.6	0.7080	0.38	-542.6	0.7422	0.27
-488.9	0.7669	0.36	-488.9	0.7852	0.38
-435.1	0.8110	0.35	-435.1	0.8276	0.38
-325.1	0.8955	0.36	-325.1	0.8973	0.36
-217.6	0.9532	0.35	-217.6	0.9550	0.39
-107.5	0.9866	0.35	-107.5	0.9875	0.39
0.0	1.0000	0.35	-0.1	1.0000	0.27

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Table 1.88 MZB/3 Radial Fission Chamber Scans along the Shield Room Axis
(positive direction)

Point	Pu239		Point	U238	
(mm)	Count Rate	s.d. (%)	(mm)	Count Rate	s.d. (%)
1030.9	0.2474	0.66	1031.1	0.0290	1.70
977.4	0.2978	0.60	977.4	0.0464	1.25
921.0	0.3545	0.55	921.0	0.0769	1.27
867.3	0.4157	0.50	867.4	0.1406	1.18
813.6	0.4610	0.47	813.6	0.2707	1.00
759.9	0.4847	0.33	759.9	0.4986	0.65
706.3	0.5431	0.34	706.3	0.6441	0.52
649.8	0.6086	0.35	649.8	0.7198	0.48
596.1	0.6679	0.33	596.1	0.7214	0.47
542.4	0.7287	0.34	542.4	0.7555	0.47
488.7	0.7746	0.33	488.7	0.7879	0.46
434.9	0.8238	0.32	434.9	0.6259	0.46
324.9	0.8993	0.30	324.9	0.8908	0.45
217.4	0.9580	0.33	217.4	0.9516	0.44
107.3	0.9868	0.32	107.3	0.9809	0.44
0.0	1.0000		0.0	1.0000	0.43

Point	U235		Point	Pu240	
(mm)	Count Rate	s.d. (%)	(mm)	Count Rate	s.d. (%)
1031.0	0.2369	0.76	1031.0	0.0557	1.31
977.4	0.2945	0.69	977.4	0.0832	1.20
921.0	0.3578	0.63	921.0	0.1263	1.10
867.3	0.4245	0.57	867.4	0.1928	0.97
813.6	0.4687	0.54	813.6	0.3097	0.70
760.0	0.4829	0.37	759.9	0.4751	0.51
706.2	0.5350	0.38	706.2	0.5949	0.41
649.8	0.5887	0.39	649.8	0.6741	0.29
596.1	0.6577	0.37	596.1	0.7067	0.37
542.4	0.7165	0.37	542.4	0.7461	0.36
488.7	0.7674	0.36	488.7	0.7857	0.38
434.9	0.8150	0.38	434.9	0.8317	0.38
324.9	0.8984	0.36	324.9	0.9026	0.36
217.4	0.9543	0.35	217.4	0.9592	0.39
107.3	0.9929	0.35	107.3	0.9912	0.39
0.0	1.0000				

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Table 1.89 MZB/3 Radial Fission Chamber Scans along the Flight Tube Axis

POSITION	Pu239		POSITION	U238	
(mm)	Count	Rate	(mm)	Count	Rate
-1139.0	0.2132	0.67	-1138.4	0.0079	2.55
-1084.9	0.2200	0.66	-1084.7	0.0169	1.92
-1031.0	0.2525	0.64	-1031.0	0.0779	1.65
-977.4	0.3002	0.60	-977.3	0.0459	1.51
-921.0	0.3564	0.55	-920.9	0.0783	1.24
-867.3	0.4103	0.51	-867.3	0.1380	1.10
-835.0	0.4388	0.49	-834.9	0.1992	1.03
-824.4	0.4509	0.48	-824.3	0.2294	1.08
-813.6	0.4571	0.54	-813.5	0.2668	1.07
-802.9	0.4639	0.47	-802.8	0.3111	1.02
-792.1	0.4691	0.46	-792.0	0.3589	0.91
-781.4	0.4642	0.35	-781.3	0.4036	0.81
-770.5	0.4730	0.36	-770.5	0.4518	0.75
-759.8	0.4809	0.36	-759.8	0.4980	0.67
-749.1	0.4899	0.36	-749.2	0.5320	0.56
-738.4	0.5011	0.36	-738.4	0.5627	0.54
-706.2	0.5346	0.35	-706.1	0.6361	0.48
-671.3	0.5757	0.36	-671.2	0.6907	0.45
-660.5	0.5683	0.36	-660.5	0.7011	0.44
-649.8	0.6021	0.33	-649.8	0.7149	0.44
-639.0	0.6136	0.35	-639.0	0.7226	0.43
-628.2	0.6291	0.34	-628.3	0.7168	0.43
-617.6	0.6387	0.34	-617.5	0.7160	0.43
-606.8	0.6525	0.33	-606.7	0.7153	0.43
-596.6	0.6573	0.36	-596.6	0.7181	0.43
-585.3	0.6750	0.37	-585.3	0.7227	0.43
-574.6	0.6901	0.33	-574.5	0.7240	0.40
-542.5	0.7172	0.31	-542.4	0.7433	0.39
-488.7	0.7661	0.33	-488.7	0.7818	0.34
-434.9	0.8133	0.32	-434.8	0.8191	0.33
-325.0	0.8907	0.31	-324.8	0.8922	0.32
-217.4	0.9566	0.33	-217.3	0.9483	0.32
-107.7	0.9884	0.32	-107.2	0.9862	0.31
0.0	1.0000		0.0	1.0000	

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Table 1.89 continued

1138.4	0.2097	0.68	1138.4	0.0080	2.16
1005.1	0.2199	0.67	1085.2	0.0170	1.46
1031.2	0.2552	0.64	1031.3	0.0266	1.31
977.6	0.3021	0.59	977.7	0.0465	1.25
921.2	0.3593	0.55	921.3	0.0780	1.03
867.0	0.1107	0.50	867.6	0.1399	0.99
833.9	0.4637	0.47	813.8	0.2659	0.89
760.1	0.4857	0.33	760.1	0.4970	0.57
706.4	0.5425	0.35	706.5	0.6464	0.40
650.0	0.6043	0.33	650.1	0.7203	0.34
596.4	0.6683	0.33	596.4	0.7233	0.34
542.1	0.7243	0.32	542.7	0.7504	0.34
488.9	0.7760	0.33	489.1	0.7900	0.33
435.2	0.8232	0.32	435.2	0.8245	0.33
325.2	0.9056	0.30	325.2	0.9031	0.32
217.5	0.9575	0.33	217.6	0.9571	0.31
107.5	0.9906	0.32	107.5	0.9863	0.31
0.2	1.0000	0.32	0.1	1.0000	0.31

Axial fission chamber scans in MZB/3

Measurements made in the axial direction are tabulated in Tables 1.90 to 1.101. The positions given for the measurements are relative to the mid-plane of the element in which measurements were made. Positions are positive in the downward direction and negative in the upward direction. However, these elements were higher than the average mid-plane positions of the neighbouring elements by 2.5 mm in the inner core, 1.4 mm in the outer core and 2.6 mm in the radial blanket.

To express the measurements relative to the mean centre of the inner core elements 2.5 mm should be subtracted from the position values given in Table 1.90.

There is an asymmetry in the axial scans which is partly due to the asymmetry in the plates in the cells above and below the mid-plane but also due to the boron follower regions at the tops of the control rods.

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Table 1.90 MZB/3 Axial Fission Chamber Scans at the Core Centre (negative direction)

POSITION (mm)	Pu239		U238		U235		Pu240	
	Count Rate	s.d. (%)	Count Rate	s.d. (%)	Count Rate	s.d. (%)	Count Rate	s.d. (%)
-797.9	0.2293	0.97	0.0143	2.82	0.2252	0.75	0.0396	1.46
-754.1	0.2426	1.04	0.0226	1.96	0.2444	0.75	0.0523	1.32
-710.2	0.2765	0.99	0.0306	1.86	0.2844	0.74	0.0678	1.21
-666.3	0.3194	1.02	0.0434	0.92	0.3329	0.70	0.0695	1.09
-622.5	0.3687	1.06	0.0622	0.68	0.3868	0.66	0.1164	1.03
-576.6	0.4215	0.99	0.0871	0.61	0.4511	0.61	0.1556	0.94
-534.7	0.4779	0.93	0.1280	0.84	0.5087	0.56	0.2036	0.91
-490.9	0.5274	0.55	0.1985	0.18	0.5572	0.47	0.2753	0.78
-447.0	0.5660	0.44	0.3100	0.15	0.5922	0.39	0.3703	0.30
-409.4	0.5960	0.44	0.4500	0.84	0.6188	0.38	0.4793	0.66
-365.7	0.6435	0.46	0.5696	0.67	0.6619	0.38	0.5843	0.52
-328.2	0.6979	0.46	0.6562	0.61	0.7107	0.40	0.6591	0.45
-284.5	0.7624	0.46	0.7322	0.57	0.7726	0.38	0.7415	0.39
-247.0	0.8190	0.45	0.7982	0.54	0.8184	0.40	0.8011	0.36
-203.7	0.8734	0.45	0.8578	0.46	0.8745	0.38	0.8646	0.33
-165.7	0.9147	0.41	0.9050	0.49	0.9151	0.37	0.9068	0.30
-122.0	0.9551	0.42	0.9461	0.52	0.9532	0.36	0.9479	0.29
-84.5	0.9723	0.39	0.9799	0.47	0.9785	0.35	0.9725	0.28
-40.5	0.9988	0.39	0.9896	0.51	0.9946	0.35	0.9963	0.19
-3.3	1.0029	0.39	1.0039	0.50	1.0017	0.35	0.9991	0.21
-0.1			1.0035	0.42	0.2252	0.75	1.0033	0.17

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Table 1.91 MZB/3 Axial Fission Chamber Scans at the Core Centre
(positive direction for U235 and Pu240)

POSITION	U235		POSITION	Pu240	
(mm)	Count Rate	s.d. (%)	(mm)	Count Rate	s.d. (%)
	0.2827	0.67	797.6	0.0494	1.32
754.0	0.2930	0.67	753.7	0.0623	1.25
709.5	0.3290	0.68	709.9	0.0818	1.13
666.0	0.3768	0.65	666.0	0.1057	1.06
622.1	0.4358	0.62	622.1	0.1405	0.98
578.2	0.4993	0.57	578.2	0.1848	0.91
534.4	0.5523	0.53	534.4	0.2447	0.58
490.5	0.5936	0.39	490.5	0.3310	0.78
446.6	0.6198	0.37	446.7	0.4481	0.70
411.6	0.6435	0.38	411.6	0.5410	0.57
			372.9	0.6227	0.52
365.4	0.6794	0.40	365.4	0.6427	0.49
321.6	0.7556	0.39	321.6	0.7237	0.40
284.2	0.8055	0.38	284.2	0.7901	0.36
240.4	0.8643	0.39	240.4	0.8506	0.33
202.9	0.9057	0.37	202.9	0.8928	0.31
159.2	0.9412	0.36	159.2	0.9397	0.29
121.8	0.9684	0.35	121.7	0.9670	0.28
78.0	0.9921	0.35	78.0	0.9875	0.28
40.5	1.0037	0.35	40.5	1.0008	0.27

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Table 1.92 MZB/3 Axial Fission Chamber Scans at the Core Centre
(positive direction for Pu239 and U238)

Pu239			U238		
Position (mm)	Count	Rate s.d. (%)	Position (mm)	Count Rate	s.d. (%)
797.5	0.2999	1.01	797.4	0.0180	2.04
753.7	0.3039	1.00	754.1	0.0264	1.74
709.8	0.3257	0.98	709.8	0.0375	1.64
666.0	0.3697	1.05	666.0	0.0527	1.59
622.1	0.4252	0.99	622.1	0.0761	1.59
578.2	0.4832	0.92	578.2	0.1099	1.55
534.4	0.5217	0.88	534.4	0.1633	1.26
525.6	0.5317	0.47	525.6	0.1802	1.27
516.8	0.5471	0.44	516.8	0.1983	1.16
508.0	0.5548	0.41	508.0	0.2144	1.14
499.3	0.5633	0.36	499.3	0.2344	1.23
490.5	0.5718	0.37	490.5	0.2580	1.17
481.7	0.5744	0.34	481.7	0.2813	1.14
472.9	0.5821	0.35	473.0	0.3059	1.24
464.2	0.5869	0.35	464.2	0.3392	1.28
455.4	0.5957	0.34	455.4	0.3740	1.22
446.7	0.5965	0.33	446.6	0.4094	1.24
437.9	0.6024	0.35	437.9	0.4523	1.18
429.2	0.6100	0.37	429.1	0.4909	0.86
420.4	0.6179	0.38	420.4	0.5120	0.65
411.6	0.6239	0.39	411.6	0.5250	0.63
402.9	0.6359	0.39	402.8	0.5436	0.64
395.4	0.6422	0.40	395.4	0.5574	0.62
387.9	0.6570	0.42	388.0	0.5727	0.70
380.4	0.6679	0.39	380.4	0.5978	0.72
372.9	0.6757	0.40	372.9	0.6160	0.63
365.4	0.6806	0.41	365.4	0.6316	0.60
321.6	0.7491	0.40	321.6	0.7166	0.57
284.2	0.8011	0.36	284.2	0.7848	0.54
240.4	0.8545	0.37	240.4	0.8470	0.53
202.9	0.8952	0.39	202.9	0.8929	0.49
159.2	0.9375	0.39	159.2	0.9281	0.53
121.7	0.9716	0.40	121.7	0.9680	0.52
78.0	0.9987	0.37	78.0	0.9863	0.51
40.5	0.9983	0.37	40.5	1.0030	0.50

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Table 1.93 MZB/3 Axial Fission Chamber Scans in the Outer Core
(Pu239 and U238 in the negative direction)

Positions are positive in the downward direction and negative in the upward direction. To express the measurements relative to the mean centre of the outer core elements 1.4 mm should be subtracted from these position values.

Pu239				U238		
POSITION (mm)	Count Rate	s.d. (%)		POSITION (mm)	Count Rate	s.d. (%)
-802.0	0.2374	0.96		-802.0	0.0125	3.13
-757.6	0.2505	1.01		-757.6	0.0187	2.86
-713.7	0.2791	0.97		-713.7	0.0268	2.40
-669.9	0.3133	1.02		-669.9	0.0382	2.04
-626.0	0.3654	0.96		-625.9	0.0530	2.03
-582.2	0.4211	0.98		-582.2	0.0801	1.85
-538.3	0.4699	0.93		-538.3	0.1238	1.66
-494.5	0.5229	0.52		-494.5	0.1978	1.46
-450.6	0.5575	0.43		-450.6	0.3299	1.20
-413.1	0.5871	0.45		-413.1	0.4624	0.94
-375.5	0.6350	0.46		-375.5	0.5757	0.73
-338.0	0.6920	0.45		-338.1	0.6510	0.69
-300.5	0.7388	0.45		-300.5	0.7268	0.67
-262.6	0.7989	0.45		-262.9	0.7905	0.63
-225.3	0.8457	0.43		-225.5	0.8484	0.60
-187.8	0.8888	0.43		-187.8	0.8932	0.61
-150.3	0.9240	0.42		-150.3	0.9344	0.59
-112.7	0.9566	0.41		-112.7	0.9602	0.59
-75.2	0.9827	0.42		-75.2	0.9967	0.56
-37.6	0.9996	0.42		-37.5	0.9983	0.57
-0.1	1.0046	0.27		-0.2	1.0036	0.49

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Table 1.94 MZB/3 Axial Fission Chamber Scans in the Outer Core
(U235 and Pu240 in the negative direction)

U235				Pu240		
POSITION (mm)	Count Rate	s.d. (%)		POSITION (mm)	Count Rate	s.d. (%)
-802.0	0.2303	0.69		-802.0	0.0355	1.50
-757.6	0.2464	0.69		-757.6	0.0459	1.44
-713.7	0.2796	0.69		-713.7	0.0617	1.36
-669.9	0.3288	0.66		-669.9	0.0817	1.29
-626.0	0.3853	0.62		-626.0	0.1065	1.20
-582.2	0.4437	0.57		-582.2	0.1434	1.10
-538.3	0.4998	0.53		-538.3	0.1938	1.03
-494.5	0.5573	0.48		-494.5	0.2664	0.97
-450.6	0.5828	0.35		-450.5	0.3777	0.84
-413.1	0.6043	0.35		-413.1	0.4851	0.71
-375.5	0.6441	0.37		-375.5	0.5758	0.58
-338.0	0.7014	0.38		-338.0	0.6536	0.50
-300.5	0.7485	0.36		-300.4	0.7260	0.45
-262.9	0.8017	0.38		-262.9	0.7875	0.42
-225.4	0.8559	0.35		-225.4	0.8432	0.39
-187.8	0.8867	0.34		-187.7	0.8837	0.38
-150.3	0.9230	0.33		-150.3	0.9361	0.35
-112.7	0.9546	0.33		-112.7	0.9550	0.34
-75.2	0.9784	0.35		-75.2	0.9854	0.34
-37.6	0.9950	0.35		-37.6	0.9964	0.33
-0.1	0.9970	0.35		-0.1	1.0026	0.17

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Table 1.95 MZB/3 Axial Fission Chamber Scans in the Outer Core
(positive direction for Pu239 and U238)

Pu239				U238		
Position (mm)	Count Rate	s.d. %		Position (mm)	Count Rate	s.d. %
801.8	0.2899	0.93		801.9	0.0137	2.97
757.4	0.2949	0.92		757.4	0.0210	2.54
713.5	0.3122	1.00		713.5	0.0279	2.08
669.7	0.3465	0.96		669.7	0.0397	2.04
625.8	0.3919	1.02		625.8	0.0555	1.68
582.0	0.4464	0.95		582.1	0.0889	1.79
538.1	0.4977	0.91		538.1	0.1366	1.50
529.4	0.5119	0.80		529.4	0.1467	1.53
520.6	0.5182	0.72		520.6	0.1581	1.53
511.8	0.5298	0.69		511.8	0.1781	1.45
503.1	0.5440	0.59		503.1	0.1954	1.43
494.3	0.5485	0.51		494.3	0.2174	1.33
485.5	0.5516	0.50		485.5	0.2356	1.34
476.6	0.5516	0.52		476.8	0.2637	1.39
468.0	0.5658	0.51		468.1	0.2992	1.32
459.2	0.5656	0.50		459.2	0.3199	1.35
450.4	0.5743	0.42		450.4	0.3559	1.39
442.9	0.5760	0.41		442.9	0.3919	1.29
435.4	0.5810	0.43		435.4	0.4227	1.11
427.9	0.5898	0.45		427.9	0.4517	0.97
420.4	0.5964	0.44		420.4	0.4727	0.82
412.9	0.6032	0.45		412.9	0.4938	0.87
405.4	0.6148	0.46				
397.9	0.6237	0.45		398.0	0.5496	0.87
390.4	0.6354	0.45		390.4	0.5747	0.71
382.9	0.6409	0.46		382.7	0.5865	0.62
375.3	0.6560	0.47		375.3	0.5958	0.64
337.6	0.7081	0.45		337.6	0.6767	0.65
300.3	0.7630	0.45		300.3	0.7554	0.61
262.7	0.8170	0.44		262.7	0.8102	0.60
225.2	0.8639	0.42		225.2	0.8599	0.58
187.6	0.9077	0.43		187.6	0.9052	0.56
150.1	0.9420	0.42		150.1	0.9447	0.57
112.5	0.9716	0.41		112.5	0.9654	0.56
75.0	0.9946	0.42		75.0	1.0003	0.55
37.5	0.9950	0.42		37.5	0.9982	0.55

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Table 1.96 MZB/3 Axial Fission Chamber Scans in the Outer Core
(U235 and Pu240 in the positive direction)

U235				Pu240		
POSITION (mm)	Count Rate	s.d. %		POSITION (mm)	Count Rate	s.d. %
801.8	0.2761	0.62		801.8	0.0400	1.46
757.4	0.2825	0.63		757.4	0.0511	1.38
713.5	0.3110	0.64		713.5	0.0666	1.32
669.7	0.3591	0.62		669.7	0.0884	1.27
625.8	0.4123	0.59		625.9	0.1170	1.15
582.0	0.4680	0.55		582.0	0.1542	1.07
538.1	0.5252	0.51		538.1	0.2080	1.04
494.3	0.5724	0.46		494.3	0.2918	0.95
450.4	0.5962	0.45		450.4	0.4078	0.82
412.9	0.6227	0.45		412.9	0.5164	0.68
375.3	0.6660	0.45		375.4	0.6036	0.55
337.8	0.7169	0.44		337.9	0.6790	0.49
300.3	0.7731	0.42		300.3	0.7491	0.44
262.7	0.8229	0.40		262.6	0.8075	0.41
225.2	0.8679	0.39		225.2	0.8620	0.38
187.6	0.9120	0.37		187.6	0.9031	0.37
150.1	0.9378	0.36		150.1	0.9465	0.35
112.5	0.9679	0.36		112.5	0.9668	0.34
75.0	0.9833	0.35		75.0	0.9887	0.33
37.5	1.0080	0.35		37.5	0.9991	0.33

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Table 1.97 MZB/3 Axial Fission Chamber Scans in the Radial Blanket
(Pu239 and U238 in the negative direction)

Positions are positive in the downward direction and negative in the upward direction. However, the element in which measurements were made was higher than the average mid-plane positions of the neighbouring radial blanket elements by 2.6 mm. To express the measurements relative to the mean centre of the radial breeder elements 2.6 mm should be subtracted from these position values.

Pu239				U238		
POSITION (mm)	Count Rate	s.d. %		POSITION (mm)	Count Rate	s.d. %
-783.4	0.2299	1.55		-783.4	0.0502	3.02
-681.9	0.2456	1.52		-681.9	0.0986	2.64
-580.4	0.3442	1.31		-580.4	0.1883	2.54
-476.0	0.4969	1.00		-476.0	0.3597	1.68
-425.6	0.5894	1.01		-425.6	0.4704	1.57
-375.3	0.6607	0.94		-375.2	0.5761	1.51
-324.8	0.7257	0.90		-324.8	0.6713	2.50
-274.4	0.8026	0.85		-274.4	0.7717	1.51
-223.9	0.8545	0.82		-223.9	0.8574	1.45
-173.5	0.9110	0.80		-173.5	0.9244	1.51
-123.1	0.9620	0.77		-123.1	0.9711	1.48
-72.7	0.9863	0.76		-72.7	0.9724	1.48
-22.3	0.9983	0.54		-22.3	1.0151	1.37

Table 1.98 MZB/3 Axial Fission Chamber Scans in the Radial Blanket
(U235 and Pu240 in the negative direction)

U235				Pu240		
POSITION (mm)	Count Rate	s.d. %		POSITION (mm)	Count Rate	s.d. %
-783.3	0.2032	1.26		-783.4	0.0839	2.40
-681.9	0.2360	1.20		-681.9	0.1353	2.01
-580.4	0.3436	1.04		-580.4	0.2286	1.58
-476.0	0.4997	0.87		-476.0	0.3977	1.21
-425.6	0.5770	0.81		-425.6	0.5046	1.06
-375.2	0.6610	0.76		-375.2	0.5937	0.96
-324.8	0.7344	0.71		-324.8	0.6948	0.88
-274.4	0.8033	0.68		-274.4	0.7668	0.82
-223.9	0.8629	0.65		-223.9	0.8468	0.78
-173.5	0.9174	0.63		-173.5	0.9075	0.74
-123.1	0.9620	0.61		-123.1	0.9499	0.72
-72.7	0.9813	0.61		-72.7	0.9730	0.71
-22.3	0.9974	0.60		-22.3	0.9995	0.70

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Table 1.99 MZB/3 Axial Fission Chamber Scans in the Radial Blanket
(Pu239 and U238 in the positive direction)

Pu239				U238		
POSITION (mm)	Count Rate	s.d. %		POSITION (mm)	Count Rate	s.d. %
783.3	0.2624	1.45		783.2	0.0568	2.97
681.7	0.2698	1.44		681.7	0.1071	2.65
580.2	0.3621	1.23		580.2	0.2065	2.44
481.9	0.5184	0.97		481.9	0.3815	1.50
431.5	0.5936	1.00		431.5	0.4777	1.46
381.1	0.6662	0.94		381.1	0.5871	1.44
330.7	0.7513	0.69		330.7	0.6812	1.42
280.3	0.8100	0.65		280.3	0.7703	1.36
229.8	0.8710	0.81		229.9	0.8420	1.36
179.4	0.9132	0.80		179.4	0.8997	1.53
129.0	0.9658	0.77		129.0	0.9402	1.50
78.6	0.9991	0.76		78.6	0.9746	1.48
28.2	1.0017	0.53		28.2	0.9849	1.38

Table 1.100 MZB/3 Axial Fission Chamber Scans in the Radial Blanket
(U235 and Pu240 in the positive direction)

U235				Pu240		
POSITION (mm)	Count Rate	s.d. %		POSITION (mm)	Count Rate	s.d. %
783.2	0.2306	1.18		783.2	0.0961	2.47
681.7	0.2568	1.15		681.7	0.1510	1.90
580.2	0.3632	1.01		580.2	0.2516	1.50
481.9	0.5142	0.86		481.9	0.4132	1.18
431.5	0.5976	0.80		431.5	0.5141	1.05
381.1	0.6693	0.75		381.1	0.6086	0.95
330.7	0.7416	0.71		330.8	0.7016	0.67
280.3	0.8258	0.67		280.3	0.7673	0.82
229.8	0.8728	0.65		229.8	0.8581	0.77
179.4	0.9306	0.63		179.4	0.9059	0.74
129.0	0.9598	0.61		129.0	0.9435	0.73
78.6	1.0003	0.60		78.6	0.9889	0.71
28.2	1.0026	0.60		28.2	1.0005	0.70

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Table 1.101 MZB/3 Axial Fission Chamber Scans in the Radial Blanket
(U235 and Pu240 in the positive direction)

U235				Pu240		
POSITION (mm)	Count Rate	s.d. %		POSITION (mm)	Count Rate	s.d. %
801.8	0.2761	0.62		801.8	0.0400	1.46
757.4	0.2825	0.63		757.4	0.0511	1.38
713.5	0.3110	0.64		713.5	0.0666	1.32
669.7	0.3591	0.62		669.7	0.0884	1.27
625.8	0.4123	0.59		625.9	0.1170	1.15
582.0	0.4680	0.55		582.0	0.1542	1.07
538.1	0.5252	0.51		538.1	0.2080	1.04
494.3	0.5724	0.46		494.3	0.2918	0.95
450.4	0.5962	0.45		450.4	0.4078	0.82
412.9	0.6227	0.45		412.9	0.5164	0.68
375.3	0.6660	0.45		375.4	0.6036	0.55
337.8	0.7169	0.44		337.9	0.6790	0.49
300.3	0.7731	0.42		300.3	0.7491	0.44
262.7	0.8229	0.40		262.6	0.8075	0.41
225.2	0.8679	0.39		225.2	0.8620	0.38
187.6	0.9120	0.37		187.6	0.9031	0.37
150.1	0.9378	0.36		150.1	0.9465	0.35
112.5	0.9679	0.36		112.5	0.9668	0.34
75.0	0.9833	0.35		75.0	0.9887	0.33
37.5	1.0080	0.35		37.5	0.9991	0.33

Foil measurements in MZB.

The foil measurements comprised fission rates in U235 and U238 (F25, F28) and the capture rate in U238 (C28). In addition the variations in F25, F28 and C28 azimuthally through both sector version of MZB were measured with foils.

The foils used for the measurements were as follows:

U235	6.35 mm x 5.51 mm x 0.076 mm,	93% U235 metal
U238	25.4 mm diameter x 0.076 mm thickness,	0.04% U235 metal

The foils were placed in UO₂ plates (depleted UO₂ plates in the case of the depleted UO₂ sector) All the foils were wrapped in aluminium foil, 0.02 mm thick, to protect them from contamination. In the radial and azimuthal scans foils were irradiated in a central cell of each element. All the reaction rates were measured in the same way as for the central reaction rate ratios (see Section 1.3 and MTN/30). The corrections applied to the measurements made using the horizontal foils to obtain the cell average values are given in Table 1.102.

As in MZA, spot checks were made on the variation of gamma-activity per fission at the core centre and at radial positions (50,63) in the outer core and (50,67) in the natural uranium metal breeder. Spot checks were also made on the differences between the variations in cell average C28 and F28 reaction rates across the reactor and the variations measured with the large horizontal foils. It was assumed that any differences in the variation for F25 would be small and could be calculated sufficiently accurately.

The data given in different MTNs differ, the contribution of U235 to F28 measured using the U238 foils being revised in MTN/94, these being the values quoted in the present document.

The results of the measurements made using foils in MZB are summarised in the Tables 1.103 to 1.110.

Azimuthal scans were measured in the sector blankets and the results can be found in MTN/57

Table 1.102 Recommended Values to Convert Horizontal Foil Scan Results to Cell Average Results

Location	F25	F28	C28
Inner Core	1.000	1.000	1.000
Outer Core	1.000 ± 0.5 %	0.958 ± 0.6 %	1.005 ± 0.5 %
Inner Edge of Breeder (Nat UO ₂)	1.000 ± 0.5 %	0.966 ± 1.6 %	1.021 ± 0.9 %
Outer Edge of Breeder (Nat UO ₂)	1.000 ± 0.5 %	0.945 ± 2.0 %	1.033 ± 1.0 %
Inner Edge of Breeder (Depl. UO ₂)	1.000 ± 0.5 %	0.979 ± 1.7 %	1.002 ± 1.0 %
Outer Edge of Breeder (Dep. UO ₂)	1.000 ± 0.5 %	0.960 ± 2.2 %	

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Table 1.104 Radial U235 Fission Rate Scan using Foils in MZB/1 and MZB/2

		MZB/1 (Nat UO2 Sector)		MZB/2 (Dep. UO2 Sector)	
Element Position	Distance from Core Centre (mm)	Fission Rate Relative to Centre	s.d. (%)	Fission Rate Relative to Centre	s.d. (%)
50-30	-1085.0	0.1478	3.1	0.1610	3.1
50-31	-1031.3	0.1724	3.1	0.1855	3.1
50-32	- 977.5	0.2163	3.1	0.2255	3.1
50-33	- 921.2	0.2753	1.1	0.2799	0.9
50-34	- 867.5	0.3404	1.0	0.3389	0.9
50-35	- 813.7	0.4070	0.9	0.3979	0.8
50-36	- 760.0	0.4639	0.7	0.4474	0.7
50-37	- 706.3	0.5300	0.7	0.5117	0.7
50-38	- 649.9	0.5937	0.7	0.5759	0.7
50-39	- 596.2	0.6620	0.5	0.6428	0.5
50-41	- 488.8	0.7743	0.4	0.7571	0.4
50-44	- 325.0	0.9071	0.4	0.8918	0.4
50-47	- 163.8	0.9738	0.4	0.9691	0.3
50-50	0.0	1.0000	0.4	1.0000	0.3
50-53	163.8	0.9732	0.4	0.9762	0.3
50-56	325.0	0.8865	0.4	0.8886	0.4
50-59	488.8	0.7629	0.4	0.7673	0.4
50-63	706.3	0.5256	0.7	0.5282	0.7

Table 1.105 Radial U238 Fission Rate Scan using Foils in MZB/1 and MZB/2

		MZB/1 (Nat UO2 Sector)		MZB/2 (Dep. UO2 Sector)	
Element Position	Distance from Core Centre	Fission Rate Relative to	s.d. (%)	Fission Rate Relative to	s.d. (%)
50-30	-1085.0	0.0171	3.5	0.0134	3.6
50-31	-1031.3	0.0276	3.3	0.0226	3.4
50-32	- 977.5	0.0455	3.2	0.0391	3.3
50-33	- 921.2	0.0778	2.1	0.0693	2.1
50-34	- 867.5	0.1366	2.1	0.1276	2.1
50-35	- 813.7	0.2592	2.2	0.2430	2.2
50-36	- 760.0	0.5277	1.2	0.5035	1.1
50-37	- 706.3	0.6803	1.0	0.6554	0.9
50-38	- 649.9	0.7674	0.9	0.7442	0.9
50-39	- 596.2	0.7311	0.4	0.7144	0.4
50-41	- 488.8	0.7934	0.4	0.7813	0.4
50-44	- 325.0	0.9070	0.4	0.8984	0.4
50-47	- 163.8	0.9741	0.4	0.9716	0.4
50-50	0.0	1.0000	0.4	1.0000	0.4
50-53	163.8	0.9707	0.4	0.9692	0.4
50-56	325.0	0.8980	0.4	0.9020	0.4
50-59	488.8	0.7867	0.4	0.7908	0.4
50-63	706.3	0.6794	0.9	0.6807	0.9

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Table 1.106 Radial U238 Capture Rate Scan using Foils in MZB/1 and MZB/2

Element Position	Distance from Core Centre (mm)	MZB/1 (Nat UO2 Sector)		MZB/2 (Dep. UO2 Sector)	
		Capture Rate Relative to Centre	s.d. (%)	Capture Rate Relative to Centre	s.d. (%)
50-30	-1085.0	0.1201	1.0	0.1240	1.2
50-31	-1031.3	0.1528	0.9	0.1568	1.2
50-32	- 977.5	0.2012	0.9	0.2018	1.1
50-33	- 921.2	0.2604	0.9	0.2557	1.0
50-34	- 867.5	0.3278	0.9	0.3186	1.0
50-35	- 813.7	0.3954	0.9	0.3828	1.0
50-36	- 760.0	0.4675	0.5	0.4455	0.4
50-37	- 706.3	0.5308	0.4	0.5084	0.4
50-38	- 649.9	0.5989	0.4	0.5764	0.4
50-39	- 596.2	0.6629	0.4	0.6408	0.4
50-41	- 488.8	0.7751	0.4	0.7564	0.4
50-44	- 325.0	0.9024	0.4	0.8890	0.3
50-47	- 163.8	0.9765	0.4	0.9686	0.3
50-50	0.0	1.0000	0.4	1.0000	0.3
50-53	163.8	0.9684	0.4	0.9746	0.3
50-56	325.0	0.8962	0.4	0.8929	0.3
50-59	488.8	0.7664	0.4	0.7637	0.3
50-63	706.3	0.5254	0.4	0.5213	0.4

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Table 1.107 Radial Reaction Rate Measurements with Foils in MZB/3
(Shield Room axis)

	Distance	U235 Fission		U238 Fission		U238 Capture	
Region	from Centre	Experiment	s.d. (%)	Experiment	s.d. (%)	Experiment	s.d. (%)
	1085	0.1716	3.3	0.0188	3.5	0.1082	0.7
	1031	0.2111	3.2	0.0297	3.3	0.1443	0.6
Radial	977	0.2644	3.2	0.0468	3.3	0.1931	0.6
Blanket	922	0.3268	3.1	0.0759	3.3	0.2511	0.5
	868	0.3920	0.9	0.1335	2.1	0.3151	0.5
	814	0.4423	0.8	0.2516	2.2	0.3771	0.5
	760	0.4776	0.6	0.5297	1.3	0.4706	0.5
Outer Core	706	0.5318	0.7	0.6787	0.9	0.5217	0.4
	650	0.5932	0.6	0.7678	0.9	0.5896	0.4
	596	0.6542	0.4	0.7281	0.4	0.6517	0.4
	542	0.7135	0.4	0.7548	0.4	0.7109	0.4
	489	0.7668	0.4	0.7930	0.4	0.7665	0.4
	434	0.8126	0.3	0.8307	0.4	0.8814	0.4
	380	-	-	-	-	-	-
	325	0.8896	0.3	0.9017	0.4	0.8937	0.4
	271	-	-	-	-	-	-
	217	0.9505	0.3	0.9583	0.5	-	-
	164	-	-	-	-	-	-
Inner	108	0.9845	0.3	0.9892	0.5	0.9846	0.3
Core	54	-	-	-	-	-	-
	0	1.0000	0.3	1.0000	0.4	1.0000	0.3
	- 54	-	-	-	-	-	-
	- 108	0.9857	0.3	0.9934	0.4	0.9874	0.3
	- 164	-	-	-	-	-	-
	- 217	0.9522	0.3	0.9489	0.5	0.9491	0.3
	- 271	-	-	-	-	-	-
	- 325	0.8912	0.3	0.8968	0.4	0.8923	0.4
	- 380	-	-	-	-	-	-
	- 434	0.8078	0.3	0.8235	0.4	0.8090	0.4
	- 489	0.7634	0.4	0.7883	0.5	0.7601	0.4
	- 542	0.7075	0.4	0.7476	0.4	0.7077	0.4
	- 596	0.6474	0.4	0.7196	0.4	0.6470	0.4
	- 650	0.5882	0.6	0.7578	0.9	0.5861	0.4
Outer Core	- 706	0.5246	0.7	0.6701	0.9	0.5171	0.4
	- 760	0.4752	0.6	0.5201	1.3	0.4652	0.5
	- 814	0.4419	0.8	0.2506	2.3	0.3731	0.5
Radial	- 868	0.3911	0.9	0.1339	2.2	0.3129	0.5
Blanket	- 922	0.3337	3.1	0.0781	3.3	0.2530	0.5
(ShieldRoom	- 977	0.2732	3.2	0.0476	3.3	0.1967	0.6
Side)	- 1031	0.2241	3.2	0.0308	3.4	0.1511	0.6
	- 1085	0.1890	3.3	0.0196	3.6	0.1171	0.7

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Table 1.108 Axial Reaction Rate Distribution Measurements with Foils in Position 50-50 in MZB/3 (U235 fission)

		U235 Fission	
Region	Distance below Centre Line (mm)	Experiment	s.d.(%)
	- 772.8	0.2226	3.1
Axial	- 685.2	0.3043	3.0
Blanket	- 597.7	0.4177	3.0
	- 510.1	0.5359	0.8
	- 374.2	0.6476	0.6
	- 293.1	0.7590	0.3
	- 212.0	0.8659	0.3
	- 131.0	0.9505	0.2
Inner	- 49.9	0.9933	0.2
Core	31.2	1.0000	0.2
	112.3	0.9721	0.2
	193.4	0.9093	0.3
	274.5	0.8121	0.2
	355.6	0.7028	0.2
	436.7	0.6163	0.6
	469.4	0.6046	0.7
Axial	556.5	0.5137	3.0
Blanket	643.6	0.3949	3.0
	730.7	0.2954	3.1

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Table 1.108 continued (U238 fission and capture)

Region	Distance below Centre Line	U238 Fission		U238 Capture	
		Experiment	s.d. (%)	Experiment	s.d. (%)
	- 754.1	0.0227	3.3	0.1837	0.6
Axial	- 666.5	0.0441	3.2	0.2654	0.5
Blanket	- 578.9	0.0883	3.2	0.3799	0.4
	- 491.4	0.1942	2.0	0.5093	0.3
	- 436.7	0.3581	1.1	0.5696	0.3
	- 355.6	0.5991	0.4	0.6650	0.3
	- 274.5	0.7577	0.3	0.7805	0.2
	- 193.4	0.8734	0.2	0.8903	0.2
Inner	- 112.3	0.9543	0.2	0.9615	0.2
Core	- 31.2	0.9917	0.2	0.9925	0.2
	+ 49.9	1.0000	0.2	1.0000	0.3
	+ 131.0	0.9582	0.2	0.9672	0.2
	+ 212.0	0.8802	0.2	0.8900	0.2
	+ 293.1	0.7672	0.3	0.7838	0.2
	+ 374.2	0.6123	0.9	0.6767	0.2
	+ 488.0	0.2515	1.9	0.5425	0.3
Axial	+ 575.1	0.1097	3.2	0.4221	0.4
Blanket	+ 662.2	0.0546	3.2	0.3042	0.4
	+ 749.3	0.0292	3.2	0.2176	0.6

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Table 1.109 Measured Axial U238 Foil Capture Rate Distribution in Position (50,37) in the Outer Core of MZB/3

Region	Distance below Centre Line (mm)	Experiment	s.d. (%)
	- 757.8	0.1817	0.6
Axial	- 670.2	0.2618	0.5
Blanket	- 582.6	0.3726	0.5
	- 495.1	0.4985	0.3
	- 402.9	0.6015	0.3
	- 328.0	0.7088	0.2
	- 253.0	0.8150	0.2
	- 178.1	0.9084	0.2
	- 103.1	0.9668	0.2
Outer	- 28.2	1.0000	0.2
Core.	+ 46.8	0.9998	0.2
	+ 121.7	0.9668	0.2
	+ 196.7	0.9014	0.2
	+ 271.6	0.8086	0.2
	+ 346.6	0.7030	0.2
	+ 431.5	0.5996	0.3
	+ 491.7	0.5157	0.3
Axial	+ 579.0	0.3977	0.4
Blanket	+ 666.2	0.2885	0.4
	+ 753.5	0.2061	0.5

Table 1.110 Measured Axial U238 Foil Capture Rate in Position (50,33) in the Radial Blanket of MZB/3

Region	Distance below Centre Line (mm)	Experiment	s.d. (%)
	- 473.7	0.4935	0.4
	- 423.3	0.5794	0.3
	- 373.0	0.6523	0.3
	- 322.6	0.7264	0.2
	- 272.3	0.7989	0.2
	- 221.9	0.8655	0.2
	- 171.6	0.9134	0.2
	- 121.2	0.9506	0.2
Inner	- 70.9	0.9812	0.2
Radial	- 20.5	1.0000	0.2
Blanket	29.8	0.9918	0.2
	80.2	0.9835	0.2
	130.5	0.9486	0.2
	180.9	0.9126	0.2
	231.2	0.8514	0.2
	281.6	0.7852	0.2
	331.9	0.7174	0.2
	382.3	0.6444	0.3
	432.6	0.5598	0.3
	483.0	0.4798	0.3

In conclusion, the reaction rate scan measurements are recommended as suitable for consideration as benchmark measurements. The inter-comparison of the results obtained using foils and chambers and inter-comparison of the C/E values obtained for different reactions, U235, U238 and Pu239 fission, U238 capture, Ni58(n,p) and Al27(n,γ), enables the consistency of the sets of data to be assessed.

1.7.3 Description of Material Data.

The materials of the cores are the standard MZA and MZB materials and dimensions as described in Section 1.1.3. The representation of the sector radial blanket and the steel and graphite radial reflectors is required for the calculation of the radial scan measurements in MZB. In MZB Version 1 the sector contains the two types of natural uranium oxide blanket element, B12-30 (Central cell B12-31) and an outer ring of elements B12-30A (Central cell B12-31A). The Blanket Sector of MZB Version 2 contains the depleted uranium oxide element B12-32 (Central cell B12-32) (see Table 1.15 for a description of the blanket element loadings). The graphite reflector sector consists of elements B12-33 in the central section of the sector and B12-31 in the left and right sections of the graphite sector (see Figure 1.10 and see Table 1.16 for a description of the graphite element loadings).

1.7.4 Temperature

The temperature was not recorded and no temperature corrections were made.

1.7.5 Additional Information Relevant to the Reaction Rate Distribution Measurements

None.

1.8 Description of Power Distribution Data

Not measured.

1.9 Description of Isotopic Measurements

Not measured.

1.10 Description of other Miscellaneous Types of Measurements

Not measured.

2. EVALUATION OF EXPERIMENTAL DATA

2.1 Evaluation of Critical or Subcritical Configuration Data

2.1.1 k-effective values of MZA and MZB (Zebra Assemblies 11 and 12).

The experimental k_{eff} values given in Section 1.1 include corrections, and the associated uncertainties, for the following:

- i. the partial insertion of the control rods in the core,
- ii. replacing the control rods by standard core elements
- iii. axial channels in radial blanket elements (for the pulse counters)
- iv. allowance for the decay of Pu241 to Am251 (to give the experimental k_{eff} values for the reference dates of 29th November, 1971 in the case of MZA and 9 May 1972 in the case of MZB)
- v. and for differences in temperature from containment ambient temperature, 23.5°C in the case of MZA and 21.4°C in the case of MZB.

The uncertainties include allowances for:

- the uncertainties in core height, diameter and plutonium content.
- uncertainty in the weight of the silver-copper braze material used on some UO₂ plates
- reproducibility of the critical condition

These were considered to be the major sources of uncertainty in the dimensions and composition (as it affects the calculation of the k_{eff} values).

The total k_{eff} uncertainties derived in this way are 16×10^{-4} for MZA and 9×10^{-4} for the three versions of MZB.

The resulting k_{eff} values and uncertainties based on the measured corrections made to derive measured reference assembly models are reproduced below in Table 2.1 (and are as given in Table 1.28 for MZA and Table 1.33 for MZB).

Table 2.1 k_{eff} Values and Uncertainties (*revised)

	MZA	MZB/1	MZB/2	MZB/3
	Single core zone	Natural uranium oxide blanket sector	Depleted uranium oxide blanket sector	Natural uranium metal blanket
Date	29 Nov. 1971	9 May 1972	9 May 1972	9 May 1972
Temperature	23.5°C	21.4°C	21.4°C	21.4°C
k_{eff}-values	1.0097 ± 0.0016	1.0048 ± 0.0009	1.0042 ± 0.0009	1.0044 ± 0.0009

The steel super-lattice grid plates were omitted from the reference version of the assemblies derived by the ZEBRA measurement team and corrections were made by them for this. However, they are represented in the present reference model and so these corrections have been removed. The plates are 0.25 cm thick and 30.4 cm long and coincide approximately with the axial blankets, being (nominally) between the planes at 50.2cm and 80.6 cm above and below the mid-plane. They correspond to a horizontally smeared density of 0.154 g/cc. The reactivity addition resulting from the inclusion of the plates has now been calculated using the MONK Monte Carlo code and so a correction could be made for omitting them from the model. The effect is 0.0002 ± 0.0003 dk for MZA, and 0.0003 ± 0.0003 dk for MZB. The uncertainty on the correction for the omission of the lattice plates is acceptably small.

Other potential sources of uncertainty are the uncertainties in the other constituents of the core (in addition to the plutonium for which an uncertainty estimate has been made), the UO₂, steel and

sodium. These materials were present in about the same proportions as in the Cadenza plate geometry assemblies and measurements were made of the reactivity worths of the materials in Cadenza cores, and also of the variations of component weights from the nominal values (the measurements are less comprehensive in the Mozart cores but many of the components are the same) .

It was concluded there (ZEBRA-LMFR-EXP-001) that the uncertainty in the total steel content of the plate cells was of the order of $\pm 0.2\%$ and in the sodium content could be as high as $\pm 0.5\%$. Based on the measurements of relative reactivity worths made at different radial positions it was concluded that the uncertainty in the Pu content gives an uncertainty in k_{eff} about 10 times larger than for the same uncertainty in the UO_2 content and 20 times larger than for the same uncertainty in the steel content. With the larger uncertainty of 0.2% in the steel content this would give an uncertainty in k_{eff} of about $\pm 0.5 \times 10^{-4} \text{ dk/k}$ due to the uncertainty in the steel content, insignificant compared with the overall estimated uncertainty. The reactivity worth of the sodium in the Cadenza cores is about $130 \times 10^{-4} \text{ dk/k}$. and so an uncertainty of $\pm 0.5\%$ in the sodium content would result in an uncertainty of $\pm 0.7 \times 10^{-4} \text{ dk/k}$ which is not significant in comparison with the uncertainties on the k_{eff} values given in Table 2.1.

Concerning the modelling of the plate geometry components (using a three dimensional square section representation of the plate) calculations of the difference between a three dimensional representation of the Cadenza plate geometry cells and a smeared two dimensional representation (in which the element sheath is also smeared with the plate contents) gave differences of $40 \times 10^{-4} \text{ dk/k}$. The uncertainties in the plate core dimensions have not been documented (and there is also the effect of the rounded corners of some of the plate core components). However, it is judged that the uncertainty would not contribute more than about $1 \times 10^{-4} \text{ dk/k}$ and so can be ignored.

A possible additional source of uncertainty is the alignment of the core sections of neighbouring elements but there are no estimates of this effect.

It is concluded that all of the significant corrections and sources of uncertainty have been included in Table 2.1 and these data are recommended as the benchmark values for the critical assembly data.

2.1.2 Reactivity differences between Assemblies.

The uncertainties on the measured differences in reactivity between the different versions of MZB are smaller than those associated with the individual directly measured k_{eff} values and can be used to verify the calculated differences.

Table 2.2 Differences in Reactivity between the MZB Assemblies

Directly measured differences in reactivity between the assemblies		
MZB(1) to MZB(2)	-0.00072 ± 0.00003	
MZB(2) to MZB(3)		$+0.00023 \pm 0.00003$

These differences are recommended as a check on the differences between k_{eff} values calculated for the three assemblies.

The quoted uncertainties are essentially those arising from the determination of the criticality and do not take into account the uncertainties in the blanket constituents themselves nor the effects of blanket and shielding uncertainties on flux gradients across the assemblies.

2.2 Evaluation of Buckling and Extrapolation Length Data

In section 1.2 a recommended value for the total geometric buckling value (the sum of the axial and radial values) of $21.5 \pm 0.3 \text{ m}^{-2}$ is given. However, this has been defined as the single value (or fundamental mode) geometric buckling which would reproduce the same value of k_{eff} as the actual energy dependent (and space dependent) bucklings. It is therefore only suitable for calculating k_{eff} and not other characteristics, such as reaction rate ratios or reaction rate distributions. The associated uncertainty in the k_{eff} value (calculated using this buckling value as a measure of the material buckling) is ± 0.0043 (much larger than the figure of ± 0.0016 for the calculation of k_{eff} using the full assembly model). The uncertainties affecting the estimation of k -effective for MZA also affect the buckling but these uncertainties are negligibly small compared with the above quoted uncertainty in the buckling value. The definition of the core region to which the buckling applies might introduce additional uncertainties because of the super-lattice structure.

2.3 Evaluation of Spectral Characteristics Data

2.3.1 Reaction Rate Ratio Measurements

As described in Section 1.3 the measurements were made using fission chambers, foils and Solid State Track Recorders (SSTRs). Fission chamber measurements were made for U235, U238, Pu239, Pu240 and Pu241. The foil measurements were made for fission in U235, U238 and Pu239 and capture in U238. The SSTRs were used to measure fission in U235 and U238 and, in MZB/1, in Pu239 also.

Corrections were applied to the foil and SSTR measurements for the radial and axial variations in the reaction rates to obtain cell average values. The corrections were based on measurements made of the radial and axial variations within plates and on the surfaces, for the different plates in a cell, supplemented by calculations made using the MURAL collision probability cell code.

The fission chamber measurements of F28/F25, F25/F49, F40/F49 and F41/F49 were made using absolutely-calibrated fission chambers in a half-element in the central core location. The fission chambers were located 1.0 ± 0.5 mm above the sodium plate. Deterministic reactor calculations made using cell average cross-sections must be combined with cell calculations of the variation of the reaction rates through the cell to give values to compare with these fission chamber measurements. A method which has been used is to combine the value calculated for the upper surface of the sodium plate (or within the sodium plate) with the cell flux averaged value, because half of the flux incident on the foil comes from above and originates from the edge regions of all the plates in a cell.

It is stated in BTN-131, that the threshold fission ratios have been increased to allow for inelastic scattering in the surrounding steel, the increase being 1.5% for F28/F25 and 0.6% for F40/F49. It is also said that because of difficulties in modelling the chambers and their surroundings it is proposed there that additional modelling uncertainties should be included, these being $\pm 1.0\%$ for F25/F49 and F41/F49 and $\pm 4.0\%$ for F28/F25 and F40/F49. These increases in the uncertainties in the fission chamber measurements are applied to the present values.

It is possible to approach the question of the assessment of uncertainties by looking at the consistency between the measurements made in the Mozart cores and in other ZEBRA cores and also at the consistency between the measurements made by the ZEBRA team and by other teams (using their own equipment) in inter-comparison exercises. Comparisons for the later Zebra cores are described in ZEBRA-LMFR-EXP-001, Section 2.3, where they led to the proposal to assign possible systematic uncertainties to the Zebra measurements associated with the techniques used by the Zebra team. It would be appropriate to consider the application of these additional uncertainties to the Mozart programme measurements also.

2.3.2 Comparisons with Measurements made in other ZEBRA Assemblies.

Comparisons of the values of $100 \cdot (C-E)/E$ calculated for the Mozart cores with those calculated for the Cadenza Assembly, Core 22, are made in Table 2.3. The calculations were made using the MONK continuous energy Monte Carlo code and the JEF-2.2 nuclear data library.

Table 2.3 Comparison of $100 \cdot (C-E)/E$ values for MONK/JEF-2.2 Calculations for the Measurements made in MZA and MZB with the Measurements made in Assembly 22

Cell average values	MZA	MZB	Core 22
F28/F25	-3.7% ($\pm 1.6\%$)	-0.6% ($\pm 2\%$)	-4.9% ($\pm 1.4\%$)
F25/F49	1.9% ($\pm 1.5\%$)	-0.2% ($\pm 1.9\%$)	0.7% ($\pm 1.6\%$)
C28/F49	-0.5% ($\pm 1.0\%$)	0.5% ($\pm 1.1\%$)	-2.4% ($\pm 1.0\%$)

Assembly 22 was studied about 10 years later than the Mozart cores. The core regions in which the measurements were made contained different cell compositions and so agreement is not to be expected. Differences are already present between the results for MZA and MZB and they are not markedly different for Core 22. The ratio which is most sensitive to spectrum changes is F28/F25 and so the differences between the C/E values for this ratio could be genuine (although it does imply that the error in the cross-section data is strongly energy dependent). The difference between the MZA and MZB results for F25/F49 is more surprising although the difference is within the combined uncertainty (which, however, includes a systematic component common to both). The difference between the results for C28/F49 in the Mozart cores and in Core 22 is outside the combined uncertainty, however.

One cannot draw any assurance from this comparison, which suggests that the random uncertainties could be larger than the quoted values.

2.3.3 Intercomparisons with the Measurements made by other Groups.

A number of intercomparisons are summarised in ZEBRA-LMFR-EXP-001, Section 2.3, leading to the recommendation to associate possible systematic uncertainties with the measurements made by the Zebra team to cover the differences between the results obtained using the Zebra measurement techniques and those of the other teams. These additional systematic uncertainties are based on the comparisons summarised in Table 2.4, namely $\pm 3\%$ associated with the measurements of F28/F25 and C28/F49, and $\pm 1\%$ with F25/F49.

Table 2.4 Summary of Differences relative to AEEW/ZEBRA Measurements.

Ratio	ANL (Core 22)	IRMA mean	KfK Bizet	CEN Bizet	Proposed Systematic Uncertainty
F28/F25	+2.9%	+1.9%	-3.8%	+0.5%	$\pm 3\%$
F25/F49	-1.6%	-0.8%	-0.8%	+0.2%	$\pm 1\%$
C28/F49	-3.2%	+2.6%	-1.3%	-3.8%	$\pm 3\%$

There were earlier intercomparisons between the Zebra and the Cadarache Masurca measurement techniques. In Zebra Assembly 10 (the assembly before the Mozart programme) the comparison showed (documents ZERS10-4 and -6) that the Zebra measured value of F28/F25 was about 5% higher than the Masurca team's value while for F25/F49 the measured values agreed to within the combined uncertainty of $\sim \pm 2\%$. For C28/F25 the Zebra values were about 3% to 4% higher than the Masurca team's value. The proposed systematic uncertainties given in Table 2.4 are considered to be appropriate also for the Mozart programme measurements.

2.3.4 Effects of Uncertainties in Composition and Dimensions.

As described in ZEBRA-LMFR-EXP-001, in BTN-23 calculations of the effects of changing cell components in the core BZA are described. These changes cause changes to the core neutron spectrum which change the spectrum averaged values of the cross-sections. Fundamental mode calculations, using a specified buckling, for the inner core and outer core of the assembly are made replacing core components with alternatives. Changing the plutonium plate in an inner core cell from the Mk VIII plate to a Mk V plate gave the largest effect for changes to the plutonium plate. Replacing the double sheath by a single sheath gave effects of a few tenths of a percent as did removing the trace quantities of hydrogen from the cell. Calculations were also made changing the sodium plate in an outer core cell. However, the main effect in this case was from the associated changes in the steel canning and H content.

The changes to k_{eff} and the reaction rate ratios for the inner core cell are given in Table 2.5. These were generally less than about 0.5%, with the largest effect being from removing the trace quantities of hydrogen from all the components. The estimation of the hydrogen content could be uncertain by about 50% and so an uncertainty in reaction rate ratios of 0.3%, arising from this source, is proposed. Uncertainties in the UO_2 , steel and sodium contents could add similar uncertainties bringing the total uncertainty in the reaction rate ratios from uncertainties in compositions to about $\pm 0.5\%$.

Table 2.5 Effects of Changes from the Standard Loading of the Inner Core Cell in BZD

	Change	k_{eff} ($\times 10^{-4}$)	Changes in percent				
			F25/F49	F28/F49	C28/F49	F40/F49	F41/F49
Mk V Pu plate	1% increase in Pu239 + reductions in Pu240 and Pu241	+18.6	-0.01	0.09	-0.03	0.19	-0.01
H removed	H removed	-0.5	-0.40	0.18	-0.12	0.58	-0.38
Steel sheath changed	Double sheath replaced by the single sheath	-0.6	-0.13	0.12	-0.06	0.32	-0.13

2.3.5 Recommended Spectral Index Values

The conclusions drawn from the above comparisons are that the measurements made in the Mozart cores and described in Section 1.3 can be recommended as benchmark measurements but with a small increase in the uncertainties of $\pm 0.5\%$ to cover possible effects of uncertainties in composition (mainly the hydrogen content of the materials) and the attributing of possible systematic uncertainties associated with the Zebra measurement techniques based on the many inter-comparisons which have been made.

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Table 2.6A Recommended Reaction Rate Ratio Measurements

Reaction rate ratio	Measured (s.d. in percent)	Addition for chamber location and casing	Addition for core material contents uncertainty	Total uncertainty
MZA				
F28/F25 (Cell Average)	0.03356 ($\pm 1.3\%$)		$\pm 0.5\%$	$\pm 1.4\%$
F25/F49 (Cell Average)	0.978 ($\pm 1.8\%$)		$\pm 0.5\%$	$\pm 1.9\%$
C28/F49 (Cell Average)	0.1291 ($\pm 1.3\%$)		$\pm 0.5\%$	$\pm 1.4\%$
F28/F25 (Chamber)	0.03348 ($\pm 0.5\%$ or 0.8% s)	$\pm 4.2\%$	$\pm 0.5\%$	$\pm 4.3\%$
F25/F49 (Chamber)	0.9818 ($\pm 0.7\%$ or 1.3% s)	$\pm 1\%$	$\pm 0.5\%$	$\pm 1.9\%$
F40/F49 (Chamber)	0.2565 ($\pm 1.1\%$ or 1.9% s)	$\pm 4.1\%$	$\pm 0.5\%$	± 4.7
F41/F49 (Chamber)	1.279 ($\pm 0.9\%$ or 3.0% s)	$\pm 1\%$	$\pm 0.5\%$	$\pm 3.3\%$
MZB/1				
F28/F25 (Cell Average)	0.02283 ($\pm 1.1\%$)		$\pm 0.5\%$	$\pm 1.2\%$
F25/F49 (Cell Average)	1.066 ($\pm 1.2\%$)		$\pm 0.5\%$	$\pm 1.3\%$
C28/F49 (Cell Average)	0.1428 ($\pm 1.2\%$)		$\pm 0.5\%$	$\pm 1.3\%$
F28/F25 (Chamber)	0.02256 ($\pm 0.7\%$ or 0.9% s)	$\pm 4.2\%$	$\pm 0.5\%$	$\pm 4.4\%$
F25/F49 (Chamber)	1.054 ($\pm 0.8\%$ or 1.3% s)	$\pm 1\%$	$\pm 0.5\%$	$\pm 1.9\%$
F40/F49 (Chamber)	0.2023 ($\pm 1.1\%$ or 1.6% s)	$\pm 4.1\%$	$\pm 0.5\%$	± 4.7
F41/F49 (Chamber)	1.356 ($\pm 0.8\%$ or 2.9% s)	$\pm 1\%$	$\pm 0.5\%$	$\pm 3.2\%$
MZB/3				
F28/F25 (Chamber)	0.02248 ($\pm 0.7\%$ or 0.9% s)	$\pm 4.2\%$	$\pm 0.5\%$	$\pm 4.4\%$
F25/F49 (Chamber)	1.059 ($\pm 0.8\%$ or 1.3% s)	$\pm 1\%$	$\pm 0.5\%$	$\pm 1.9\%$

These reaction rate ratio measurements are recommended as benchmark measurements but with the qualification that there could be additional systematic uncertainties associated with the Zebra measurement techniques, as given in the following Table.

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Table 2.6B Possible Additional Systematic Uncertainty associated with the Zebra Techniques

Reaction rate ratio	Possible additional uncertainty
MZA	
F28/F25 (Cell Average)	$\pm 3\%$
F25/F49 (Cell Average)	$\pm 1\%$
C28/F49 (Cell Average)	$\pm 3\%$
F28/F25 (Chamber)	$\pm 3\%$
F25/F49 (Chamber)	$\pm 1\%$
F40/F49 (Chamber)	
F41/F49 (Chamber)	
MZB/1	
F28/F25 (Cell Average)	$\pm 3\%$
F25/F49 (Cell Average)	$\pm 1\%$
C28/F49 (Cell Average)	$\pm 3\%$
F28/F25 (Chamber)	$\pm 3\%$
F25/F49 (Chamber)	$\pm 1\%$
F40/F49 (Chamber)	
F41/F49 (Chamber)	
MZB/3	
F28/F25 (Chamber)	$\pm 3\%$
F25/F49 (Chamber)	$\pm 1\%$

2.3.6 Spectrum Measurements at the Centre of MZA.

The measurements summarised in Table 1.42 comprise a synthesis of the Time-of-Flight measurements and the PRC measurements at energies below about 1 MeV and a synthesis of the three high energy techniques above about 235 keV. The spectra have been condensed to quarter lethargy groups and Gaussian smoothing has been applied.

There is a possible ambiguity about the way the sub-critical core TOF spectrum measurements were adjusted to relate to the critical core (fundamental mode or critical core) and we note also that the energy scale of the PRC measurements has been adjusted to give more consistency between the different measurements. Nevertheless there is an acceptable overall consistency between the different measurements.

Bearing in mind the possible ambiguity between core and fundamental mode, and the possible effect of the adjustment to the PRC energy scale, which could affect the overall spectrum shape, the measurements are considered to be a useful check on core spectrum calculations and the data in Table 1.42 are recommended as benchmark measurements.

2.3.7 PRC Spectrum Measurements in the Radial Blanket and Shield Region of MZB/2.

The measurements presented in Table 1.43 have been obtained using just the one measurement technique, PRC, and so it isn't possible to judge their quality by making intercomparisons with other techniques. On the basis of the intercomparisons made for the measurements made in the core of MZA the uncertainty assessment is judged to be reasonable and the measurements are considered suitable as benchmark measurements.

2.4 Evaluation of Reactivity Effects Data

2.4.1 Reactivity Scale Measurements.

Reactivity changes were measured relative to the change in insertion of the calibrated control rod used to maintain criticality, and expressed in terms of "standard cms" of movement of the rod. The standard cm is the reactivity change resulting from a 1 cm movement at the point of maximum reactivity change with movement of the rod, the point of inflection. Other control rod movements are then expressed in terms of the equivalent standard cms. This requires the "rod profile" to be measured, the relative changes in reactivity with rod movement at different levels of insertion.

The "standard cm" of movement was calibrated by "period" measurements to give reactivity changes in absolute terms. This equivalence depends on the delayed neutron data used to interpret the measurements and introduces a systematic uncertainty of $\pm 5\%$. It also depends on the measured period because this affects the relative contributions of the delayed neutrons from fission in the different isotopes, the typical period in the case of the Zebra measurements being 100 secs. The delayed neutron data used (the Smith-Tomlinson set, MTN/104)) and the associated uncertainties are discussed more fully in Part 2 of the Mozart Programme, ZEBRA-LMFR-EXP-003, which describes the measurements of the reactivity worths of mock-up control rods. Relative reactivity worth measurements are not affected by this uncertainty. Alternative reactivity scales were also considered, in particular one based on the comparison of the measured and calculated effect of changes in the plutonium content of cells and one based on the comparison of the measured and calculated worths of edge elements. Again, this is discussed more fully in Part 2.

In addition to this systematic uncertainty of $\pm 5\%$ there are random uncertainties in the measured "standard cms" arising from uncertainties in rod profile and from reproducibility and drift. There is also the possibility of an interaction between the perturbation and the control rod worth which can necessitate the recalibration of rod worth. These effects are typically at the $\pm 1\%$ level.

The quoted measured values of reactivity effects given in Section 1.4 take into account the random components of the uncertainty but usually do not explicitly include the systematic component of $\pm 5\%$ although a note is included saying that this uncertainty is to be applied.

The effects of uncertainties in core composition and dimensions give effects at the tenths of a percent level and so are not significant.

Reactivity worth measurements

The measurements are made by replacing plates in the cells of core elements by plates containing the material of interest and measuring the change in insertion of the regulating rod when the perturbed element replaces the unperturbed element.

Corrections are made for changes in the weight of steel in the cell and for any change in the height of cells so that a value is obtained for the reactivity worth of the core material introduced into the cell. These corrections for changes in the weight of steel and cell height are based on measurements made with a range of steel components in plate geometry.

Sodium voiding reactivity worth

The sodium reactivity worth measurements summarised in Section 1.4 Tables 1.50 to 1.52, are measurements of the effect of removing sodium from the cells, with the other components remaining unaltered. Corrections have been made by the measurers for any changes in core height and for the change in the weight of steel (which was assessed to have a negligible effect). The measurements were made for different axial sections at the centre of MZA and MZB/2, and at different radial

positions in MZB/2. Note that the axial dimension given in the Tables is to be interpreted as the sum of the effects measured for the positive and negative ranges. Random uncertainties are typically 10% - 20%.

The $\pm 5\%$ systematic uncertainty in the reactivity scale is not included in the tabulated values because the relative effects for different regions of the core will not be affected by this, only an absolute value.

Small sample reactivity worths

The results of the measurements of the reactivity effects of the replacement of materials in the cells are given in Tables 1.53 to 1.58. They include measurements for plutonium metal plates of different enrichments, the effect of changing the quantity of plutonium in the cells, removing the UO_2 , and changing the sodium and steel content. In addition, the effect of adding absorbers, tantalum and boron is measured. More comprehensive measurements of the reactivity effects of these absorber materials are made in the MZC phase of the Mozart programme (described in the Part 2 document, ZEBRA-LMFR-EXP-003).

The uncertainties do not include the $\pm 5\%$ systematic uncertainty in the reactivity scale. Furthermore they appear to be too small, (being in many cases less than 1%) to have included the random uncertainty arising from the uncertainty in control rod profile, and arising from reproducibility and drift, which in the Cadenza cores was a combined uncertainty of the order of 1%. It is recommended that a random uncertainty of $\pm 1\%$ be combined with the figures given in Tables 1.53 to 1.58.

Plate elements replaced by Pin geometry elements.

The changes in reactivity for the replacement of 25 elements (at the core centre and inner core boundary of MZB) have a quoted uncertainty of about 0.4×10^{-4} dk/k. These measurements, described in Section 1.4, could usefully be combined with the more comprehensive Cadenza pin versus plate geometry measurements (ZEBRA-LMFR-EXP-001) in providing results for a different environment.

The reactivity worth measurements summarised in Section 1.4 are recommended as benchmarks with the qualification that the random uncertainty on the plate sample worth measurements be increased by the addition of a $\pm 1\%$ uncertainty to cover the effects of the uncertainty in rod profile, reproducibility and drift. Also, when absolute effects (as distinct from relative effects) are being considered, account must be taken of the $\pm 5\%$ systematic uncertainty in the reactivity scale.

2.5 Evaluation of Reactivity Coefficients Data

There are no benchmark measurements.

2.6 Evaluation of Kinetics Data

There are no benchmark measurements.

2.7 Evaluation of Reaction-Rate Distributions

Axial and radial reaction rate scan measurements in MZA and MZB.

Axial and radial measurements were made in MZA and MZB using both fission chambers and foils and included U235 fission, Pu239 fission, U238 fission and U238 capture, and the threshold reactions Ni58(n,p) and Al27 (n, α). The distributions were measured through the different sector radial blankets of MZB.

The results of the measurements are presented in Section 1.7 and a discussion of the sources of uncertainty is included. Intercomparisons of the measurements made using fission chambers and foils provide a basis for assessing the results. We see from Tables 1.62 to 1.65 that in some cases the differences are significantly larger than the combined uncertainties. The set of measurements is sufficiently comprehensive for it to be possible to identify discrepant measurements from the comparison of C/E values.

The measurements presented in Section 1.7 are recommended as a benchmark set of measurements, taking into account any discrepancies between the foil and chamber measurements by increasing the uncertainties when these are present.

As an illustration of the uncertainties we can note the following values for MZA:

Foil measurements

- for F25 ranged from 0.3% at the core centre to 3% at the outer edge of the blanket,
- for F28 ranged from 1% to 5%
- for C28 from 0.4% to 1% (0.4% to 2% when corrected to a cell average C28 scan)
- for Ni(n,p) from 0.2% to 2%
- and for Al(n, α) from 0.2% to 2%

The Fission Chamber measurements

- for F49 ranged from 0.2% at the core centre to 0.7% blanket,
- for F25 ranged from 0.2% to 0.9%
- for F28 ranged from 0.3% to 3.2%
- for F40 ranged from 0.3% to 2.6%
- for F37 ranged from 0.2% to 1.7%

The values for the measurements in MZB are similar.

2.8 Evaluation of Power Distribution Data

Not measured.

2.9 Evaluation of Isotopic Measurements

Not measured.

2.10 Evaluation of other Miscellaneous Types of Measurements

Not measured.

3. BENCHMARK SPECIFICATIONS

3.0 Overview of the Calculational Methodology and the Models.

The XYZ geometry models are based on XY geometry plans describing the arrays of square section elements which form the assemblies. The XY geometry plan of MZA is illustrated in Figure 1.6 and for MZB/3 in Figures 1.8B to 1.10.

The elements consist of axial arrays of cells contained within the square element sheaths. The calculational models therefore involve setting up the data for the three stages:

- (a) the cells,
- (b) the elements
- (c) the arrays of elements plus the steel reflector rods.

The cells themselves are built up from the individual components. The plate geometry core cells are axial arrays of plates enclosed in the element sheath.

In the following sections these three stages are described in detail. The same approach is involved in the models used to calculate all assembly properties: criticality, spectra and spectral indices, reactivity worths and reaction rate distributions. The calculations of criticality require the most accurate modelling, with accuracies of better than 0.1%, whereas a less accurate model could be used for calculating the other properties. This could imply continuous energy Monte Carlo calculations of the criticality. Deterministic methods could be used for calculating the reaction rate distributions and the localised reactivity worths (if suitable Monte Carlo tallying and perturbation methods are not available).

The elements are located on the base-plate and are arranged in groups of 5x5. These groups are separated by a small gap of 0.2665 cm, by the mild steel super-lattice grids which are above and below the core sections of the elements and hold the elements in place. These grids extend (nominally) between 50.2 cm and 80.6 cm above and below the mid plane and are 30.4 cm high, being situated in the blanket/reflector areas of the elements. These are represented in the detailed calculational models. Simplified models are also defined. These could require a calculated correction to be included in the "measured k_{eff} value" to allow for the effect of the simplification.

The distance between the centres of elements within a group of 5x5 is 5.3721 cm and the overall average spacing is 5.4254 cm (the distance between the centres of two superlattices divided by 5). The models which include the representation of the superlattice spacing have an irregular lattice layout and consequently are perhaps more suitable for Monte Carlo calculations. For deterministic calculations it is usual to assume that the elements are located in a regular lattice having the average spacing of elements in the assembly, 5.4254 cm, and this is adopted in the simplified models and the superlattice grid plates are omitted.

Figure 3.1 illustrates the plan view of a plate cell in an element sheath. The plates are treated as square with a width of 5.067 cm. The plutonium, uranium oxide and sodium plates consist of a square core region which is surrounded by canning material. As is shown in the Figures 1.11 to 1.16 in Section 1.1.2 the edge regions of the canned plates do not have a simple geometry but they are represented in calculations as being rectangular parallelepipeds. The core region is also represented as being a rectangular parallelepiped, although the corners of some core regions are rounded. The element sheath has an inner width of 5.102 cm and an outer width of 5.2544 cm. There is therefore a small gap between the edge of the plate and the inner face of the element sheath, a plate width of 5.067 cm compared with the inner width of the element of 5.102 cm, an average gap of $0.035/2 = 0.0175$ cm. This gap will not be aligned in all of the plates in an element. Similarly, there is a small gap between the elements in the 5x5 arrays, the element outer width being 5.2544 cm compared with the lattice spacing of 5.3721 cm, a gap of 0.1177 cm, but again this gap cannot be assumed to be regular because

of possible bowing of elements over the 3 metre length.

The gaps between the plates and element sheath, and between elements, are represented in the first calculational model, denoted as Model A and shown diagrammatically in Figure 3.1, but treating these as uniform streaming gaps is probably not a realistic physical model. The gaps between the groups of 5x5 elements and the superlattice plates are represented in this model.

In Model B the gaps between the plates and the element sheath, and between the element sheaths within the groups of 5x5 elements are eliminated and the steel of the element sheath is smeared over the space between the plate edges and the lattice square boundary within the groups of 5x5 elements, but the gaps between groups of 5x5 elements are preserved. This is considered to be equally as valid a model as Model A and the difference between calculations made using the two models is considered to be an uncertainty in the modelling applying to both models.

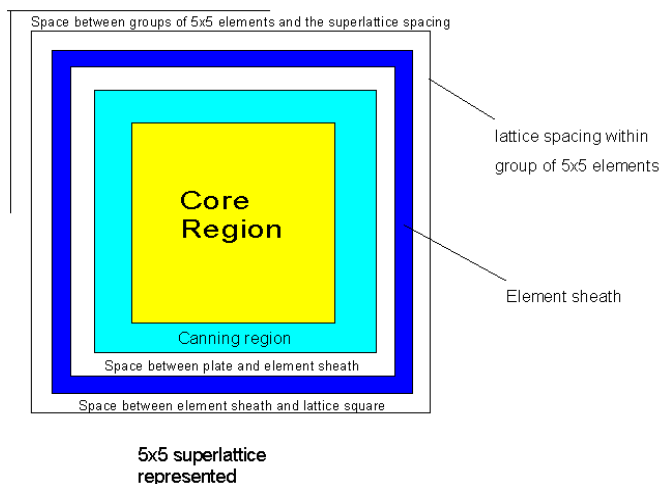
In Model C there is a further simplification. A lattice which is uniform over the whole assembly is adopted and the steel of the element sheath is smeared over the enlarged lattice spacing of 5.4254 cm square. The superlattice plates are also omitted.

In the Models AS, BS and CS the simplification is made that there is just one type of inner core and outer core element in the Models A, B and C respectively. This is chosen to be the dominant element in the region.

For deterministic calculations a further simplification is described and the corresponding compositions derived (Model M). This is to combine the canning in the edge region of the plates with the element steel so that in each plane there are only two regions, the plate core region and the outer steel canning plus element sheath region. This was the model used in the UK collision probability cell code MURAL and is referred to as the MURAL model.

When the original analyses were performed (in the early 1970s) the model was simplified still further and the material in each plate layer was homogenised transversely, combining the core material with the plate edge material and the associated element sheath steel (for the layer having the thickness of the core region). The axial layers above and below the plate core region, containing canning material, were similarly homogenised. Three-dimensional core models were also impractical and two-dimensional XY geometry models and cylindrical models were used. The XY models treated the axial dimension by means of group and zone dependent axial bucklings derived from the cylindrical models. Details of these models can be found in the MTN documents.

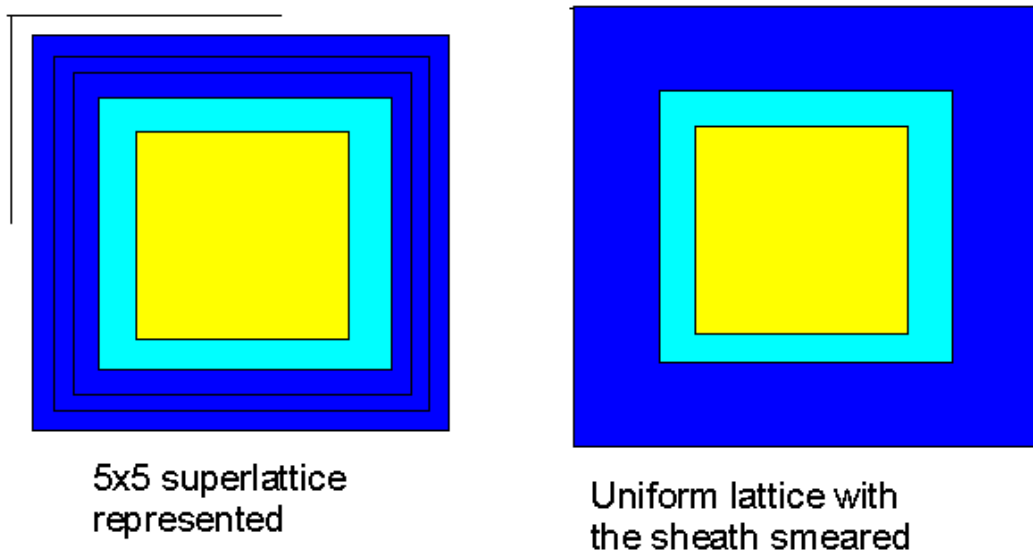
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Model A

Figure 3.1 Diagram of a Plate within an Element Sheath

(Drawing not to scale)



Model B

Model C

Figure 3.2 Diagram of Simplified Models in which the Gaps between Plates, Element Sheath and Lattice Grid are Eliminated.

In Model B the superlattice spacing is preserved and in Model C a uniform lattice is adopted, eliminating the gaps between the groups of 5x5 elements. (Drawing not to scale.)

3.1 Critical or Subcritical Configuration Benchmark Specifications

3.1.1 Description of the Calculational Methodology and the Models

The models adopted for criticality calculations are based on the 213 element core version of MZA (shown in Figure 3.3 and 3.4) and on MZB Version 3 (the version with the uniform radial blanket, Versions 1 and 2 having the radial blanket sectors with different uranium oxide compositions, natural and depleted). These are shown in Figures 3.5 to 3.7B (which shows the Version 1 sector but details the graphite reflector region). The control rods are not represented in the criticality models and the corrections described in Section 1.1 were made for the replacement of these by core elements.

The dimensions of the plates are also simplified, the volume x atomic density being preserved. It is assumed that all plates have the same width of 5.067 cm, but the core widths and thicknesses correspond to the actual dimensions, although any rounded corners are not represented, plates and core regions being treated as rectangular parallelepipeds. The canning of the plates has been assumed to fill the region between the core and the 5.067 cm x 5.067 cm square although the actual canning has a more complicated form, as shown in the Figures in Section 1.1.

Groups of the same type of plate, in particular the plutonium metal plates, have been assumed to have the same dimensions in order to simplify the calculational models. The average values of the dimensions of the different types of plutonium metal plate have been adopted. The dimensions (and hence atomic compositions) of plates can then differ from the values given in other documents.

The core of MZA (Figure 3.4) contains 4 types of core element which differ in the plutonium metal plates and the sodium plates used. These differences are small and an alternative model containing just the A type element is also proposed and evaluated (Model AS etc). The elements in the outer ring of the radial blanket (Figure 3.3) are also different from the elements used in the inner rings of the radial blanket, the difference being in the sodium plates and the graphite plates. For k_{eff} calculations, and to compare with measurements made within the core region (spectra, spectral indices and reactivity worths) the radial blanket can be assumed to consist entirely of the one radial blanket element type, B11-1.

MZB contains four types of element in the inner core (Figure 3.5), and in the outer core (Figure 3.6) 6 types of element. Again the differences are small and a model using just one type of inner core and outer core elements (Model AS etc) is set up. The radial blanket of core MZB/3 contains 3 types of element (and in the wings of the sector there are some modified elements which are not shown in Figure 3.7A). The differences between the three types are small and a single type, B11-1, can be used in calculations of k_{eff} and measurements made in core regions. For calculations of radial reaction rate distributions the graphite reflector (Fig. 3.7B) should be represented.

Calculations of the effects of model simplifications.

Calculations have been made for the different models using the MONK and MCNP Monte Carlo codes and the results are presented in Tables 3.1A and 3.1B. The accuracy of the differences between the calculated values is about $\pm 2 \times 10^{-4}$ dk/k (1 s.d.). The overall conclusion is that the k-effective differences between the Models A and B are not significant. However, because the differences are not consistent for the Model C between MCNP and MONK an additional uncertainty of $\pm 5 \times 10^{-4}$ dk/k is combined with the uncertainties for Model C.

As described in Section 1.1, **cylindrical models** were established based on measurements. The areas of the cylindrical regions are based on the numbers of elements in the region and an area of 5.4254 cm squared per element. For MZA the circular core of the same area was found to be $(10 \pm 1) \times 10^{-4}$ dk/k more reactive than the as-built core. For MZB/3 (which has a uniform radial blanket) the total correction for core smoothing to obtain circular boundaries was estimated in MTN/30 to be $(0 \pm 1) \times$

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10^{-4} dk/k. These corrections are adopted here for the cylindrical models.

The recommended measured values of k_{eff} are those given in Section 2.1.1, Table 2.1, reproduced here, with the value for Model C and the Cylindrical Model added.

Table 3.1 k_{eff} values and Uncertainties to be applied when using Models A and B, Model C and the Cylindrical Model. (*revised)

	MZA	MZB/1	MZB/2	MZB/3
Date	29 Nov. 1971	9 May 1972	9 May 1972	9 May 1972
Temperature	23.5°C	21.4°C	21.4°C	21.4°C
k_{eff} values (Models A and B)	1.0097 ± 0.0016	1.0048 ± 0.0010	1.0042 ± 0.0010	1.0044 ± 0.0010
k_{eff} values (Model C, the uniform lattice model with no void channels)	1.0097 ± 0.0017	1.0048 ± 0.0011	1.0042 ± 0.0011	1.0044 ± 0.0011
k_{eff} values (Cylindrical model)	1.0107 ± 0.0017	1.0048 ± 0.0011	1.0042 ± 0.0011	1.0044 ± 0.0011

Simplified models have also been set up which have just a single type of inner core and outer core element, the dominant ones (the models being denoted by S, for example Model CS is model C with this simplification of the compositions). The effects of the simplifications are small but are probably best calculated using deterministic methods and simpler models than the Monte Carlo methods which have been used.

Table 3.1A k_{eff} values calculated for MZA Models A, B and C

	MZA MCNP-JENDL-3.3	MZA MCNP-JEFF-3.1	MZA MONK JEF-2.2
Model A	1.00948 ± 0.00015	1.01418 ± 0.00015	1.0121 ± 0.00015
Model B	1.00987 ± 0.00016	1.01412 ± 0.00016	1.0124 ± 0.00015
Difference (B-A) Average = $+3 \times 10^{-4}$	$(+3.9 \pm 2.1) \times 10^{-4}$	$(-0.6 \pm 2.1) \times 10^{-4}$	$(+3 \pm 2) \times 10^{-4}$
Model C	1.00931 ± 0.00016	1.01392 ± 0.00015	1.0124 ± 0.00015
Difference (C-B)	$(-5.6 \pm 2.3) \times 10^{-4}$	$(-2.0 \pm 2.2) \times 10^{-4}$	$(0 \pm 2) \times 10^{-4}$
Difference (C-A)	$(-1.7 \pm 2.2) \times 10^{-4}$	$(-2.6 \pm 2.1) \times 10^{-4}$	$(+3 \pm 2) \times 10^{-4}$
Model CS (one type of element)	1.00981 ± 0.00015	1.01430 ± 0.00019	
Difference (CS-C) Average = $+4 \times 10^{-4}$	$(+5.0 \pm 2.2) \times 10^{-4}$	$(+3.8 \pm 2.4) \times 10^{-4}$	
Difference (CS-B)	$(-0.6 \pm 2.2) \times 10^{-4}$	$(+1.8 \pm 2.4) \times 10^{-4}$	
Difference (CS-A) Average = $+2 \times 10^{-4}$	$(+3.3 \pm 2.1) \times 10^{-4}$	$(+1.2 \pm 2.4) \times 10^{-4}$	

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Table 3.1B k_{eff} values calculated for MZB/3 Models A, B and C

	MZB/3 MCNP-JENDL-3.3	MZB/3 MCNP-JEFF-3.1	MONK JEF-2.2 MZB/3ModelS
Model A	1.00518 $\pm$ 0.00012	1.00898 $\pm$ 0.00012	1.0072 $\pm$ 0.00015
Model B	1.00523 $\pm$ 0.00014	1.00963 $\pm$ 0.00014	1.0066 $\pm$ 0.00015
Difference (B-A)	(+0.5 $\pm$ 1.8) $\times 10^{-4}$	(+6.5 $\pm$ 1.8) $\times 10^{-4}$	(-6 $\pm$ 2) $\times 10^{-4}$
Model C	1.00502 $\pm$ 0.00010	1.00886 $\pm$ 0.00015	1.0069 $\pm$ 0.00015
Difference (C-B)	(-2.1 $\pm$ 1.7) $\times 10^{-4}$	(-7.7 $\pm$ 2.1) $\times 10^{-4}$	(+3 $\pm$ 2) $\times 10^{-4}$
Difference (C-A) Average = -2 $\times 10^{-4}$	(-1.6 $\pm$ 1.6) $\times 10^{-4}$	(-1.2 $\pm$ 1.9) $\times 10^{-4}$	(-3 $\pm$ 2) $\times 10^{-4}$
Model CS (one type of element)	1.00427 $\pm$ 0.00014	1.00854 $\pm$ 0.00014	
Difference (CS-C)	(-7.5 $\pm$ 1.7) $\times 10^{-4}$	(-3.4 $\pm$ 2.1) $\times 10^{-4}$	
Difference (CS-B) Average = -10 $\times 10^{-4}$	(-9.6 $\pm$ 1.7) $\times 10^{-4}$	(-10.9 $\pm$ 2.0) $\times 10^{-4}$	
Difference (CS-A) Average = -7 $\times 10^{-4}$	(-9.1 $\pm$ 1.8) $\times 10^{-4}$	(-4.4 $\pm$ 1.8) $\times 10^{-4}$	

Components used in the MZA model.

The arrangement of elements in the assembly is shown in Figures 3.3 and 3.4, and the arrangements of the component plates in the cells and the cells in the elements in Section 3.1.2.

The Simplified MZA Model uses a single type of core element (C11-1A) and radial blanket element (B11-1) and contains the following components:

Core and Axial blanket

PUV8
UO24R4
NASTBR4
GI8
STSTBR8
U8

Plenum

ALSC3
MST1
MST3

Additional components required for the Radial blanket

U2
GII8
MST2
MST8
STSTD8
ALG8
AL2O34

Element sheath

SHEATH

Steel reflector

MST9F10

The Detailed MZA Model uses, in addition, for the core region elements C11-1B, 1C and 1D containing the alternative plutonium metal plates, PUVI8, PUVII8 and PUVIII8, and the alternative sodium plate NASTDL4. The additional radial blanket element B11-1A uses the mild steel sheath, MSHTH, and the sodium plate NASTDL4.

Components used in the MZB Models.

The arrangements of elements in the assembly is shown in Figures 3.5 to 3.7B and the arrangement of the component plates in the cells and the cells in the elements in Section 3.1.2.

The simplified MZB models use the inner core element C12-30A, the outer core element C11-1B (which has the same sodium plate), and the radial blanket element (B11-1). (Most elements in the outer core region use the sodium plate NASTDL4.)

MZB Version 3 uses the following components:

Inner Core and Axial blanket, Cells C12-30A and B12-30

PUIV4
PUIX8
UO23R4
NASTDL4
STSTBR8
GIII8
U8

Outer Core and Axial blanket (Cells C11-1B and B11-1A) - the additional plates:

PUVI8
UO24R4
GI8

Plenum

ALSC3
MST1
MST3

Main Radial blanket

U2
NASTBR4
GII8
MST2
MST8
STSTD8
ALG8
AL2O34

Element sheaths

SHEATH

Steel reflector MST9F10

The Detailed MZB Models use, in addition, the alternative plutonium metal plates and sodium plates in the inner and outer core.

MZB Inner Core. Alternative plates used in the elements C12-30B, BG and D. There are three additional core cells and an additional axial blanket cell. Cell C12-30BG differ from cell C12-30B in the sodium plate used.

Additional plutonium metal plates: PUX8, PUXI8

Additional sodium plates: NASTDM4

MZB Outer Core. This comprises the elements C11-1A, B, C and D used in the core of MZA, together with the additional elements BG and DG which contain the alternative sodium plates NASTDM4 in place of NASTDL4 in elements B and D.

The MZB sector radial blanket elements contain the following components:

MZB Version 1 Sector Radial Blanket (B12-31) containing the natural uranium oxide plates - additional component. (mild steel sheath): NAJII4 and sheath MSHTH

MZB Version 2 Sector Depleted Uranium Radial Blanket element (B12-32 central region cell B12-36): UO2DP4, NAJI4, STSTF8

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Core Plans of the MZA Assembly.

	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	
67																X	X	X	X	X															67	
66															X						X															66
65											X	X	X	X								X	X	X	X											65
64								X	X								B	B	B							X	X									64
63							X						B	B	B	B	B	B	B	B	B	B	B				X									63
62							X					B	B											B	B				X							62
61						X					B	B													B	B					X					61
60					X					B																	B					X				60
59				X				B																				B					X			59
58				X				B									D	D	D											B			X			58
57			X				B	B							D	D	D	C	C	C	D	D	D						B	B			X			57
56			X				B							D	D	C	C	C	C	C	C	C	D	D						B			X			56
55			X				B						D	C	C	C	C	B	B	B	B	C	C	C	C	D					B		X			55
54			X				B				D	D	C	C	B	B	B	B	B	B	B	B	C	C	D	D					B		X			54
53	X						B				D	C	C	B	B	A	A	A	A	A	B	B	C	C	D						B			X		53
52	X						B				D	C	C	B	A	A	A	A	A	A	A	B	C	C	D						B				X	52
51	X						B	B			D	C	C	B	B	A	A	A	A	A	A	B	B	C	C	D					B	B			X	51
50	X						B	B			D	C	C	B	B	A	A	A	A	A	A	B	B	C	C	D					B	B			X	50
49	X						B	B			D	C	C	B	B	A	A	A	A	A	A	B	B	C	C	D					B	B			X	49
48	X						B				D	C	C	B	A	A	A	A	A	A	A	B	C	C	D						B				X	48
47	X						B				D	C	C	B	B	A	A	A	A	A	B	B	C	C	D						B				X	47
46			X				B				D	D	C	C	B	B	B	B	B	B	B	C	C	D	D						B		X			46
45			X				B				D	C	C	C	C	B	B	B	B	C	C	C	C	D							B		X			45
44			X				B				D	D	C	C	C	C	C	C	C	C	C	C	D							B			X			44
43			X				B	B			D	D	D	C	C	C	C	C	D	D	D								B	B			X			43
42				X			B										D	D	D											B			X			42
41				X				B																					B				X			41
40					X				B																			B				X				40
39						X				B	B														B	B					X					39
38							X				B	B												B	B					X						38
37								X					B	B	B	B	B	B	B	B	B	B	B						X							37
36									X	X							B	B	B							X	X									36
35											X	X	X	X									X	X	X	X										35
34																X							X													34
33																	X	X	X	X	X															33
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	

Figure 3.3 The MZA Assembly Loading Pattern (The 213 element Reference Core).

The Core elements are denoted by A, B, C, D and the control rods have been replaced by 8 C elements and 1 D element. A denotes C11-1A, etc.

The outer ring of *Italic B* elements denotes the outer ring of blanket elements, these being B11-1B elements, the positions between the core and the B elements being occupied by B11-1 blanket elements. For k_{eff} calculations the radial blanket can be assumed to consist entirely of type B11-1 elements.

X denotes the outer ring of square section steel bars, MST9F10, the space between the B blanket elements and the outer X boundary being occupied by these steel bars

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		42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58		
58									D	D	D									58
57						D	D	D	C	C	C	D	D	D						57
56					D	D	C	C	C	C	C	C	C	D	D					56
55				D	C	C	C	C	B	B	B	C	C	C	C	D				55
54			D	D	C	C	B	B	B	B	B	B	B	C	C	D	D			54
53			D	C	C	B	B	A	A	A	A	A	B	B	C	C	D			53
52			D	C	C	B	A	A	A	A	A	A	A	B	C	C	D			52
51		D	C	C	B	B	A	A	A	A	A	A	A	B	B	C	C	D		51
50		D	C	C	B	B	A	A	A	A	A	A	A	B	B	C	C	D		50
49		D	C	C	B	B	A	A	A	A	A	A	A	B	B	C	C	D		49
48			D	C	C	B	A	A	A	A	A	A	A	B	C	C	D			48
47			D	C	C	B	B	A	A	A	A	A	B	B	C	C	D			47
46			D	D	C	C	B	B	B	B	B	B	B	C	C	D	D			46
45				D	C	C	C	C	B	B	B	C	C	C	C	D				45
44					D	D	C	C	C	C	C	C	C	C	D					44
43						D	D	D	C	C	C	D	D	D						43
42									D	D	D									42
		42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58		

Figure 3.4 MZA (213 Fissile element) Core Loading

A denotes C11-1A, etc.

In this model for calculating k_{eff} , central spectra and spectral indices, and reactivity perturbation worths, the 9 control rods have been replaced by 8 C elements and one D element.

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Core Plans of the MZB Assembly.

	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	
67																																				67
66																																				66
65																																				65
64																																				64
63																																				63
62																																				62
61															D	D	D	D	D	D	D														61	
60													D	D	D	D	D	D	D	D	D	D	D												60	
59												D	D	D	D	G	G	G	G	G	D	D	D	D											59	
58										D	D	D	D	G	B	B	B	B	B	B	B	G	G	D	D	D									58	
57										D	D	G	B	B	B	B	B	B	B	B	B	B	B	G	D	D									57	
56										D	D	G	B	B	B	A	A	A	A	A	A	B	B	B	B	G	D	D							56	
55										D	D	B	B	B	B	A	A	A	A	A	A	A	A	B	B	B	B	D	D						55	
54										D	D	B	B	B	A	A	A	A	A	A	A	A	A	A	B	B	B	D	D						54	
53										D	D	D	B	B	B	A	A	A	A	A	A	A	A	A	B	B	B	D	D	D					53	
52										D	D	G	B	B	A	A	A	A	A	A	A	A	A	B	B	B	B	G	D	D					52	
51										D	D	G	B	B	A	A	A	A	A	A	A	A	A	A	B	B	B	G	D	D					51	
50										D	D	G	B	B	A	A	A	A	A	A	A	A	A	A	B	B	B	G	D	D					50	
49										D	D	G	B	B	A	A	A	A	A	A	A	A	A	A	B	B	B	G	D	D					49	
48										D	D	G	B	B	A	A	A	A	A	A	A	A	A	A	B	B	B	G	D	D					48	
47										D	D	D	B	B	A	A	A	A	A	A	A	A	A	B	B	B	B	D	D	D					47	
46										D	D	B	B	B	A	A	A	A	A	A	A	A	A	B	B	B	D	D							46	
45										D	D	B	B	B	B	A	A	A	A	A	A	A	B	B	B	B	D	D							45	
44										D	D	G	B	B	B	B	A	A	A	A	A	A	B	B	B	G	D	D							44	
43										D	D	G	B	B	B	B	B	B	B	B	B	B	B	B	G	D	D								43	
42										D	D	D	G	G	B	B	B	B	B	B	B	B	G	D	D	D									42	
41												D	D	D	D	G	G	G	G	G	G	D	D	D	D									41		
40												D	D	D	D	D	D	D	D	D	D	D	D											40		
39															D	D	D	D	D	D	D														39	
38																																				38
37																																				37
36																																				36
35																																				35
34																																				34
33																																				33
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	

Figure 3.5 MZB Inner Core.

A denotes C12-30A

B denotes C12-30B

G denotes C12-30BG

D denotes C12-30D

The 8 double and 1 single element control rod have been replaced by 17 x C12-30B elements.

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	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	
67																																				67
66																																				66
65																																				65
64													G	F	D	D	D	D	D	F	G														64	
63											D	D	D	C	C	C	C	C	C	C	D	D	F	G											63	
62									G	D	C	C	B	B	B	A	A	A	B	B	B	C	C	D	F										62	
61								D	C	C	B	A	A								A	A	B	C	D	D									61	
60							D	C	E	B	A											A	B	B	C	D									60	
59						D	C	B	A	A													A	A	B	C	D								59	
58					F	D	C	A																		A	B	D	G						58	
57					G	D	C	B	A																	A	B	C	D						57	
56					F	C	B	A																			A	B	C	D					56	
55					D	C	A																					A	C	D					55	
54				G	D	B	A																					A	B	D	G				54	
53				F	C	B																							B	D	F				53	
52				D	C	B																								B	C	D			52	
51				D	C	A																								A	C	D			51	
50				D	C	A																								A	C	D			50	
49				D	C	A																								A	C	D			49	
48				D	C	A																								A	C	D			48	
47				F	C	B																								B	C	F			47	
46				G	D	B	A																							A	B	C	G		46	
45					D	C	A																							A	C	D			45	
44					D	C	B	A																						A	B	C	F		44	
43					D	C	B	A																						A	B	C	D	G		43
42					G	C	B	A																						A	C	D	F		42	
41						D	C	B	A	A																A	A	B	C	D					41	
40						D	C	B	B	A														A	B	E	C	D							40	
39						D	D	C	B	A	A											A	A	B	C	C	D								39	
38						F	D	C	C	B	B	B	A	A	A	B	B	B	C	C	D	G													38	
37							G	F	D	D	C	C	C	C	C	C	C	C	D	D	D														37	
36													G	F	D	D	D	D	F	G															36	
35																																				35
34																																				34
33																																				33
	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	

Figure 3.6 MZB Outer Core

A denotes C11-1A
D denotes C11-1D

B denotes C11-1B
E denotes C11-1BG

C denotes C11-1C
F denotes C11-1DG

The elements C11-1BG and C11-1DG differ from the elements C11-1B and C11-1D in the sodium plate used, NASTDM4 in place of NASTDL4 (the difference being negligibly small).

	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71									
71																																																	71			
70																			Y	Y	Y	Y	Y	Y	Y																								70			
69															Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y																						69	
68													Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y																			68		
67										Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y																		67	
66								Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y																	66	
65								Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y															65	
64						Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y												Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y													64
63					Y	Y	Y	Y	Y	Y	Y	Y	Y	Y															Y	Y	Y	Y	Y	Y	Y	Y	Y	Y													63	
62					Y	Y	Y	Y	Y	Y	Y	Y	Y																		Y	Y	Y	Y	Y	Y	Y	Y	Y													62
61				Y	Y	Y	Y	Y	Y	Y	Y	Y																					Y	Y	Y	Y	Y	Y	Y	Y	Y											61
60				Y	Y	Y	Y	Y	Y	Y	Y																						Y	Y	Y	Y	Y	Y	Y	Y	Y										60	
59				Y	Y	Y	Y	Y	Y	Y																								Y	Y	Y	Y	Y	Y	Y	Y	Y										59
58				Y	Y	Y	Y	Y	Y																											Y	Y	Y	Y	Y	Y	Y	Y									58
57			Y	Y	Y	Y	Y	Y																												Y	Y	Y	Y	Y	Y	Y	Y	Y								

Y denotes B11-1 O denotes B11-1B W denotes B11-1D
Three rings of the square section steel bars, MST9F10, surround the radial blanket (see Figure 3.7B).

The elements of the sector blanket regions of MZB versions 1 and 2 are replaced in version 3 by the elements W = B11-1D which differs from the element B11-1 in the sodium plate used (NASTDM4) and the graphite plate (GIII8). These differences in fact are considered to have a negligible effect. Some non-standard elements located in the wings of the sector blanket region have been replaced by W elements in this plan of the assembly. (Note: There is a small difference between the radial blanket loadings of Version 1 and 2 in that there is an extra oxide radial blanket element in Version 2 at position 57-31 and the steel bar is moved to position (70,37).)

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Figure 3.7B MZB Version 1 Radial Blanket with the Natural Uranium Oxide Blanket Sector

Y denotes B11-1 O denotes B11-1B Z denotes B11-1C V denotes B11-5
Sector W denotes B12-30 Sector X denotes B12-30A, Reflector T denotes B12-31 U denotes B12-33
Steel bars, denoted by s, surround the inner radial breeder. These extend sideways, in the central
area, beyond the area shown, by the numbers of bars indicated in the rows (see Fig. 1.21).
MZB Version 2 contains the depleted uranium oxide elements B12-32 in the blanket sector.

3.1.2 Components and Dimensions of MZA and MZB Plates, Cells and Elements.

Dimensions of Plates

Table 3.2 Dimensions of the Plates (A repeat of Table 1.6)

(All plates are nominally 5.067 cm square)

Identifier	Type of Plate Plates with a canned core region	Thickness (cm)	Core thickness (cm)	Can thickness (cm)	Core width (cm)
PUIV4	PuO ₂ /UO ₂	0.6278	0.55312	0.03734	4.953
PUII8	Pu metal Mk.II (pert. sample)	0.3175	0.2159	0.0508	4.671
PUIII8	Pu metal Mk.III (pert. sample)	0.3154	0.2138	0.0508	4.671
PUV8	Pu metal Mk.V	0.3256		0.04572	4.671
PUVI8	Pu metal Mk.VI	0.3282		0.04572	4.671
PUVII8	Pu metal Mk.VII	0.3260		0.04572	4.671
PUVIII8	Pu metal Mk.VIII	0.3274		0.04572	4.671
PUIX8	Pu metal Mk.IX	0.3265		0.04572	4.671
PUX8	Pu metal Mk.X	0.3264		0.04572	4.671
PUXI8	Pu metal Mk.XI	0.3261		0.04572	4.671
PUXII8	Pu metal Mk.XII	0.3260		0.04572	4.671
	(Average values used in calcs.)	0.3265	0.23506	0.04572	4.671
UO22R4	UO ₂ (2 radiused corners)	0.6289	0.55524	0.03683	4.851
UO23R4	UO ₂ (3 radiused corners)	0.6313	0.55764	0.03683	4.851
UO24R4	UO ₂ (4 radiused corners)	0.6279	0.55424	0.03683	4.851
UO2DP4	Depleted UO ₂	0.624			
NASTBR4	Sodium (1965 batch, bright can)	0.616	0.54234	0.03683	4.963
NASTDL4	Sodium (First batch 1971, dull can)	0.616	0.54234	0.03683	4.963
NASTDM4	Sodium (2nd batch 1971, dull can)	0.616	0.54234	0.03683	4.963
NAJI4	Sodium (PNC)	0.615	0.5055	0.05475	4.987
NAJII4	Sodium (PNC design)	0.615	0.5055	0.05475	4.987
NAST4P	Sodium (1965 batch, 2.36 cm dia. hole)	(0.6185)			
B4CNAT4	Natural Boron Pert. Sample	0.6198	0.54614	0.03683	4.963

Note: Thicknesses in brackets are assumed or nominal values

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Table 3.2 continued

Identifier	Type of Plate Plates without a can	Thickness (cm)
U8	Natural Uranium	0.317
U2	Natural Uranium	1.2723
U3	Natural Uranium	7.6225
U8P	UNat (2.36 cm dia. hole)	(0.3175)
U16	Natural Uranium	0.1593
93U516	93% Enriched Uranium (Pert)	0.158
MST1	Mild Steel	2.5385
MST2	Mild Steel	1.2718
MST3	Mild Steel	7.6063
MST8	Mild Steel	0.3147
STSTBR8	Stainless Steel (bright)	0.3172
STSTD8	Stainless Steel (dull)	0.3236
STSTF8	Stainless Steel (40% density)	0.317
AL2O34	Alumina	0.6317
ALG8	45% Aluminium	0.3170
ALSC3	Aluminium cylinders	7.62
GI8	Graphite (W+G) Mk.1	0.3180
GII8	Graphite (Morganite) Mk.II	0.31775
GIII8	Graphite	0.319
G2	Graphite CY9	1.27025
G1	Graphite CY9	2.53873
G3	Graphite CY9	7.62
G75	Graphite CY9	19.05
G13	Graphite CS	33.3375
TA8	Tantalum Pert. Sample	0.318

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The Cell Models

Table 3.3 MZA Core Region Cell Patterns, and MZB Outer Core Cells

All components have a square section. The outer width of all plates is taken to be 5.067 cm.

Cell C11-1A	Cell C11-1B	Cell C11-1C	Cell C11-1D	Core Width (cm)	Core thickness (cm)	Can thickness (cm)	Plate Thickness (cm)
NASTBR4	NASTDL4	NASTDL4	NASTDL4	4.963	0.54234	0.03683	0.616
UO24R4	UO24R4	UO24R4	UO24R4	4.851	0.55424	0.03683	0.6279
NASTBR4	NASTDL4	NASTDL4	NASTDL4	4.963	0.54234	0.03683	0.616
PUV8	PUVI8	PUVII8	PUVIII8	4.671	0.23506	0.04572	0.3265
GI8	GI8	GI8	GI8	5.067	0.3180		0.3180
UO24R4	UO24R4	UO24R4	UO24R4	4.851	0.55424	0.03683	0.6279
NASTBR4	NASTDL4	NASTDL4	NASTDL4	4.963	0.54234	0.03683	0.616
NASTBR4	NASTDL4	NASTDL4	NASTDL4	4.963	0.54234	0.03683	0.616
UO24R4	UO24R4	UO24R4	UO24R4	4.851	0.55424	0.03683	0.6279
STSTBR8	STSTBR8	STSTBR8	STSTBR8	5.067	0.3172		0.3172
PUV8	PUVI8	PUVII8	PUVIII8	4.671	0.23506	0.04572	0.3265
NASTBR4	NASTDL4	NASTDL4	NASTDL4	4.963	0.54234	0.03683	0.616
UO24R4	UO24R4	UO24R4	UO24R4	4.851	0.55424	0.03683	0.6279
NASTBR4	NASTDL4	NASTDL4	NASTDL4	4.963	0.54234	0.03683	0.616
Total height							7.4958

Additional cells of this type used in the MZB Outer Core Region

Cell C11-1BG	Cell C11-1DG	Cell C11-1G	Core Width (cm)	Core thickness (cm)	Can thickness (cm)	Plate Thickness (cm)
NASTDM4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
UO24R4	UO24R4	UO24R4	4.851	0.55424	0.03683	0.6279
NASTDM4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
PUVI8	PUVIII8	PuXII8	4.671	0.23506	0.04572	0.3265
GI8	GI8	GI8	5.067	0.3180		0.3180
UO24R4	UO24R4	UO24R4	4.851	0.55424	0.03683	0.6279
NASTDM4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
NASTDM4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
UO24R4	UO24R4	UO24R4	4.851	0.55424	0.03683	0.6279
STSTBR8	STSTBR8	STSTBR8	5.067	0.3172		0.3172
PUVI8	PUVIII8	PuXII8	4.671	0.23506	0.04572	0.3265
NASTDM4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
UO24R4	UO24R4	UO24R4	4.851	0.55424	0.03683	0.6279
NASTDM4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
Total height						7.4958

Note: All cells are contained in stainless steel sheaths.

The cells differ in the plutonium metal plates and sodium plates used but the same dimensions are assumed for all the plutonium metal plates. The sodium plates have the same dimensions.

Height of the Cell C11-1A = 7.4958 cm. Height of the 12 core region C11-1A cells = 89.9496 cm.

This compares with the average measured value of 89.94 cm

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Table 3.4 MZB Inner Core Cell Patterns

Cell C12-30A	Cell C12-30B	Cell C12-30BG	Cell C12-30D	Core Width (cm)	Core thickness (cm)	Can thickness (cm)	Plate Thickness (cm)
NASTDL4	NASTDL4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
UO23R4	UO23R4	UO23R4	UO23R4	4.851	0.55764	0.03683	0.6313
NASTDL4	NASTDL4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
PUIV4	PUIV4	PUIV4	PUIV4	4.953	0.55312	0.03734	0.6278
NASTDL4	NASTDL4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
UO23R4	UO23R4	UO23R4	UO23R4	4.851	0.55764	0.03683	0.6313
STSTBR8	STSTBR8	STSTBR8	STSTBR8	5.067	0.3172		0.3172
NASTDL4	NASTDL4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
UO23R4	UO23R4	UO23R4	UO23R4	4.851	0.55764	0.03683	0.6313
NASTDL4	NASTDL4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
PUIX8	PUX8	PUX8	PUXI8	4.671	0.23506	0.04572	0.3265
NASTDL4	NASTDL4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
UO23R4	UO23R4	UO23R4	UO23R4	4.851	0.55764	0.03683	0.6313
NASTDL4	NASTDL4	NASTDM4	NASTDM4	4.963	0.54234	0.03683	0.616
Cell height							8.1087

Note: All these cells are contained in stainless steel sheaths.

The cells differ in the plutonium and sodium plates used. The UO₂ plate is different from that used in the MZA core and the MZB outer core and the plate thicknesses are different.

Height of the cell C12-30A = 8.1087 cm

Height of the 11 core region C12-30A cells = 89.1957 cm. This compares with the average measured value of 89.20 cm

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Table 3.5 MZA and MZB Axial Blanket Cells

B11-1	B11-1A	B11-1AG	Core Width (cm)	Core thickness (cm)	Can thickness (cm)	Plate Thickness (cm)
NASTBR4	NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
U8	U8	U8	5.067	0.317		0.317
GI8	GI8	GI8	5.067	0.318		0.318
NASTBR4	NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
STSTBR8	STSTBR8	STSTBR8	5.067	0.3172		0.3172
U8	U8	U8	5.067	0.317		0.317
NASTBR4	NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
GI8	GI8	GI8	5.067	0.318		0.318
NASTBR4	NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
U8	U8	U8	5.067	0.317		0.317
STSTBR8	STSTBR8	STSTBR8	5.067	0.3172		0.3172
NASTBR4	NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
GI8	GI8	GI8	5.067	0.318		0.318
NASTBR4	NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
U8	U8	U8	5.067	0.317		0.317
STSTBR8	STSTBR8	STSTBR8	5.067	0.3172		0.3172
NASTBR4	NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
GI8	GI8	GI8	5.067	0.318		0.318
U8	U8	U8	5.067	0.317		0.317
NASTBR4	NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
Total cell height						8.7366

Notes

1. All these axial blanket cells, being in core elements, are contained in stainless steel sheaths.
2. The plate sequences of the axial blanket cells are the same in the top and bottom regions, and are not reflected.
3. The plenum cells appear in both stainless steel and mild steel sheaths as detailed in the Tables of element contents.

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Table 3.5 continued

B12-30	B12-30G	Core Width (cm)	Core thickness (cm)	Can thickness (cm)	Plate Thickness (cm)
NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
U8	U8	5.067	0.317		0.317
GIII8	GIII8	5.067	0.319		0.319
NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
STSTBR8	STSTBR8	5.067	0.3172		0.3172
U8	U8	5.067	0.317		0.317
NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
GIII8	GIII8	5.067	0.319		0.319
NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
U8	U8	5.067	0.317		0.317
STSTBR8	STSTBR8	5.067	0.3172		0.3172
NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
GIII8	GIII8	5.067	0.319		0.319
NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
U8	U8	5.067	0.317		0.317
STSTBR8	STSTBR8	5.067	0.3172		0.3172
NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
GIII8	GIII8	5.067	0.319		0.319
U8	U8	5.067	0.317		0.317
NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
Total cell height (cm)					8.7406

Height of the cell B11-1 = 8.7366 cm and the Height of the 4 cells constituting the upper or lower axial blanket = 34.9464 cm.

This compares with the measured values of:

MZB inner core upper axial blanket = 35.03 cm . Outer core upper axial blanket = 35.03 cm .

MZB inner core lower axial blanket = 34.85 cm. Outer core lower axial blanket = 34.90 cm .

The GIII8 plate is slightly thicker than the GI8 plate (0.319 compared with 0.318 cm) and so the height of the cell B12-30 is 8.7406 and the height of the 4 cells is 34.9624 cm

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Table 3.6 Plenum Region Cells

B11-2	Plate height	B11-2A	Plate height
(upper)	(cm)	(lower)	(cm)
ALSC3	7.62	ALSC3	7.62
MST1	2.5385	MST3	7.6063
ALSC3	7.62	ALSC3	7.62
MST3	7.6063	MST1	2.5385
ALSC3	7.62	ALSC3	7.62
Cell height	33.0048		33.0048

Height of plenum region = 33.0048 cm.

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Table 3.7 Radial Blanket Cells

B11-3	B11-3A	B11-3B	B11-3C	Core Width (cm)	Core thickness (cm)	Can thickness (cm)	Plate Thickness (cm)
NASTBR4	NASTDL4	NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
GII8	GII8	GI8	GIII8	5.067	0.31775		0.31775
MST8	MST8	MST8	MST8	5.067	0.3147		0.3147
NASTBR4	NASTDL4	NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
GII8	GII8	GI8	GIII8	5.067	0.31775		0.31775
U2	U2	U2	U2	5.067	1.2723		1.2723
STSTDL8	STSTDL8	STSTDL8	STSTDL8	5.067	0.3236		0.3236
GII8	GII8	GI8	GIII8	5.067	0.31775		0.31775
NASTBR4	NASTDL4	NASTDL4	NASTDM4	4.963	0.54234	0.03683	0.616
GII8	GII8	GI8	GIII8	5.067	0.31775		0.31775
Cell height							5.0296

B11-4/4A	B11-4B	B11-4C	Plate Thickness (cm)
ALG8	ALG8	ALG8	0.317
MST8	MST8	MST8	0.3147
GII8	GI8	GIII8	0.31775
ALG8	ALG8	ALG8	0.317
AL2O34	AL2O34	AL2O34	0.6317
U2	U2	U2	1.2723
ALG8	ALG8	ALG8	0.317
ALG8	ALG8	ALG8	0.317
GII8	GI8	GIII8	0.31775
ALG8	ALG8	ALG8	0.317
MST2	MST2	MST2	1.2718
AL2O34	AL2O34	AL2O34	0.6317
GII8	GI8	GIII8	0.31775
ALG8	ALG8	ALG8	0.317
U2	U2	U2	1.2723
ALG8	ALG8	ALG8	0.317
GII8	GI8	GIII8	0.31775
AL2O34	AL2O34	AL2O34	0.6317
ALG8	ALG8	ALG8	0.317
ALG8	ALG8	ALG8	0.317
Cell height			10.1502

Note: Cells B11-3 and B11-4 are in stainless steel sheaths, the remainder (including B11-4A) are in mild steel sheaths.

Height of the cell B11-3 = 5.0296. Height of 20 cells = 100.592 cm

The cell B11-3B is 0.001 cm thicker because the plate GI8 is 0.00025 cm thicker than GII8.

Height of the cell B11-4 = 10.1502 cm. Height of 3 cells = 30.4506 cm.

Again the cells B11-4B and 4C differ slightly because of the small differences between the thicknesses of the graphite plates, G.

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Table 3.8 Radial Blanket Cell Patterns for Sectors: The Natural UO₂ Sector

B12-31	B12-31A	Core Width (cm)	Core thickness (cm)	Can thickness (cm)	Plate Thickness (cm)
UO23R4	UO22R4	4.851	0.55764	0.03683	0.6313
NAJII4	NAJI4	4.987	0.5055	0.05475	0.615
UO23R4	UO22R4	4.851	0.55764	0.03683	0.6313
NAJII4	NAJI4	4.987	0.5055	0.05475	0.615
UO23R4	UO22R4	4.851	0.55764	0.03683	0.6313
UO23R4	UO22R4	4.851	0.55764	0.03683	0.6313
NAJII4	NAJI4	4.987	0.5055	0.05475	0.615
UO23R4	UO22R4	4.851	0.55764	0.03683	0.6313
Cell height					5.0015

Depleted UO₂ Sector Cells

B12-36	Core Width (cm)	Core thickness (cm)	Can thickness (cm)	Plate Thickness (cm)
UO2DP4		0.624		0.624
NAJI4	4.987	0.5055	0.05475	0.615
STSTF8		0.317		0.317
UO2DP4		0.624		0.624
NAJI4	4.987	0.5055	0.05475	0.615
UO2DP4		0.624		0.624
STSTD8		0.3236		0.3236
NAJI4	4.987	0.5055	0.05475	0.615
UO2DP4		0.624		0.624
Cell height				4.9816

Note: All these cells are in mild steel sheaths.

The height of the cell B12-31 = 5.0015 cm.
The height of the cell B12-36 = 4.9816 cm

20 cells have a height of 100.03 cm.
20 cells have a height of 99.632 cm

Cell Structure of the Elements

Table 3.9 MZA Core and MZB Outer Core Element Loadings

Region	C11-1A	C11-1B	C11-1BG	C11-1C	C11-1D	C11-1DG	C11-1G	Height (cm)
Upper plenum	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	33.00
Upper blanket	4 cells B11-1	4 cells B11-1A	4 cells B11-1AG	4 cells B11-1A	4 cells B11-1A	4 cells B11-1AG	4 cells B11-1AG	35.03
Core	12 cells C11-1A	12 cells C11-1B	12 cells C11-1BG	12 cells C11-1C	12 cells C11-1D	12 cells C11-1DG	12 cells C11-1G	89.94
Lower blanket	4 cells B11-1	4 cells B11-1A	4 cells B11-1AG	4 cells B11-1A	4 cells B11-1A	4 cells B11-1AG	4 cells B11-1AG	34.90
Lower plenum	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	33.00

Note: Core and axial blanket heights are averages from measurements on eight MZB elements in slotted sheaths. The values differ very slightly from those measured on MZA where averages for six elements were obtained.

In MZA the values were:

Upper axial blanket = 35.03 cm, Lower axial blanket = 34.92 cm, Core = 89.97 cm
with an uncertainty of ± 0.06 cm on these average values.

The plenum heights are nominal and correspond to the plate thicknesses.

Table 3.10 MZB Inner Core Element Loadings

Region	C12-30A	C12-30B	C12-30BG	C12-30D	Height (cm)
Upper plenum	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	33.00
Upper axial blanket	4 cells B12-30	4 cells B12-30	4 cells B12-30G	4 cells B12-30G	35.03
Core	11 cells C12-30A	11 cells C12-30B	11 cells C12-30BG	11 cells C12-30D	89.20
Lower axial blanket	4 cells B12-30	4 cells B12-30	4 cells B12-30G	4 cells B12-30G	34.85
Lower plenum	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	33.00

Note: Core and axial blanket heights are averages from measurements on six elements having slotted sheaths. The plenum heights are nominal.

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Table 3.11 Blanket Element Loadings

Region	B11-1	B11-1B	B11-1C	B12-30	B12-30A	B12-32	Height (cm)
Upper plenum	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	1 cell B11-2	33.00
Upper outer radial blanket	3 cells B11-4	3 cells B11-4A	3 cells B11-4B	3 cells B11-4C	3 cells B11-4C	3 cells B11-4C	30.45
Inner radial blanket or special	20 cells B11-3	20 cells B11-3B	20 cells B11-3C	20 cells B12-31	20 cells B12-31A	20 cells B12-36	See note (b)
Lower outer radial blanket	3 cells B11-4	3 cells B11-4A	3 cells B11-4B	3 cells B11-4C	3 cells B11-4C	3 cells B11-4C	30.45
Lower plenum	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	1 cell B11-2A	33.00

Notes:

(a) All elements have mild steel sheaths except B11-1 which has a stainless steel sheath.

(b) The heights of the central regions, based on plate thicknesses in Table 3.2, and rounded to the nearest mm, are:

For element types B11-1, B11-1B and B11-1C 100.6 cm

For element types B12-30 and B12-30A 100.0 cm

For element type B12-32 containing the B12-36 cells 99.6 cm

The height of the central region of element type B12-32, based on measurements of two elements in the slotted sheath is 99.2 cm.

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Table 3.12 Loadings of Steel and Graphite Reflector Elements

Element Type B11-5 (mild steel)	Height (cm)
Spacer material	6731
18 x MST3 plates + 1 x MST2 plate	138.43
Spacer material	66.04
Element Type B12-33 (graphite)	Height (cm)
3 x STSTF8 shims	0.95
7 x G3 plates	53.34
5 x G13 plates	166.69
7 x G3 plates + 2 x G1 plates	58.42
Element Type B12-31 (graphite)	Height (cm)
4 x STSTF8 shims	1.27
7 x G3 plates + 9 x G75 plates + 7 x G3 plates	278.13
Element Type B12-31A (graphite)	Height (cm)
4 x STSTF8 shims	1.27
1 x G2 plate + 1 x G1 plate + 36 x G3 plates	278.13
5 x G13 plates	166.69

Notes:

1. Dimensions are nominal.
2. Element types B11-5, B12-31 and B12-31A are contained in stainless steel sheaths. Element type B12-33 is contained in a mild steel sheath.
3. Element types B12-33, B12-31 and B12-31A do not have a piston (7.62 cm).

Dimensions of the Cylindrical Models of MZA and MZB/3.

Figures 3.8 and 3.9 show the half-height cylindrical models diagrammatically.

Axial dimensions are based on the heights of sections given in the Tables of element dimensions. Radial dimensions are based on the numbers of element in each region and the lattice area of 5.4254 cm squared (29.435 cm²).

The heights of the MZA and MZB regions are as follows:

Core regions

MZA: The height of the 12 core region C11-1A cells = 89.9496 cm (half height 44.9748 cm).

This compares with the average measured value of 89.94 cm

MZB Inner Core The height of the 11 core region C12-30A cells = 89.1957 cm (half height 44.59785 cm).

This compares with the average measured value of 89.20 cm

Axial blanket regions

The height of 4 x B11-1 cells constituting the MZA upper or lower axial blanket and the MZB outer core axial blanket = 34.9464 cm.

The GII8 plate is slightly thicker than the GI8 plate (0.319 compared with 0.318 cm) and so the height of the 4 x B12-30 cells in the MZB inner core axial blanket is 34.9624 cm

These compare with the following measured values:

MZB inner core upper axial blanket = 35.03 cm . Outer core upper axial blanket = 35.03 cm .

MZB inner core lower axial blanket = 34.85 cm. Outer core lower axial blanket = 34.90 cm .

Axial plenum region

The height of the plenum region = 33.0048 cm.

Central radial blanket regions

Height of 20 x B11-3 cells = 100.5922 cm (half height 50.2961).

Upper and lower radial blanket regions

Height of 3 x B11-4 cells = 30.4506 cm.

Again the cells B11-4B and 4C differ slightly because of the small differences between the thicknesses of the GI8, GII8 and GIII8 plates.

Additional radial blanket elements

The heights of the central regions, based on plate thicknesses in Table 3.2, are:

For element types B11-1, B11-1B and B11-1C 100.6 cm

For element types B12-30 and B12-30A 100.0 cm

For element type B12-32 containing the B12-36 cells 99.6 cm

The height of the central region of element type B12-32, based on measurements of two elements in the slotted sheath is 99.2 cm.

Figure 3.8 Cylindrical Geometry Half-height Model of MZA

(-3A denotes the element B11-3A, 4A denotes B11-4A and -2A denotes B11-2A.)

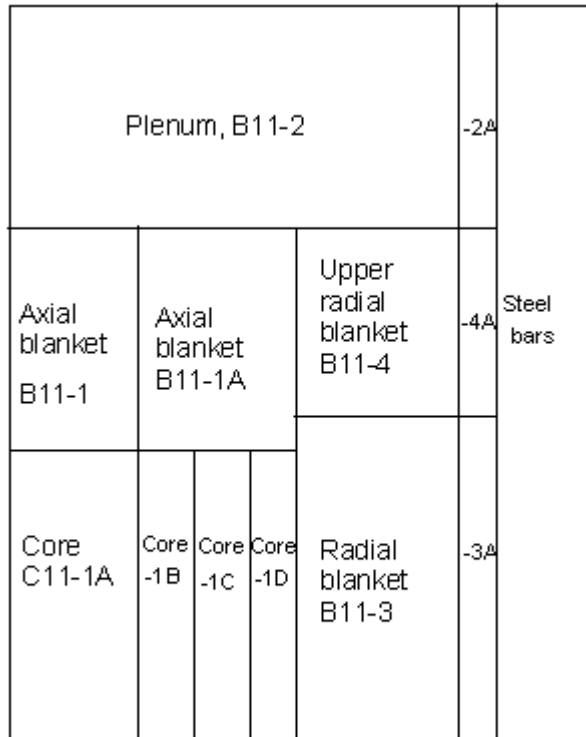


Figure 3.9 Cylindrical Geometry Half-height Model of MZB/3

Plenum, B11-2			Steel bars
Axial blanket over inner core, B12-30 and B12-30B	Axial blanket over outer core, B11-1 to 1AG	Upper radial blanket B11-4	
		Radial Blanket B11-3	
Inner Core C12-30A to D	Outer Core C11-1A to G		

The Cylindrical Model of MZA.

Using the numbers of elements of the different types, the radii of the different regions are calculated based on a lattice area of 5.4254 cm squared. The axial and radial dimensions of a half-height model of MZA are given in Tables 3.13 and 3.14 and the model is illustrated in Figure 3.8.

Table 3.13 Radial Dimensions of the Cylindrical Model of MZA

Region	Number of element positions.	Outer Radius (cm)
Core C11-1A elements	45	20.533
C11-1B	44	28.877
C11-1C	72	38.839
C11-1D	52	44.673
Radial Blanket		
B11-1 elements	312	70.135
B11-1B	96	76.278
Steel bars	268	91.266

Table 3.14 Axial Dimensions of the Half-height Cylindrical Model of MZA

Region	Half-Height/Thickness (cm)
Core	44.9748
Axial blanket	34.9464
Plenum	33.0048
Steel extension	2.064
Inner radial blanket (B11-3)	50.2961
Outer radial blanket (B11-4)	30.4506
Steel extension	1.2486

Note:

Axial dimensions for the "inner" and "outer" radial blanket apply to both B11-1 and B11-1B types of elements. The "outer" radial blanket region (B11-4) is above and below the inner radial blanket region (B11-3) (and is above it in the half-height model, where it is called the Upper radial blanket; see Figure 3.8).

The Steel extension above the upper plenum region, and below the lower plenum region isn't shown on the Figure.

The Cylindrical Model of MZB/3.

Using the numbers of elements of the different types, the radii of the different regions are calculated. The axial and radial dimensions of a half-height model of MZB/3 are given in Tables 3.15 and 3.16 and the model is illustrated in Figure 3.9.

Table 3.15 Radial Dimensions of the Cylindrical Model of MZB/3

Region	Number of element positions.	Total number of elements	Outer Radius (cm)
Inner Core			
C12-30A	141	141	36.347
C12-30B	100	241	47.519
C12-30BG	42	283	51.493
C12-30D	130	413	62.206
Outer core			
C11-1A elements	53	466	66.077
C11-1B	49	515	69.464
C11-1C	65	580	73.718
C11-1D	65	645	77.739
C11-1DG	16	661	78.697
C11-1G	16	677	79.644
Radial Blanket			
B11-1 elements	627	1304	110.534
Radial Shield			
Steel bars	420	1724	127.094

Table 3.16 Axial Dimensions of the Half-height Cylindrical Model of MZB/3

Region	Half-Height/Thickness (cm)
Inner Core	44.5979
Outer Core	44.9748
Inner Core Axial Blanket	34.9624
Outer Core Axial blanket	34.9464
Plenum	33.0048
Steel extension	2.064
Inner radial blanket (B11-3)	50.2961
Outer radial blanket (B11-4)	30.4506
Steel extension	1.2486

The "outer" radial blanket region is above and below the inner radial blanket region (and is above it in the half-height model, where it is called the Upper radial blanket; see Figure 3.9).

The Steel extension above the upper plenum region, and below the lower plenum region isn't shown on the Figure.

3.1.3 Compositions of the Components

The dimensions and compositions have been copied from the ZEBRA Database. In some cases the numbers have been rounded to fewer significant figures, when it was thought that the extra figures had arisen because of data manipulation on computers which converted the numbers to a different form. In some cases the Database includes the weights in percentage terms, as well as absolutely (in the case of canning material, for example). In other cases the percentage weights have been calculated, and again rounded when it seemed probable that the weights had originally been given in percentage terms and to fewer significant figures. The atomic densities have been calculated using the code ADEFTA and the ICRP recommended atomic weights. In some cases the absolute values of the component weights have been used and in other cases the percentage weights, when these seemed to be the original measured values. There can be small differences between the values calculated in the two ways.

Other simplifications have been made. It has been assumed that all of the plates have a width of 5.067 cm whereas in some cases they have a smaller width. Also, groups of the same type of plate, such as the plutonium metal plates, and the sodium plates, have been assumed to have the same dimensions to simplify the calculational models. The atomic compositions of plates might differ from the values given in other documents for this reason but the total weights are the same.

The reference date for the compositions of the plates in the ZEBRA Database is January 1971. The compositions of the plutonium plates given in the Database have been corrected from the measured values to refer to this reference date. This has the curious consequence that the **Am241 compositions can be negative when the plutonium was produced at a date later than January 1971** and this is the case for a number of the later plutonium plates.

Suppose the plutonium was produced at a time, t , after the reference date of the Database (and contained no Am241 at that time) and the amount of Pu241 is $N_0(\text{Pu241})$. The figure recorded in the database, $N_t(\text{Pu241})$, is this figure increased by the factor $\exp(\lambda.t)$ (where λ is the Pu241 decay constant)

$$N_t(\text{Pu241}) = N_0(\text{Pu241}).\exp(\lambda.t)$$

and the amount of Am241 is given as the negative quantity:

$$N_t(\text{Am241}) = N_0(\text{Pu241}).(1 - \exp(\lambda.t))$$

The amount of Pu241 plus Am241 is equal to $N_0(\text{Pu241})$ and at the time t following the reference date (at the plutonium production date) the amount of Am241 is then calculated to be zero and at subsequent times the Pu241 and Am241 content is calculated correctly.

Table 3.17 Mixed Uranium-Plutonium Oxide Plate PUIV4

The mixed oxide plate, PUIV4.

COMMENTS: (Not corrected for Pu-241 decay. The reference date for the compositions of the plates in the ZEBRA Database is January 1971.) This plate is the same as the PuO₂/UO₂ plate used in the ZEBRA 8 series of measurements.

Core region:

Dimensions: Plate thickness 0.6278 ± 0.0005 cm, can thickness = 0.03734 cm, core thickness = 0.55312 cm

Plate width assumed in model = 5.067 cm, core width = 4.953 cm,

total plate volume = 16.1184 cm^3 , core volume = 13.5693 cm^3 , can volume = 2.5491 cm^3

Core density 9.63047 gm/cm^3

Material	Atoms/barn.cm
Volume	$13.5693 \text{ (cm}^3\text{)}$
C	6.2771E-05
O	4.2860E-02
AL	2.7943E-05
SI	2.6845E-05
FE	1.3500E-05
NI	1.2846E-05
U234	7.4340E-07
U235	1.1548E-04
U238	1.5938E-02
NP237	2.4466E-07
PU239	4.7730E-03
PU240	5.3344E-04
PU241	5.3651E-05
PU242	4.7919E-06
AM241	2.2856E-05
Total	6.4446E-02

Values allowing for Pu-241 decay to 11/1971, factor 0.96 (MZA criticality)

PU241	5.1505E-05
AM241	2.5002E-05

Values allowing for Pu-241 decay to 5/1972, factor 0.9376 (MZB/1 criticality)

PU241	5.0303E-05
AM241	2.6204E-05

(Pu-241 half-life = 14.35 years, $\lambda = 0.0483$)

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PUIV4 plate. Can region

Material	Atoms/barn.cm
Volume	2.5491 cm ³
H	2.0111E-05
C	1.6876E-04
SI	5.9180E-04
P	2.6177E-05
S	2.5282E-05
CR	1.3956E-02
MN	1.0995E-03
FE	5.0428E-02
NI	6.9005E-03
NB	2.8363E-04
Total	7.3500E-02

Table 3.18 Plutonium Metal Plates

(Not corrected for Pu-241 decay. The reference date for the compositions of the plates in the ZEBRA DataBank is January 1971. This is the date of the analysis in the case of the PUV8 plate, the manufacture and analyses made for the plates with negative Am241 contents being later. Hypothetical compositions have then been calculated for January 1971)

Gallium is the metallic plutonium stabilising material.

Can thickness of all plates = 0.04572 cm.

The average plate thickness is taken to apply to all of the plates. This is 0.3265 cm and the corresponding average core thickness is 0.23506 cm.

Assumed plate width = 5.067 cm Core width of all plates = 4.671 cm

Average core region volume = 5.1286 cm^3 Average can region volume = $8.3827 - 5.1286 = 3.2541 \text{ cm}^3$. These values have been adopted for all plates.

The can region in fact has two components, the copper plating and the steel outer can, but these are combined in the composition of the canning region

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CORE REGION Atomic densities for PUV8 to PUVIII8 (in Atoms/barn.cm)

Material	PUV8	PUVI8	PUVII8	PUVIII8
H	1.7475E-04	1.0485E-04	1.3980E-04	1.2815E-04
C	2.5027E-04	2.2876E-04	2.0335E-04	4.2429E-04
N	1.3413E-05	2.4312E-05	6.7066E-06	2.4312E-05
O	5.0640E-05	3.5962E-05	5.4310E-05	8.8804E-05
AL	2.1760E-05	1.7408E-05	1.6973E-05	2.3065E-05
SI	2.3831E-05		1.0870E-05	1.4215E-05
CR	5.1941E-06	3.1616E-06	4.0649E-06	3.6133E-06
MN	1.0687E-06	1.0687E-06	8.5494E-07	1.4962E-06
FE	1.6610E-05	1.9344E-05	1.0513E-05	1.6400E-05
NI	1.1804E-05	6.8024E-06	9.0032E-06	8.6031E-06
GA	2.2424E-03	2.2555E-03	2.0492E-03	2.0247E-03
MO	1.9583E-06			
U238	1.3318E-06	2.4663E-07	9.3720E-07	6.9057E-07
PU238	2.9103E-05	3.6995E-05	3.1569E-05	3.0583E-05
PU239	2.9328E-02	2.8972E-02	2.9028E-02	2.9035E-02
PU240	6.7928E-03	7.3421E-03	6.9606E-03	6.9371E-03
PU241	1.0541E-03	1.2305E-03	1.1954E-03	1.2056E-03
PU242	1.6639E-04	2.0132E-04	1.8725E-04	1.8773E-04
AM241	5.2072E-05	9.9858E-06	5.6505E-06	-4.0430E-06
Total	4.0237E-02	4.0490E-02	3.9915E-02	4.0151E-02

**Values for 11/1971 (MZA criticality) (Pu-241 half-life = 14.35 years, $\lambda = 0.0483$)
Factor = 0.960**

PU241	1.0119E-03	1.1813E-03	1.1476E-03	1.1574E-03
AM241	9.4236E-05	5.9206E-05	5.3467E-05	4.4181E-05

Values for 5/1972 (MZB/1 criticality) Factor = 0.9376

PU241	9.8832E-04	1.1537E-03	1.1208E-03	1.1304E-03
AM241	1.1785E-04	8.6769E-05	8.0243E-05	7.1186E-05

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CORE REGION Atomic densities for PUIX8 to PUXII8 (in Atoms/barn.cm)

Material	PUIX8	PUX8	PUXI8	PUXII8
H	1.5145E-04	1.0485E-04	1.7475E-04	1.7475E-04
C	2.8155E-04	2.9524E-04	2.2876E-04	2.6298E-04
N	9.2216E-06	1.0060E-05	1.1737E-05	6.7066E-06
O	5.7245E-05	4.5503E-05	4.1833E-05	4.1833E-05
AL	2.3065E-05	2.1760E-05	1.8713E-05	1.7408E-05
SI	2.8430E-05	1.5887E-05	1.8396E-05	2.2159E-05
CR	6.0974E-06	4.2908E-06	6.0974E-06	9.2590E-06
MN	1.7099E-06	1.0687E-06	1.0687E-06	8.5494E-07
FE	1.3036E-05	1.4928E-05	2.2287E-05	1.4928E-05
NI	2.6810E-05	1.6206E-05	1.7606E-05	2.3809E-05
GA	2.1190E-03	2.2417E-03	2.2490E-03	2.3032E-03
U238	5.2779E-06	1.4305E-06	6.9057E-07	1.6771E-06
PU238	3.5515E-05	3.4035E-05	3.7488E-05	3.6995E-05
PU239	2.8995E-02	2.9107E-02	2.8990E-02	2.9064E-02
PU240	6.9474E-03	6.9117E-03	6.9709E-03	6.8990E-03
PU241	1.2173E-03	1.2115E-03	1.2314E-03	1.2378E-03
PU242	1.8046E-04	1.8531E-04	1.8482E-04	1.7997E-04
AM241	-1.6708E-05	-4.1940E-05	-4.5984E-05	-4.9880E-05
Total	4.0082E-02	4.0180E-02	4.0160E-02	4.0247E-02

Values allowing for Pu-241 decay to 11/1971

PU241	1.1686E-03	1.1630E-03	1.1821E-03	1.1883E-03
AM241	3.1984E-05	6.5200E-06	3.2720E-06	-3.6800E-07

(The PUXII8 plate had clearly not been manufactured this early)

Values allowing for Pu-241 decay to 5/1972.

PU241	1.1413E-03	1.1359E-03	1.1546E-03	1.1606E-03
AM241	5.9252E-05	3.3658E-05	3.0855E-05	2.7359E-05

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CAN REGION Atomic Densities (in Atoms/barn.cm)

Material	PUV8	PUVI8	PUVII8	PUVIII8
H	1.3404E-05	1.3955E-05	1.3771E-05	1.3771E-05
C	9.2801E-05	1.1413E-04	1.1357E-04	1.1340E-04
SI	4.1625E-04	3.6853E-04	3.6675E-04	3.6619E-04
P	1.8432E-05	1.3545E-05	1.3479E-05	1.3461E-05
S	9.3252E-06			
TI				
CR	9.2549E-03	9.4688E-03	9.4231E-03	9.4087E-03
MN	7.5220E-04	8.6563E-04	8.6145E-04	8.6013E-04
FE	3.4310E-02	3.5798E-02	3.5625E-02	3.5570E-02
NI	4.5397E-03	4.1944E-03	4.1742E-03	4.1678E-03
CU	1.6626E-02	1.6626E-02	1.6626E-02	1.6626E-02
Total	6.6033E-02	6.7463E-02	6.7217E-02	6.7140E-02

Material	PUIX8	PUX8	PUXI8	PUXII8
H	1.3771E-05	1.3587E-05	1.3404E-05	1.3220E-05
C	1.1312E-04	1.2050E-04	1.1825E-04	1.1685E-04
SI	3.6529E-04	5.2025E-04	5.1057E-04	5.0450E-04
P	1.3425E-05	2.6701E-05	2.6205E-05	2.5895E-05
S		1.5471E-05	1.5188E-05	1.5004E-05
TI		5.7590E-06	5.6508E-06	5.5851E-06
CR	9.3855E-03	9.9679E-03	9.7825E-03	9.6661E-03
MN	8.5801E-04	8.5308E-04	8.3722E-04	8.2726E-04
FE	3.5483E-02	3.3844E-02	3.3215E-02	3.2820E-02
NI	4.1575E-03	4.8383E-03	4.7483E-03	4.6918E-03
CU	1.6626E-02	1.6868E-02	1.6868E-02	1.6868E-02
Total	6.7015E-02	6.7073E-02	6.6140E-02	6.5554E-02

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**Repeat of the above data for the U-Pu isotopes compared with other reported values.
Zebra Database Values (Date 1/1971)**

This comparison has been included to help with comparisons made with the original data published in the early 1970s

	PUV8	PUVI8	PUVII8	PUVIII8	PUIX8	PUX8	PUXI8	PUXII8
CORE								
U238	0.0027	0.0005	0.0019	0.0014	0.0107	0.0029	0.0014	0.0034
PU238	0.0590	0.0750	0.0640	0.0620	0.0720	0.0690	0.0760	0.0750
PU239	59.7070	58.9820	59.0970	59.1110	59.0300	59.2570	59.0190	59.1690
PU240	13.8870	15.0100	14.2300	14.1820	14.2030	14.1300	14.2510	14.1040
PU241	2.1640	2.5260	2.4540	2.4750	2.4990	2.4870	2.5280	2.5410
PU242	0.3430	0.4150	0.3860	0.3870	0.3720	0.3820	0.3810	0.3710
AM241	0.1069	0.0205	0.0116	-0.0083	-0.0343	-0.0861	-0.0944	-0.1024

Estimate allowing for decay of Pu241 to 11/1971. 4% of the Pu-241 will have decayed to Am241 by this date.

PU241	2.0774	2.4250	2.3558	2.3760	2.3990	2.3875	2.4269	2.4394
AM241	0.1935	0.1215	0.1098	0.0907	0.0657	0.0134	0.0067	-0.0008

(The PUXII8 plate had clearly not been manufactured this early)

Values given in the MTN-7 MZA Printouts.

	PUV8	PUVI8	PUVII8	PUVIII8	PUIX8	PUX8	PUXI8	PUXII8
CORE								
U238	0.0000	0.0000	0.0000	0.0000				
PU238	0.0000	0.0000	0.0000	0.0000				
PU239	59.6980	58.9630	59.0940	59.1280				
PU240	13.8890	15.0050	14.2320	14.1720				
PU241	2.0544	2.4243	2.3499	2.3642				
PU242	0.3400	0.4150	0.3860	0.3880				
AM241	0.1200	0.0160	0.0030	0.0000				

The MTN-7 printouts for MZA (for 12/1971) give data which differ from the current version of the Zebra Database (reference date 1/1971, although probably revised at a later date and calculated back to the reference date). The MTN-7 data are simpler in that the contents for U238 and Pu238 are zero. The reference date for this document is 11/1971.

Table 3.19 The Natural Uranium Oxide Plates

UO22R4

CORE

Material	Atoms/barn.cm
H	2.4415E-05
C	9.2196E-06
N	1.9326E-05
O	4.5573E-02
AL	1.3681E-06
SI	2.6286E-06
CA	3.3770E-06
CR	1.0649E-06
FE	6.0587E-06
NI	4.1929E-07
U235	1.6393E-04
U238	2.2614E-02
TOTAL	6.8419E-02

CAN

Material	Atoms/barn.cm
H	1.8826E-05
C	8.1199E-05
AL	1.4065E-06
SI	8.3530E-04
P	1.9848E-05
S	4.4966E-06
TI	7.5295E-06
CR	1.2633E-02
MN	7.0291E-04
FE	4.5639E-02
NI	5.5345E-03
CU	9.0449E-04
NB	7.7608E-06
MO	9.4061E-05
AG	1.2325E-03
TOTAL	6.7716E-02

TOTAL VOLUME	-----	16.1467	cm ³
CORE VOLUME	-----	13.0660	cm ³
CAN VOLUME	-----	3.0807	cm ³

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UO23R4.

CORE

Material	Atoms/barn.cm
Volume (cm ³)	13.1225
H	3.1012E-05
C	1.1970E-05
O	4.6295E-02
AL	3.4753E-06
SI	2.3148E-05
MN	1.1378E-07
FE	1.3432E-06
NI	1.2782E-06
MO	3.2579E-07
U235	1.6647E-04
U238	2.2980E-02
Total	6.9515E-02

CAN

Material	Atoms/barn.cm
Volume (cm ³)	3.0858
H	1.9269E-05
C	1.2483E-04
SI	6.2774E-04
P	3.4147E-04
S	3.5123E-05
CR	1.3455E-02
MN	8.3300E-04
FE	4.7031E-02
NI	8.2033E-03
Total	7.0670E-02

TOTAL VOLUME ----- 16.2083 (cm³)
CORE VOLUME ----- 13.1225 (cm³)
CAN VOLUME ----- 3.0858 (cm³)

This plate is used in the Cadenza Assemblies but the dimensions given there are slightly different.

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UO24R4.

(This is the same as the plate used in the ZEBRA 8 Series.)

CORE

Material	Atoms/barn.cm
Volume	13.0425 (cm ³)
H	2.4503E-05
C	3.0842E-05
O	4.5733E-02
SI	1.3190E-05
FE	6.6332E-06
U234	1.1871E-06
U235	1.6462E-04
U238	2.2694E-02
Total	6.8668E-02

CAN

Material	Atoms/barn.cm
Volume	3.0785 (cm ³)
H	1.7335E-05
C	1.4546E-04
SI	6.0964E-04
P	2.2563E-05
S	2.1792E-05
CR	1.2365E-02
MN	9.7951E-04
FE	4.3411E-02
NI	6.0134E-03
CU	8.1603E-04
AG	1.2368E-03
TOTAL	6.5639E-02

TOTAL VOLUME ----- 16.1210 (cm³)
CORE VOLUME ----- 13.0425 (cm³)
CAN VOLUME ----- 3.0785 (cm³)

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UO2DP4 Depleted UO2 plate

Material	Atoms/barn.cm
H	2.9927E-06
C	1.5068E-05
O	4.4711E-02
SI	1.5036E-05
CR	9.2818E-06
MN	1.3177E-06
FE	1.6203E-05
NI	7.1953E-06
U235	4.5327E-05
U238	2.2282E-02
TOTAL	6.7105E-02
VOLUME	16.0209 cm ³

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Table 3.20 Natural Uranium Metal Components

Blanket Region Natural Uranium Components

	Thickness (cm)	Width (cm)	Volume (cm ³)
U8	0.317	5.067	8.1388
U2	1.2723	5.067	32.6657

Natural Uranium Plate, U8. Volume 8.1388 cm³

(This is the plate used in the ZEBRA 8 Series but the thickness used here is slightly less at 0.317 cm versus 0.3175 cm)

Material	Atoms/barn.cm
H	4.4048E-05
C	4.9283E-04
SI	2.1076E-04
FE	1.0599E-04
U235	3.3369E-04
U238	4.6021E-02
Total	4.7208E-02

Natural Uranium Plate, U2. Volume 32.6657 cm³

Material	Atoms/barn.cm
H	4.3899E-05
C	4.6047E-04
SI	1.9692E-04
FE	9.9032E-05
U235	3.3962E-04
U238	4.6785E-02
Total	4.7925E-02

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Table 3.21 Sodium Plates.

Atomic Densities (in Atoms/barn.cm)

NASTDL4.

Core

	NASTDL4	NASTDM4
Material	Atomic density	Atomic density
Volume	13.3586 (cm ³)	13.3586 (cm ³)
H	1.3418E-05	1.3418E-05
O	5.6353E-06	5.6353E-06
NA	2.3168E-02	2.3168E-02
CA	3.5994E-06	3.5994E-06
FE	1.6144E-07	1.6144E-07
Total	2.3191E-02	2.3191E-02

Can

	NASTDL4	NASTDM4
Material	Atomic density	Atomic density
Volume	2.4569 (cm ³)	2.4569 (cm ³)
H	2.4319E-05	2.1522E-05
C	2.8978E-04	2.1672E-04
SI	6.0218E-04	7.8781E-04
P	3.2445E-05	3.2216E-05
S	3.2865E-05	1.6234E-05
CR	1.4602E-02	1.5953E-02
MN	1.3425E-03	1.2635E-03
FE	5.4467E-02	5.2254E-02
NI	7.0225E-03	7.8948E-03
NB	3.0815E-04	3.4089E-04
Total	7.8723E-02	7.8781E-02

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NASTBR4

(This is the sodium plate used in the ZEBRA 8 Series)

Atomic Densities (in Atoms/barn.cm)

Core

ISOTOPE NAME	Atomic density
Volume	13.3586 (cm ³)
H	2.1098E-06
LI	3.8296E-07
B	1.4752E-07
O	1.9937E-06
NA	2.3119E-02
K	4.6230E-07
CA	1.7244E-06
FE	3.8077E-08
TOTAL	2.3126E-02

Can

ISOTOPE NAME	Atomic density
Volume	2.4569 (cm ³)
H	2.1496E-05
C	2.1646E-04
SI	6.0171E-04
P	2.7979E-05
S	2.7023E-05
CR	1.5000E-02
MN	1.0806E-03
FE	5.4056E-02
NI	7.2502E-03
NB	3.0316E-04
Total	7.8585E-02

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Sodium plates NAJI4, and NAJII4

Atomic Densities (in Atoms/barn.cm)

CORE

	NAJI4	NAJII4
ISOTOPE NAME	Atomic density	Atomic density
Volume	12.5719 (cm ³)	12.5719 (cm ³)
H	1.2832E-05	1.2832E-05
O	5.2693E-06	5.2693E-06
NA	2.3437E-02	2.3437E-02
CA	2.1872E-06	2.1872E-06
FE	2.1443E-07	2.1443E-07
Total	2.3458E-02	2.3458E-02

CAN

ISOTOPE NAME	Atomic density	Atomic density
Volume	3.2179 (cm ³)	3.2179 (cm ³)
H	2.2253E-05	2.2253E-05
C	2.2408E-04	2.6143E-04
SI	7.8263E-04	6.2291E-04
P	4.3449E-05	4.0552E-05
S	1.3988E-05	3.3570E-05
CR	1.6366E-02	1.5374E-02
MN	1.2983E-03	1.3391E-03
FE	5.4491E-02	5.6160E-02
NI	8.0025E-03	7.3605E-03
NB	2.6073E-04	2.3176E-04
Total	8.1505E-02	8.1446E-02

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Table 3.22 Stainless Steel Plates

STSTBR8 is the Stainless Steel "Bright" plate used in the ZEBRA-8 Series)

STSTD8 is the Stainless Steel "Dull" plate used in the ZEBRA-8 Series

Note: these two plates have the same composition but slightly different masses.

Atomic Densities (in Atoms/barn.cm)

	STSTBR8	STSTD8
Thickness	0.3172 cm	0.3236 cm
Volume	8.14395 (cm ³)	8.30826 (cm ³)
Material	Atomic density	Atomic density
H	2.3265E-05	2.3115E-05
C	7.8091E-04	7.7587E-04
AL	1.7381E-04	1.7269E-04
SI	1.3358E-03	1.3272E-03
TI	2.9384E-04	2.9195E-04
CR	1.6325E-02	1.6220E-02
MN	9.3901E-04	9.3295E-04
FE	5.8278E-02	5.7902E-02
NI	7.7510E-03	7.7009E-03
CU	7.3801E-05	7.3324E-05
MO	9.7764E-05	9.7133E-05
Total	8.6072E-02	8.5517E-02

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The 40% Stainless Steel Plate, STSTF8.

The plate is of square picture frame shape, the central square region being void.

PLATE height 0.317 cm, (CORE, assumed square section void, height 0.317 cm, width 3.925 cm),
Width assumed to be 5.067 cm, Volume 3.25523 cm³

Atomic Densities (in Atoms/barn.cm)

ISOTOPE	Atomic density
Volume	3.2552 (cm ³)
H	1.8134E-05
C	8.7500E-05
AL	1.1855E-04
SI	7.9722E-04
P	3.9832E-05
S	1.4248E-05
TI	2.4813E-04
CR	1.5906E-02
MN	1.4971E-03
FE	5.5368E-02
NI	8.7978E-03
CU	5.0335E-05
NB	4.9183E-06
MO	8.0968E-05
Total	8.3029E-02

INNER VOID REGION - SQUARE SECTION - WIDTH 3.925 cm

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Table 3.23 Mild Steel Plates

Atomic Densities (in Atoms/barn.cm)

Atomic densities

	MST1	MST2	MST3	MST8
H	2.8122E-05	2.7967E-05	2.8087E-05	2.7730E-05
C	5.1129E-04	5.0847E-04	5.1066E-04	5.0417E-04
AL	1.4007E-04	1.3930E-04	1.3989E-04	1.3812E-04
TI	3.9465E-05	3.9247E-05	3.9416E-05	3.8915E-05
CR	2.7256E-05	2.7106E-05	2.7222E-05	2.6876E-05
MN	3.2675E-04	3.2495E-04	3.2634E-04	3.2220E-04
FE	8.3911E-02	8.3448E-02	8.3806E-02	8.2742E-02
NI	4.8294E-05	4.8028E-05	4.8234E-05	4.7622E-05
CU	4.4603E-05	4.4357E-05	4.4548E-05	4.3982E-05
MO	9.8477E-06	9.7934E-06	9.8355E-06	9.7106E-06
TOTAL	8.5086E-02	8.4617E-02	8.4980E-02	8.3902E-02
PLATE THICKNESS	2.5385 cm	1.2718 cm	7.6063 cm	0.3147 cm
WIDTH	5.067 cm	5.067 cm	5.067 cm	5.067 cm
VOLUME	65.1747 (cm ³)	32.6528 (cm ³)	195.288 (cm ³)	8.07976 (cm ³)
Density	7.84440g/ (cm ³)	7.80114 g/(cm ³)	7.83464 g/(cm ³)	7.73519 g/(cm ³)

These four mild steel components have essentially the same composition. The hydrogen fraction is a nominal one.

Table 3.24 The Steel Bar MST9F10.

The width of the square section steel bar is 5.08 cm.

The atomic density has been calculated based on both the actual square width of 5.08 cm (volume 25.8064 cm³ per 1 cm length) and the average element spacing of 5.4254 cm, (the volume being 29.4350 cm³ per 1 cm length).

Atomic Densities (in Atoms/barn.cm)

Steel bar MST9F10 Total length ~3 m

ISOTOPE	Atomic density	Atomic density
	5.08 cm width square	5.4254 cm width square
Volume	25.8064 (cm ³)	29.435 (cm ³)
H	4.6306E-05	4.0597E-05
C	6.8972E-04	6.0468E-04
SI	3.1158E-04	2.7317E-04
P	4.2944E-05	3.7649E-05
S	3.7110E-05	3.2535E-05
MN	7.1275E-04	6.2488E-04
FE	8.1432E-02	7.1392E-02
Total	8.3272E-02	7.3006E-02

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Table 3.25 Graphite Plates and Blocks.

Atomic Densities (in Atoms/barn.cm)

	G18	G118	G1118
Thickness	0.318 cm	0.31775 cm	0.319 cm
Volume	8.16449 (cm ³)	8.15807 (cm ³)	8.19016 (cm ³)
Element			
H	4.8551E-05	2.0286E-05	1.9906E-05
C	8.1417E-02	8.5101E-02	8.3507E-02
S	1.2207E-05	1.2751E-06	2.3351E-06
FE	6.1336E-06	1.8306E-06	
TOTAL	8.1484E-02	8.5125E-02	8.3529E-02

	G13	G3	G75
	Graphite CS	Graphite CY9	Graphite CY9
Thickness	33.3375 cm	7.62 cm	19.05 cm
Volume	(cm ³)	(cm ³)	(cm ³)
Element			
H	2.2500E-04	8.5000E-04	8.6800E-04
C	8.6550E-02	8.1690E-02	8.3650E-02
TOTAL	8.6775E-02	8.2540E-02	8.3737E-02

Table 3.26 Aluminium Plates.

Atomic Densities (in Atoms/barn.cm)

ISOTOPE	ALG8	ALSC3
AL	2.6704E-02	4.7590E-02
SI	1.0296E-05	4.5790E-06
MN	6.5793E-07	9.3634E-07
FE	3.6374E-05	2.9936E-05
CU	4.5505E-07	1.8214E-06
Total	2.6752E-02	4.7627E-02

ALG8

PLATE THICKNESS 0.3170 ± 0.0005 cm
VOLUME 8.1388 cm³

ALSC3

PLATE THICKNESS 7.620 cm
VOLUME 195.64 cm³

AL2O34

ISOTOPE	Atoms/barn.cm ²
H	5.1483E-05
B10	4.5063E-06
B11	1.6599E-05
O	6.6386E-02
AL	4.4240E-02
TOTAL	1.1070E-01

PLATE THICKNESS 0.6317 ± 0.0005 cm
VOLUME 16.21858 cm³

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Table 3.27 Sheath Material
(Weight per unit cm length.)

SHEATH (Stainless Steel) (This sheath is also used in the ZEBRA-8 Series)

Atomic Densities (in Atoms/barn.cm)

Mat.	Atoms/barn.cm	Smeared over lattice area to 5.3721 cm square	Smeared over lattice area to 5.4254 cm square
	Model A	Model B	Model C
Area	1.57832 (cm ²)	3.18497 (cm ²)	3.76048 (cm ²)
Factor		0.495553	0.419712
H	2.3206E-05	1.1500E-05	9.7398E-06
C	7.7892E-04	3.8600E-04	3.2692E-04
AL	3.4674E-04	1.7183E-04	1.4553E-04
SI	9.9934E-04	4.9522E-04	4.1943E-04
TI	2.9310E-04	1.4524E-04	1.2302E-04
V	9.1827E-05	4.5505E-05	3.8541E-05
CR	1.6104E-02	7.9802E-03	6.7589E-03
MN	1.1921E-03	5.9073E-04	5.0032E-04
FE	5.6622E-02	2.8059E-02	2.3765E-02
NI	9.0065E-03	4.4632E-03	3.7801E-03
CU	7.3613E-05	3.6479E-05	3.0896E-05
MO	1.4627E-04	7.2486E-05	6.1393E-05
TOTAL	8.5678E-02	4.2458E-02	3.5960E-02

NOMINAL SHEATH LENGTH ----- 1.0 cm
SHEATH WALL THICKNESS ----- 0.0762 cm
INTERNAL SHEATH WIDTH ----- 5.102 cm
OUTER SHEATH WIDTH ----- 5.2544 cm
VOLUME PER UNIT LENGTH ----- 1.57832

MODEL B smears the material over the space between the plates (5.067 cm square) and the lattice area (5.3721 cm square) within the groups of 5 x 5 elements.

MODEL C smears the material over the space between the plates and the overall assembly average lattice area (5.4254 cm square).

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MSHTH (Mild Steel Sheath)

Atomic Densities (in Atoms/barn.cm)

Volumes in cm³

Material	Atoms/barn.cm	Smeared over lattice area to 5.3721 cm square	Smeared over lattice area to 5.4254 cm square
	Model A	Model B	Model C
Volume	1.57832 (cm ³)	3.18497 (cm ³)	3.76048 (cm ³)
Factor		0.495553	0.419712
H	2.6058E-04	1.2913E-04	1.0937E-04
C	3.0978E-04	1.5351E-04	1.3002E-04
SI	4.6757E-05	2.3171E-05	1.9624E-05
P	1.4132E-05	7.0032E-06	5.9314E-06
S	4.6407E-05	2.2997E-05	1.9478E-05
MN	2.7489E-04	1.3622E-04	1.1537E-04
FE	7.7981E-02	3.8644E-02	3.2730E-02
TOTAL	7.8933E-02	3.9115E-02	3.3129E-02

NOMINAL SHEATH LENGTH ----- 1.0 cm
SHEATH WALL THICKNESS ----- 0.0762 cm
INTERNAL SHEATH WIDTH ----- 5.102 cm
OUTER SHEATH WIDTH ----- 5.2544 cm
VOLUME PER UNIT LENGTH ----- 1.57832 cm³

SMEARED VOLUMES PER UNIT LENGTH:

MODEL B (to 5.3721 cm square lattice area) 3.18497 cm²
MODEL C (to 5.4254 cm square lattice area) 3.76048 cm²

Superlattice Mild Steel Plates

The mild steel superlattice grids are of width 0.25 cm, and are situated in a gap of 0.2665 cm between the groups of 5x5 elements. The composition is assumed to be that of the mild steel element sheath MSHTH. They are treated as filling the gap of 0.2665 cm and so the atomic densities of MSHTH Model A are reduced by the factor 0.938.

Material	Atoms/barn.cm
H	2.4442E-04
C	2.9057E-04
SI	4.3858E-05
P	1.3256E-05
S	4.3530E-05
MN	2.5785E-04
FE	7.3146E-02
TOTAL	7.4039E-02

3.1.4 Temperature Data

The temperatures are given in Table 3.1. These are:

MZA 23.5°C MZB 21.4°C

3.1.5 Experimental and Benchmark Model Criticality Parameters

The recommended k_{eff} values corresponding to the different models are given in Table 3.1 and are reproduced here:

	MZA	MZB/1	MZB/2	MZB/3
Models A and B	1.0097 ± 0.0016	1.0048 ± 0.0010	1.0042 ± 0.0010	1.0044 ± 0.0010
Model C, the uniform lattice model with no void channels	1.0097 ± 0.0017	1.0048 ± 0.0011	1.0042 ± 0.0011	1.0044 ± 0.0011
Cylindrical model	1.0107 ± 0.0017	1.0048 ± 0.0011	1.0042 ± 0.0011	1.0044 ± 0.0011

3.2 Benchmark-Model Specifications for Buckling and Extrapolation Length Measurements

As described in Sections 1.2 and 2.2, the axial and radial bucklings were measured in the central region of MZA and the quoted accuracies would apply to calculations made for the central cell. However, although the measurements are of good quality they are not considered to be useful as a check on methods and nuclear data because the accuracy is significantly less than that of the criticality measurement. The buckling has been defined as the fundamental mode value which reproduces the criticality and is not validated to calculate other properties. The way the superlattice spacing is to be treated is unclear.

The dimensions and compositions are those of the central group of elements in MZA, C11-1A, which have the core region cell C11-1A.

The temperature was not given.

See section 1.2.7 for the measured values.

3.3 Benchmark-Model Specifications for the Spectral Characteristics Measurements

3.3.1 Description of the Calculational Methodology and Model

Any of the models described in Section 3.1 as being suitable for making criticality calculations would also be suitable for calculating the central spectra in MZA and central spectral indices in MZA and MZB.

The central spectra are the cell integrated flux spectra in the central cell, or group of cells in MZA.

There are two types of spectral index measurement, the cell averaged reaction rate ratios and the fission chamber measurements.

The calculated cell averaged reaction rate ratios to be compared with the measured values are the ratios obtained from the components of the neutron balance for the central cell, divided by the numbers of atoms in the cell of the material for which the reaction is calculated. For U238 with cross-section $\sigma_{238}(E)$, and density $N_{238}(x)$ at position x in the cell, the cell averaged reaction rate is

$$R_{238} = \left\{ \int_{\text{cell}} \left\{ \int_E N_{238}(x) \cdot \sigma_{238}(E) \cdot \Phi(x, E) \cdot dE \right\} dV \right\} / \left\{ \int_{\text{cell}} N_{238}(x) \cdot dV \right\}$$

where the integration is over the neutron energy, E and the cell volume elements, dV at position x .

To compare with the fission chamber measurements, the reaction rates on the mid-plane in a half-element are required (the fission chamber being located at the mid plane of an element which has the plates removed from the top half to make way for the chamber and cabling). This could be approximated as the reaction rates in the flux emerging from the top of a central cell plus that emerging from the edge regions of cells (the cross-sections used being the effective cross-sections for those regions). Alternatively the average central region spectrum of the assembly calculation could be used because the uncertainties have been chosen to cover such modelling approximations.

3.3.2 Dimensions

Any of the models described in Section 3.1 as suitable for making criticality calculations would also be suitable for calculating the central spectra and spectral indices.

3.3.3 Material Data

See Section 3.1.

3.3.4 Temperature Data

Records of the temperature at which the measurements were performed are not available. For the purposes of the calculations, the models and temperatures used for the criticality calculations can be adopted.

3.3.5 Experimental and Benchmark Spectra and Reaction Rate Ratios

These are presented in Section 1.3 Table 1.42 and 1.43 for the spectrum measurements and Section 2.3 Tables 2.6A and B for the reaction rate ratios.

3.4 Benchmark-Model Specifications for Reactivity Effects Measurements

3.4.1 Description of the Calculational Methodology and Model

The types of measurement considered here are the element replacement measurements and the modified cell measurements (including the sodium voiding measurements). Depending on the size of the change it can be calculated either by direct calculation of the k_{eff} value for the modified system or alternatively using perturbation theory methods. The XYZ geometry criticality models of Section 3.1 are the basis relative to which the reactivity perturbations are to be calculated.

A cell calculation is required for each perturbation and it is the perturbation effect of the whole element, or group of 9 elements (in the case of the sodium voiding reactivity measurements), containing the perturbed cells which must be calculated (not simply a perturbation theory calculation for the addition or replacement of the single material component). Also, it should be noted that a correction has been applied to the measured value for any change in core height resulting from the replacement of a component in the cells, and in some cases for the canning material also. This requires that atomic densities (or plate widths) must be used which are consistent with the axial dimensions remaining unaltered.

3.4.2 Dimensions

Any of the XYZ geometry models described in Section 3.1 as suitable for making criticality calculations would also be suitable as the unperturbed core to which the perturbation is to be applied. It is the material contents of regions of the cells which are to be changed to calculate the perturbation effects.

3.4.3 Material Data

The standard core materials are described in Section 3.1.

The weights of sodium removed and the weights of steel, tantalum and boron absorber added are given in the tables in Section 1.4.

The additional materials used are the plutonium plates PUII8 and PUIII8, the 93% enriched uranium plate, steel plates, tantalum plates and boron plates.

The weights of the boron and tantalum plates are given in Table 1.45 but it is the weights given in the Tables of measured perturbation effects (as given in Section 1.4) which should be used because all components interchanged were weighed. It was recommended to use a "standard" atomic composition for the steel components and so one of the steel plates could be used to relate the atomic densities to the weight of steel. It is assumed that the weight of boron given in the Table is the weight of B10.

Additional materials

Table 3.28 Plutonium Metal Plates used in Small Sample Perturbation Measurements

The plutonium plates used in the core elements contain ~18% Pu240 whereas these PUII and PUIII plates contain ~5% and ~10% Pu240, respectively. In the perturbation measurements a plate replaces a plutonium metal plate or a can and so the perturbation is to be treated as due to the change in the core material of the plate. The effect of the differences in the material of the can is corrected for and so the can region atomic densities are not required.

The PUII8 plate is the one used in the ZEBRA 8 series of experiments (the Pu241 content having reduced by decay since those measurements). The core volumes are assumed to be the same as the other plutonium metal plates, corresponding to a thickness of 0.23506 cm, whereas the actual thickness of the core is 0.2159 cm. As a consequence the atomic densities are smaller than those in the ZEBRA 8 documentation by the factor 0.9185.

	PUII8	PUIII8
CORE	Atoms/barn.cm	Atoms/barn.cm
NP237	1.1392E-05	
PU239	3.3152E-02	3.0958E-02
PU240	1.7169E-03	3.5825E-03
PU241	9.3525E-05	3.7118E-04
PU242		3.1047E-05
AM241	4.1161E-05	1.2236E-04
H	1.3980E-04	1.3980E-04
C	9.5806E-05	
AL	4.2650E-05	
SI	4.0973E-05	
FE	2.0605E-05	
NI	1.9607E-05	
GA	2.1557E-03	2.0529E-03
Total	3.7530E-02	3.7258E-02

SteelCan	Weight (g)	Weight (g)
H	0.000081	0.000078
C	0.011291	0.010938
SI	0.054842	0.053128
P	0.003226	0.003125
S	0.003226	0.003125
CR	2.925974	2.834551
MN	0.151622	0.146884
FE	11.49423	11.1350
NI	1.485571	1.439153
Total Wt.	16.13	15.626
CU region.		
CU	5.87	5.649
Plate thickness	0.3175 ± 0.0005 (cm)	0.3154 ± 0.0005 (cm)

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Table 3.29 The 93% Enriched Uranium Plate

PLATE IDENTITY 93U516

Thickness 0.158 cm, Width 5.067 cm, Volume 4.6214 cm³

Nuclide	COMPOSITION GRAMS WT.	Percentage of weight	Atoms/ barn.cm
H	0.0003	0.0004	4.4187E-05
C	0.018	0.0245	2.2248E-04
O	0.039	0.0530	3.6187E-04
AL	0.007	0.0095	3.8514E-05
.SI	0.011	0.0149	5.8144E-05
FE	0.025	0.0340	6.6455E-05
U235	68.27	92.7578	4.3119E-02
U238	5.23	7.1059	3.2615E-03
Total	73.6003	100.0000	4.7172E-02

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Table 3.30 The Pin Geometry Components.

The calandria, which fit inside the standard element sheaths, contain a 4x4 array of pins. Their length is approximately 1/3 the inner core height, a little under 30 cm. The pin array is similar to that used in the Cadenza experiments (Zebra Assembly 23 - see the document ZEBRA-LMFR-EXP-001). Some details are given in MTN/54 Appendix 1. The compositions are very similar to the fuel pin PUPINA used in the Cadenza cores and this should be taken as the basis of the model used for calculations, with adjustments based on the average compositions given in MTN/54 Appendix 1 Table A4, reproduced below. In this Table the compositions have been averaged and include the contributions of the endplates. The calandria were contained in mild steel sheaths.

Atomic Compositions of Plate versus Pin/Calandria Cells

Atomic Densities (in Atoms/barn.cm)

Material	Plate Cell C12-38(MS)	PUO2/UO2 Pin/Calandria (M S Sheath)	PUO2/UO2 Pin/Calandria (S S Sheath)	Plate Cell B12-30G(MS)	UO2 Pin/Calandria (M S Sheath)	UO2 Pin/Calandria (S S Sheath)
Pu239	0.0008945	0.0008939	0.0008939	-	-	-
Pu240	0.0001796	0.0002021	0.0002021	-	-	-
Pu241	0.0000274	0.0000324	0.0000324	-	-	-
Pu242	0.0000041	0.0000052	0.0000052	-	-	-
U235	0.0000431	0.0000416	0.0000416	0.0000528	0.0000528	0.0000528
U238	0.005945	0.005817	0.005817	0.007285	0.007073	0.007073
O	0.01259	0.01400	0.01400	0.000002	0.01425	0.01425
C	0.000081	0.000067	0.000067	0.01083	0.000052	0.000077
Na	0.00908	0.00867	0.00867	0.00963	0.00867	0.00867
Fe	0.01344	0.01345	0.01231	0.01375	0.01345	0.01231
Cr	0.002689	0.002747	0.003611	0.002771	0.002747	0.003611
Ni	0.001394	0.001299	0.001782	0.001340	0.001299	0.001782
Mn	0.000205	0.000243	0.000292	0.000200	0.000243	0.000292
P	-	0.000006	0.000006	-	0.000006	0.000006
S	-	0.000003	0.000003	-	0.000003	0.000003
Si	0.000156	0.000138	0.000190	0.000223	0.000150	0.000202
Al	0.000009	0.000003	0.000022	0.000016	0.000007	0.000026
Ca	0.000001	0.000002	0.000002	0.000001	0.000004	0.000004
Mo	0.000003	-	0.000008	0.000009	-	0.000008
Ti	0.000010	-	0.000016	0.000028	-	0.000016
V	-	-	0.000005	-	-	0.000005
Nb	0.000028	-	-	0.000026	-	-
Cu	0.000229	-	0.000004	0.000007	-	0.000004
H	0.000033	0.000039	0.000026	0.000033	0.000039	0.000026
Ga	0.000046	-	-	-	-	-

3.4.4 Temperature Data

Records of the temperature at which the measurements were performed are not available. For the purposes of the calculations, the models and temperatures used for the criticality calculations can be adopted. These are:

MZA 23.5°C MZB 21.4°C

3.4.5 Experimental and Benchmark Reactivity Perturbation Measurements

Sodium voiding reactivity worth

The sodium reactivity worth measurements are summarised in Section 1.4 Tables 1.50 to 1.52. They are measurements of the reactivity change resulting from removing sodium from the cells, with the other components remaining unaltered. The measurements were made for different axial sections at the centre of MZA and MZB/2, and at different radial positions in MZB/2. ***The $\pm 5\%$ systematic uncertainty in the reactivity scale is not included in the uncertainties given in the tables.***

Small sample reactivity worths

The results of the measurements of the reactivity effects of the replacement of materials in the cells are given in Tables 1.53 to 1.58. They include measurements for plutonium metal plates having different isotopic compositions, the effect of changing the quantity of plutonium in the cells, removing the UO_2 , and changing the sodium and steel content, and the effect of adding absorbers, tantalum and boron. More comprehensive measurements of the reactivity effects of these absorber materials were made in the MZC phase of the programme (described in the Part 2 document, ZEBRA-LMFR-EXP-003).

The uncertainties given in the tables do not include the $\pm 5\%$ systematic uncertainty in the reactivity scale and the proposed additional random uncertainty arising from the uncertainty in control rod profile, and from reactivity reproducibility and drift, (which in the Cadenza cores was a combined uncertainty of the order of 1%). It was therefore recommended that a random uncertainty of $\pm 1\%$ be combined with the figures given in Tables 1.53 to 1.58 and a footnote to this effect has been added to the Tables.

Plate element replaced by a Pin geometry element.

The measurement described in Section 1.4 could usefully be combined with the more comprehensive Cadenza experiments ZEBRA-LMFR-GCFR-EXP-001 in providing a measurement in a different environment.

3.5 Description of Reactivity Coefficient Measurements

There were no benchmark measurements.

3.6 Description of Kinetics Measurements

There were no benchmark measurements.

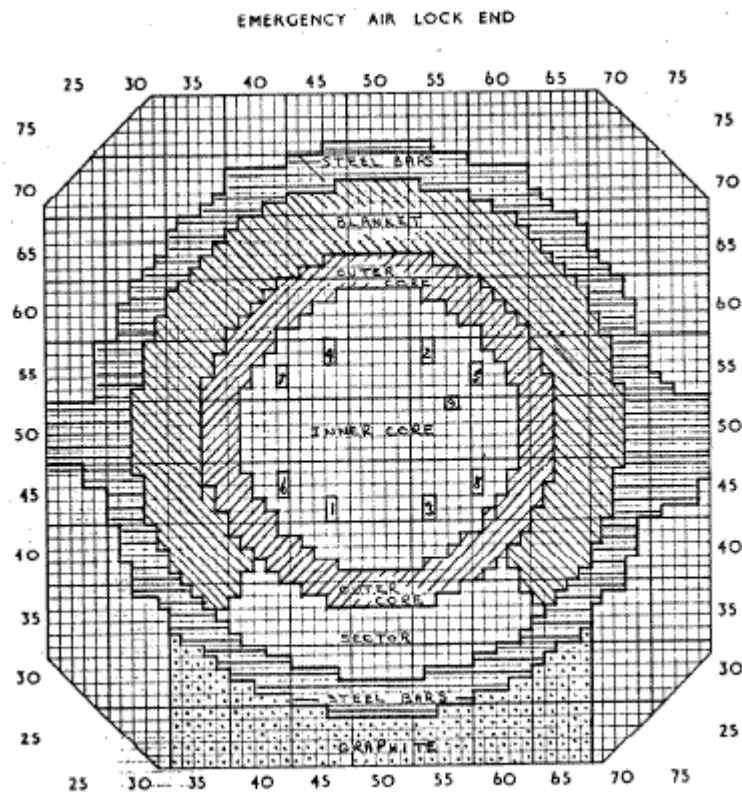


Figure 3.10 (Same as Figure 1.21) Plan of the Versions of MZB used in the Reaction Rate Distribution Measurements

3.7 Benchmark-Model Specifications for Reaction Rate Distribution Measurements

3.7.1 Description of the Calculational Methodology and Model

For the calculation of reaction rate distributions in MZA the criticality model can be used but for the axial scans, in particular, the control rods must be represented, especially the absorber regions in the top sections of the rods. No studies are available to show how approximate a modelling of the control rods would be acceptable. There is an axial asymmetry caused by the absorber sections of the rods and also by the axial asymmetry of the core cells.

In addition to the representation of the control rods, for calculations of the radial reaction rate scans in the sector versions of MZB (MZB/1 and MZB/2) the sectors must be modelled and the graphite reflector region included. Reference should be made to the core plan, Figure 3.7B and also given in 3.10.

The MZA core loading was reduced from the standard loading of 213 elements to 209 elements in order to enable the reactor to be made critical with all of the rods excepting Rod 9 to be fully raised, Rod 9 being at about 50 cm (see Figure 1.20 for a plan view of the core).

A symmetrical loading of core elements was used for the reaction rate scan measurements made in the three versions of MZB, having 413 inner core and 260 outer core elements, four elements less than the standard critical loading (see Figure 3.10). The control rods 7 and 8 were fully raised and rod 9 was positioned at about 75 cm in MZB/1 (which has the depleted uranium oxide sector) and at about 50 cm

in MZB/2 (with the natural uranium oxide sector). The graphite reflector sector was present in all three versions.

The materials of the cores are the standard MZA and MZB materials. The representation of the sector radial blanket and the steel and graphite radial reflectors is required for the calculation of the radial scan measurements in MZB (although for the calculation of keffective and core properties of MZB the graphite reflector can be omitted). In MZB Version 1 the sector contains the two types of natural uranium oxide blanket element, B12-30 (Central cell B12-31) and an outer ring of elements B12-30A (Central cell B12-31A). The Blanket Sector of MZB Version 2 contains the depleted uranium oxide element B12-32 (Central cell B12-32) (see Tables 3.7 and 3.8 for a description of the radial blanket cell constituents and Table 3.11 for a description of the radial blanket element loadings). The graphite reflector sector consists of elements B12-33 in the central section of the sector and B12-31 in the left and right sections of the graphite sector (see Figure 3.7B and Table 3.12 for a description of the graphite element loadings, with the atomic densities being given in Table 3.25).

Details of the control rod dimensions and compositions are given in Sections 3.7.2 and 3.7.3.

3.7.2 Dimensions of the Zebra Control Rods

Data on the control rods are included here but in the analyses which were made by the Mozart team they were not included in the models. The absorber at the top of the rods introduces an axial asymmetry to the core flux but the core cells also introduce an axial asymmetry which was not treated explicitly (cell average cross-sections being used). This will also be the case for the standard cell homogenisation methods currently in use. The way this axial asymmetry was treated in the analyses of the axial reaction rate scan measurements in the central core region was to displace the centre of the calculated distribution to the peak of the reaction rate distribution, which is a displacement of 8.5 mm downwards.

The materials used in the control rods were chosen to match the core and blanket regions of the neighbouring elements but with the boron absorber section above the narrow upper blanket region. The control rods used in MZA (Zebra 11) were single elements while in MZB (Zebra 12) they were double elements, apart from the fine control rod, FR9 which was a single element.

The control rods were loaded so that when raised the centre line of the core section coincided with the centre line of the core section of the standard core elements. When lowered, the centre line of the boron absorber section took that position.

All control rod plates are assumed to be 4.318 cm square (an area of 18.6451 cm²). The control rod sheath has an assumed outer dimension of 5.2544 cm square, the same as the standard elements.

Dimensions in the following Tables are given in cm (the Zebra materials database, PLATEDATA, gives them in mm). The number of significant figures given for the compositions have been simplified when it was thought that the extra figures in the Zebra database were a consequence of computer manipulation.

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Table 3.31 Control Rod Plate Identifiers and Dimensions

(All plates are 4.318 cm square)

Identifier	Type of Plate	Plate Thickness (cm)	Core thickness (cm)	Core width (cm)
PUIVC4	Pu02/U02	0.635	0.56032	4.1
PUIIC8	Pu metal Mk.II	0.3175	0.2159	3.922
PUIIIC8	Pu metal Mk.III	0.3154	0.2138	3.922
U02C4R4	U02 (4 radiused corners)	0.6279	0.55424	4.1
UC8	Natural uranium	0.3167		
NASTC4	Sodium (1965 batch)	0.616	0.54234	4.244
GC8	Graphite (CY9)	0.3155		
STSTC8	Stainless steel	0.3180		
ALCG8	45% aluminium	0.3167		
B10C2	B10	1.27	1.19634	4.244

Table 3.32 Control Rod Sheaths

Identifier	Type of sheath
CRSHEATH	Single element rod
DCRSH	Double element rod (MZB except FR9))

In the Shut-off rods (SOR3 and SOR4) used in MZB a B10 pellet assembly was used in the top absorber section. This consisted of six steel tubes per double rod. The tubes were of ID = 1.80 cm, OD = 2.05 cm and 98.1 cm length and one tube weighed 455 g. They each contained 72 pellets, 1.73 cm OD and total length 92.7 cm, filled at each end by brass pieces protruding 2.5 cm into the bottom end and ~2.8 cm into the top end. The brass pieces extended 1.3 cm beyond the end of the tube and then had spigots 1.0 cm long which fitted into holes in steel pieces 1.3 cm thick and 4.3 cm square, to hold the tubes upright. Thus the assembly of tubes, end pieces and steel pieces had a total length of 103.2 cm. The pellets consisted of about 2.72 g B10 in 3.03 g boron, 1.10 g carbon and 0.02 g aluminium stearate.

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Table 3.33 Control Rod Core Region and Blanket Region Cell Patterns

Cell C11-2A	Cell C11-2B	Cell C 12-32		Cell B11-5
U02C4R4	U02C4R4	U02C4R4		ALCG8
NASTC4	NASTC4	PUIVC4		GC8
PUIIC8	PUIIC8	U02C4R4		UC8
NASTC4	NASTC4	NASTC4		ALCG8
U02C4R4	U02C4R4	U02C4R4		ALCG8
		PUIVC4		UC8
		NASTC4		STSTC8
		U02C4R4		ALCG8
		PUIIC8		
		U02C4R4		
		NASTC4		
		U02C4R4		
		PUIVC4		
		U02C4R4		
		NASTC4		
Cell Height	Height	Height		Height
2.8032 cm	2.8053 cm	9.0767 cm		2.5337 cm

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Table 3.34 Control Rod Boron Absorber Region Cell Patterns

Cell B11-6	Cell B11-7	Cell B11-8	Cell B11-9
3 x ALCG8	ALCG8	3 x ALCG8	10 x ALCG8
B10C2	B10C2	B10C2	B10C2
2 x ALCG8	3 x ALCG8	7 x ALCG8	10 x ALCG8
	B10C2	B10C2	
	3 x ALCG8	7 x ALCG8	
	B10C2	B10C2	
	3 x ALCG8	3 x ALCG8	
	B10C2		
	3 x ALCG8		
	B10C2		
	3 x ALCG8		
	B10C2		
	3 x ALCG8		
	B10C2		
	ALCG8		
Cell Height	Cell Height	Cell Height	Cell Height
2.8535 cm	15.224 cm	10.144 cm	7.604 cm

Cell B12-32	Cell B12-33	Cell B12-34	Cell B12-35
2 x ALCG8	2 x ALCG8	5 x ALCG8	12 x ALCG8
B10C2	B10C2	B10C2	B10C2
3 x ALCG8	2 x ALCG8	5 x ALCG8	12 x ALCG8
Cell Height	Cell Height	Cell Height	Cell Height
2.8535 cm	2.5368 cm	4.437 cm	8.8708 cm

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Table 3.35 Control Rod Element Loadings in MZA

Element Type C11-2/1 Used in Safety Rods 1+2 Shut-off Rods 5+6	Element Type C11-3/1 Used in Shut-off Rods 3+4	Height (cm)	Element Type C11-4/1 Used in Control Rods 7+8	Element Type C11-5/1 Used in Fine Rod 9	Height (cm)
16xUC8 Plates	16xUC8 Plates	5.1	16xUC8 Plates	16xUC8 Plates	5.1
32 cells B11-6	6 cells B11-7	91.3	9 cells B11-8	12 cells B11-9	91.3
24xUC8 Plates	24xUC8 Plates	7.6	24xUC8 Plates	24xUC8 Plates	7.6
3 cells B11-5	3 cells B11-5	7.6	3 cells B11-5	3 cells B11-5	7.6
32 cells C11-2A	32 cells C11-2A	89.70	32 cells C11-2B	32 cells C11-2B	89.77
3 cells B11-5	3 cells B11-5	7.6	3 cells B11-5	3 cells B11-5	7.6
199xUC8 Plates	199xUC8 Plates	63.0	199xUC8 Plates	199xUC8 Plates	63.0

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Table 3.36 Control Element Loadings in MZB

Region	Element Type C12-32 Used in Safety Rods 1+2	Element Type C12-34 Used in Shut off Rods 5+6	Element Type C12-35 Used in Control Rods 7+8	Height (cm)
Top shims	16 x STSTC8 plates	15 x STSTC8 plates	23 x STSTC8 plates	(b), (d)
Absorber	32 cells B12-32	36 cells B12-33	20 cells B12-34	See note (c)
Upper blanket	6 cells B11-5	6 cells B11-5	6 cells B11-5	15.20
Core	10 cells C12-32	10 cells C12-32	10 cells C12-32	90.77
Lower blanket	14 cells B11-5	14 cells B11-5	14 cells B11-5	35.47
Bottom Shims	16 x STSTC8 plates	16 x STSTC8 plates	16 x STSTC8 plates	5.09

Notes:

- (a) All rods except FR9 are double rods, each element position containing the loading described.
- (b) Shut-off Rod SOR5 contains 16xSTSTC8 plates as top shims. The thickness of the shims is 0.318 cm.
- (c) Absorber section lengths are:

SR1 and 2	91.3 cm
SOR5 and 6	91.3 cm
CR7 and 8	88.7 cm
- (d) The top shims go to the top cap of the sheaths. The bottom shims sit on a 30.5 cm spacer for all rods except FR9 when the bottom shims go down to the piston.

Table 3.37 Shut-off Rods 3 and 4 and Fine Control Rod FR9 in MZB.

Region	Element Type C12-33 Used in Shut off Rods 3+4	Height (cm)		Element Type C12-36 Used in Fine Rod 9	Height (cm)
Top shims	2 x STSTC8 plates	0.636		24 x UC8 plates	7.60
Absorber	B10 pellet assembly	See note (a)		10 x B12-35	88.71
Upper blanket	3 cells B11-5	7.60		24 x UC8 plates	7.60
				3 cells B11-5	7.60
Core	10 cells C12-32	90.68		10 cells C12-32	90.77
Lower blanket	14 cells B11-5	35.47		3 cells B11-5	7.60
Bottom Shims	16 x STSTC8 plates	5.09		200 x UC8 plates	63.30

(a) The B10 pellet assembly consists of six steel tubes per double rod. The tubes have ID = 1.80 cm, OD = 2.05 cm and 98.1 cm length. 72 pellets, 1.73 cm OD and total length 92.7 cm, are contained in each tube which is filled at each end by brass pieces protruding 2.5 cm into the bottom end and ~2.8 cm into the top end. The brass pieces extend 1.3 cm beyond the end of the tube and then have spigots 1.0 cm long which fit into holes in steel pieces 1.3 cm thick and 4.3 cm square, to hold the tubes upright. Thus the assembly of tubes, end pieces and steel pieces has a total length of 103.2 cm.

The area of steel (per element) associated with the B10 pellet assembly is 2.2678 cm². The area of boron pellets (assumed to fill the space within the 1.8 cm diameter tubes) is 7.6341 cm² per element.

The pellets consist of about 2.72 g B10 in 0.31 g B11, 1.10 g carbon and 0.02 g aluminium stearate. The weight per unit length (per element) is 6.338 g of B10, 0.722 g of B11, 2.563 g of C and 0.0466 g of aluminium stearate. The densities within the 1.8 cm ID tubes are, 0.8302 g/cc B10, 0.0946 g/cc B11, 0.3357 g/cc C and 0.0061 g/cc of aluminium stearate (assumed to be Al(C₁₈H₃₆O₂)₃ that is, about 0.0002 g/cc Al, 0.0045 g/cc C, 0.00075 g/cc H and 0.00065 g/cc O).

Composition of the boron carbide pellets

	Density within the tubes (g/cc)	Atomic density Atoms/barn.cm
H	0.00075	4.5166E-04
B10	0.8302	4.9995E-02
B11	0.0946	5.1790E-03
C	0.33645	1.6884E-02
O	0.00065	2.4465E-05
Al	0.0002	4.4608E-06
Total	1.2629	7.2540E-02

3.7.3 Compositions of the Zebra Control Rods

Atomic Densities (in Atoms/barn.cm) Volumes in cm³

Table 3.38 Control Rod Mixed Oxide Plate PUIVC4

PLATE CORE COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
O	10.831	11.827	4.3282E-02
U235	0.429	0.468	1.1669E-04
U238	59.861	65.367	1.6077E-02
NP237	0.001	0.001	2.6972E-07
PU239	18.078	19.741	4.8350E-03
PU240	2.029	2.216	5.4040E-04
PU241	0.205	0.224	5.4372E-05
PU242	0.087	0.095	2.2980E-05
AM241	0.006	0.007	1.5914E-06
C	0.01	0.011	5.3231E-05
AL	0.01	0.011	2.3696E-05
SI	0.01	0.011	2.2765E-05
FE	0.01	0.011	1.1448E-05
NI	0.01	0.011	1.0894E-05
Total	91.577		6.5053E-02
Volume			9.4190 (cm ³)

CAN COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
H	0.000064	0.0005	1.5797E-05
C	0.0064	0.05	1.3256E-04
SI	0.0524	0.41	4.6415E-04
P	0.0026	0.02	2.0883E-05
S	0.0026	0.02	2.0169E-05
CR	2.2864	17.90	1.0939E-02
MN	0.1903	1.49	8.6173E-04
FE	8.8734	69.47	3.9527E-02
NI	1.2760	9.99	5.4087E-03
NB	0.0830	0.65	2.2225E-04
Total	12.773164		5.7613E-02
Volume			2.4207 (cm ³)

Table 3.39 Control Rod Plutonium Metal Plate PUIIC8

PLATE CORE COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
H	0.00007	0.00014	1.2594E-05
C	0.0068	0.01340	1.0266E-04
AL	0.0068	0.01340	4.5701E-05
SI	0.0068	0.01340	4.3905E-05
FE	0.0068	0.01340	2.2079E-05
NI	0.0068	0.01340	2.1010E-05
GA	0.8942	1.76237	2.3256E-03
NP237	0.0161	0.03173	1.2316E-05
PU239	47.149	92.92573	3.5765E-02
PU240	2.452	4.83263	1.8522E-03
PU241	0.134	0.26410	1.0080E-04
AM241	0.0590	0.11628	4.4382E-05
Total	50.73837		4.0348E-02
Volume			3.3210 (cm ³)

CAN COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
C	0.0082	0.07	1.5820E-04
SI	0.040	0.34	3.3003E-04
P	0.0024	0.02	1.7955E-05
S	0.0024	0.02	1.7342E-05
CR	2.128	18.14	9.4837E-03
MN	0.110	0.94	4.6398E-04
FE	8.359	71.26	3.4684E-02
NI	1.080	9.21	4.2642E-03
Total	11.73		
Cu	3.93		1.4331E-02
Grand total	15.66		6.3750E-02
Volume			2.5988 (cm ³)

Table 3.40 Control Rod Plutonium Metal Plate PUIIC8

PLATE CORE COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
GA	0.85	1.678	2.2324E-03
PU239	43.947	86.764	3.3664E-02
PU240	5.111	10.091	3.8987E-03
PU241	0.521	1.029	3.9577E-04
PU242	0.045	0.089	3.4042E-05
AM241	0.1773	0.350	1.3468E-04
Total	50.6513		4.0359E-02
Volume			3.2887 (cm ³)

CAN COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
C	0.0081	0.07	1.5852E-04
SI	0.0395	0.34	3.3059E-04
P	0.0023	0.02	1.7454E-05
S	0.0023	0.02	1.6858E-05
CR	2.105	18.14	9.5159E-03
MN	0.109	0.94	4.6636E-04
FE	8.269	71.26	3.4803E-02
NI	1.069	9.21	4.2814E-03
Total	11.6042		
Cu	4.071		1.5059E-02
Grand total	15.6752		6.4649E-02
Volume			2.5620 (cm ³)

Table 3.41 Control Rod Uranium Oxide Plate UO₂C4R4

PLATE CORE COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
H	0.00037	0.0004	2.3728E-05
C	0.0056	0.0059	3.0136E-05
SI	0.0056	0.0059	1.2888E-05
FE	0.0056	0.0059	6.4814E-06
O	11.1554	11.8513	4.5094E-02
U234	0.0042	0.0045	1.1599E-06
U235	0.59	0.6268	1.6225E-04
U238	82.3612	87.4992	2.2363E-02
Total	94.12797		6.7694E-02
Volume			9.3168 (cm ³)

PLATE CAN COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
H	0.000065	0.0005	1.6246E-05
C	0.0065	0.05	1.3633E-04
SI	0.064	0.49	5.7406E-04
P	0.0026	0.02	2.1146E-05
S	0.0026	0.02	2.0424E-05
CR	2.390	18.4	1.1579E-02
MN	0.200	1.54	9.1710E-04
FE	9.012	69.38	4.0652E-02
NI	1.312	10.1	5.6316E-03
CU	0.230	1.77	9.1180E-04
AG	0.580	4.465	1.3545E-03
Total	13.80		6.1815E-02
Volume			2.3905 (cm ³)

Table 3.42 Control Rod Uranium Carbide Plate UC8

PLATE COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
C	0.058	0.054	4.9248E-04
SI	0.058	0.054	2.1061E-04
FE	0.058	0.054	1.0592E-04
U235	0.767	0.710	3.3280E-04
U238	107.080	99.129	4.5875E-02
Total	108.021		4.7017E-02
Volume			5.9049 (cm ³)

Table 3.43 Control Rod Sodium Plate NASTC4

PLATE CORE COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
H	0.000033	0.00040	2.0185E-06
LI	0.000041	0.00050	3.6416E-07
B	0.000024	0.00029	1.3686E-07
O	0.000493	0.00602	1.8996E-06
NA	8.193000	99.97601	2.1970E-02
K	0.000285	0.00348	4.4938E-07
CA	0.001063	0.01297	1.6351E-06
FE	0.000033	0.00040	3.6428E-08
Total	8.194966		2.1977E-02
Volume			9.7684 (cm ³)

CAN COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
C	0.0078	0.06	2.2777E-04
SI	0.051	0.39	6.3689E-04
P	0.0026	0.02	2.9441E-05
S	0.0026	0.02	2.8435E-05
CR	2.353	17.99	1.5872E-02
MN	0.179	1.37	1.1428E-03
FE	9.113	69.67	5.7232E-02
NI	1.284	9.82	7.6732E-03
NB	0.085	0.65	3.2089E-04
Total	13.078		8.3163E-02
Volume			1.7170 (cm ³)

Table 3.44 Control Rod Stainless Steel Plate STSTC8

PLATE COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
C	0.0731	0.16	6.1816E-04
SI	0.4109	0.90	1.4860E-03
P	0.0183	0.04	6.0009E-05
S	0.0183	0.04	5.7958E-05
TI	0.3653	0.80	7.7492E-04
CR	7.9905	17.50	1.5609E-02
MN	0.9132	2.00	1.6883E-03
FE	32.4460	71.06	5.9009E-02
NI	3.4245	7.50	5.9264E-03
Total	45.6601		8.5230E-02
Volume			5.9291 (cm ³)

PLATE IDENTITY GC8

PLATE CORE COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
H	0.00100	0.01000	1.0157E-04
B	0.000075	0.00079	7.1020E-07
C	9.543	99.90520	8.1338E-02
NA	0.00066	0.00691	2.9390E-06
AL	0.00048	0.00500	1.8212E-06
SI	0.00191	0.02000	6.9621E-06
S	0.00005	0.00052	1.5961E-07
CA	0.00058	0.00607	1.4815E-06
V	0.00010	0.00105	2.0096E-07
MN	0.00015	0.00157	2.7951E-07
FE	0.00381	0.03989	6.9841E-06
CU	0.00019	0.00199	3.0609E-07
ZN	0.00005	0.00052	7.8279E-08
Total	9.552055		8.1461E-02
Volume			5.8825 (cm ³)

Table 3.45 Control Rod Aluminium Plate ALCG8

PLATE CORE COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
AL	7.0644	99.500	2.6702E-02
SI	0.0133	0.187	4.8295E-05
MN	0.00225	0.032	4.1768E-06
FE	0.01773	0.250	3.2378E-05
CU	0.00225	0.032	3.6110E-06
Total	7.1		2.6791E-02
Volume			5.9049 (cm ³)

Table 3.46 Control Rod Enriched Boron Plate B10C2

PLATE CORE COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
H	0.0082	0.04	2.2737E-04
B10	17.90	85.13	4.9962E-02
B11	1.57	7.47	3.9855E-03
C	0.3154	1.50	7.3388E-04
O	0.4333	2.06	7.5688E-04
AL	0.0841	0.40	8.7111E-05
SI	0.1577	0.75	1.5693E-04
K	0.0841	0.40	6.0115E-05
CR	0.0841	0.40	4.5203E-05
FE	0.1472	0.70	7.3663E-05
NI	0.1577	0.75	7.5095E-05
CU	0.0841	0.40	3.6987E-05
Total	21.0259		5.6200E-02
Volume			21.5479 (cm ³)

PLATE CAN COMPOSITION

Material	Weight, g	Weight %	Atoms/barn.cm
NI	37.05	100	1.7836E-01
Volume			2.1314 (cm ³)

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Table 3.47 Control Rod Sheath CRSHEATH

Weight per 1 cm of length

Material	Weight, g	Weight %	Atoms/barn.cm	Atoms/barn.cm	Atoms/barn.cm
Assumed Outer Width			5.2544 cm	5.3721 cm	5.4254 cm
H	0.0015	0.00	9.9986E-05	8.7743E-05	8.2535E-05
C	0.05	0.13	2.7968E-04	2.4543E-04	2.3086E-04
SI	0.04	0.11	9.5685E-05	8.3969E-05	7.8984E-05
P	0.01	0.03	2.1691E-05	1.9035E-05	1.7905E-05
S	0.01	0.03	2.0949E-05	1.8384E-05	1.7293E-05
MN	0.22	0.59	2.6904E-04	2.3610E-04	2.2208E-04
FE	36.82	99.11	4.4294E-02	3.8871E-02	3.6563E-02
Total	37.1515		4.5081E-02	3.9561E-02	3.7213E-02
Area (cm ²)			8.9636	10.2143	10.8589

Table 3.48 Control Rod Sheath DCRSHTH

Weight per 1 cm of length

Material	Weight, g	Weight %	Atoms/barn.cm	Atoms/barn.cm	Atoms/barn.cm
Assumed Outer Width			5.2544 cm	5.3721 cm	5.4254 cm
H	0.00045	0.001	2.9996E-05	2.6323E-05	2.4760E-05
C	0.06	0.134	3.3561E-04	2.9452E-04	2.7703E-04
SI	0.05	0.112	1.1961E-04	1.0496E-04	9.8730E-05
P	0.01	0.022	2.1691E-05	1.9035E-05	1.7905E-05
S	0.01	0.022	2.0949E-05	1.8384E-05	1.7293E-05
MN	0.27	0.603	3.3018E-04	2.8975E-04	2.7255E-04
FE	44.40	99.106	5.3413E-02	4.6873E-02	4.4091E-02
Total	44.80045		5.4271E-02	4.7626E-02	4.4799E-02
Area (cm ²)			8.9636	10.2143	10.8589

All plates are assumed to be 4.318 cm square and the control rod sheath has an assumed outer dimension of 5.2544 cm square, the same as the standard elements. The area occupied by the sheath material is then 8.9636 cm².

In addition, atomic number densities are given for smearing over the lattice area of 5.3721 cm square (an area occupied by the sheath material of 10.2143 cm²) and the average core lattice area (including the superlattice grid) of 5.4254 cm square (an area of 10.8589 cm²).

3.7.4 Temperature Data

Records of the temperature at which the measurements were performed are not available. For the purposes of the calculations, the models and temperatures used for the criticality calculations can be adopted. These are:

MZA 23.5°C MZB 21.4°C

3.7.5 Experimental and Benchmark Reaction Rate Scan Measurements

The results of the measurements are presented in Section 1.7. These are recommended as benchmark measurements.

3.8 Power Distribution Measurements

Not measured.

3.9 Isotopic Measurements

Not measured.

3.10 Miscellaneous Types of Measurement

Not measured.

4. RESULTS OF SAMPLE CALCULATIONS

Calculations of k_{eff} and central reaction rate ratios have been made using the MONK9A continuous energy Monte Carlo code and the nuclear data libraries, JEF-2.2, JENDL-3.2 and ENDF/B-VI version 4. The temperature of the libraries is 300K.

Calculations have also been made using MCNP5 and the libraries JEFF-3.1 and JENDL-3.3

4.1 K-effective Values for the MOZART Cores, MZA and MZB/3 (*revised)

Table 4.1 MONK9A/JEF-2.2 k_{eff} results (20 million histories)

Core	C (JEF-2.2)	E	(C-E)% (JEF-2.2)
MZA Model A	1.0121 ± 0.00015	1.0097 ± 0.0016	$+0.24 \pm 0.16$
MZB/3 Model AS	1.0072 ± 0.00015	1.0044 ± 0.0010	$+0.28 \pm 0.16$

Table 4.2 MONK9A/JENDL-3.2 k_{eff} results

Core	C (JENDL-3.2)	E	(C-E)% (JENDL-3.2)
MZA Model A	1.0076 ± 0.00015	1.0097 ± 0.0016	-0.21 ± 0.16
MZB/3 Model AS	1.0029 ± 0.00015	1.0044 ± 0.0010	-0.15 ± 0.10

Table 4.3 MONK9A/ENDF/B-VI v-4- k_{eff} results

Core	C (ENDF/B-VI v4)	E	(C-E)% (ENDF/B-VI v4))
MZA Model A	1.0165 ± 0.00015	1.0097 ± 0.0016	$+0.68 \pm 0.16$
MZB/3 Model AS	1.0128 ± 0.00015	1.0044 ± 0.0010	$+0.84 \pm 0.10$

Table 4.4 MCNP5/JEFF-3.1 k_{eff} results

Core	C (JEFF-3.1)	E	(C-E)% (JEFF-3.1)
MZA Model A	1.01418 ± 0.00015	1.0097 ± 0.0016	$+0.45 \pm 0.16$
MZB/3 Model A	1.00898 ± 0.00012	1.0044 ± 0.0010	$+0.46 \pm 0.10$

Table 4.5 MCNP5/JENDL-3.3 k_{eff} results

Core	C (JENDL-3.3)	E	(C-E)% (JENDL-3.3)
MZA Model A	1.00948 ± 0.00015	1.0097 ± 0.0016	-0.02 ± 0.16
MZB/3 Model A	1.00518 ± 0.00012	1.0044 ± 0.0010	$+0.08 \pm 0.10$

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Table 4.6 k-effective results for the ZEBRA CADENZA Assemblies (for comparison purposes)

ZEBRA Core	C	E	100(C-E)/E
MONK-JEF-2.2			
Plate Geometry Core, Assembly 22	1.0005 ± 0.0001	1.0022 ± 0.0008	(-0.17 ± 0.08)%
Pin Geometry Core, Assembly 23	1.0038 ± 0.0001	1.0016 ± 0.0013	(+0.22 ± 0.13)%
MONK-JENDL-3.2			
Plate Geometry Core, Assembly 22	0.9956 ± 0.0001	1.0022 ± 0.0008	(-0.66 ± 0.08)%
Pin Geometry Core, Assembly 23	0.9984 ± 0.0001	1.0016 ± 0.0013	(-0.32 ± 0.13)%
MONK-ENDF/B-VI v-4			
Plate Geometry Core, Assembly 22	1.0083 ± 0.0001	1.0022 ± 0.0008	(+0.61 ± 0.08)%
Pin Geometry Core, Assembly 23	1.0107 ± 0.0001	1.0016 ± 0.0013	(+0.91 ± 0.13)%
MCNP-JEFF-3.1			
Plate Geometry Core, Assembly 22	1.00614 ± 0.00015	1.0022 ± 0.0008	(+0.39 ± 0.08)%
Pin Geometry Core, Assembly 23	1.00836 ± 0.00016	1.0016 ± 0.0013	(+0.68 ± 0.13)%
MCNP-JENDL-3.3			
Plate Geometry Core, Assembly 22	0.99656 ± 0.00015	1.0022 ± 0.0008	(-0.56 ± 0.08)%
Pin Geometry Core, Assembly 23	0.99902 ± 0.00015	1.0016 ± 0.0013	(-0.26 ± 0.13)%

There are large differences between the Zebra Assembly 22 and Zebra 23 k-effective (C-E) values, ranging from 0.26% to 0.41%.

The (C-E) values for MZA and MZB are within about 0.2% of each other and within about 0.3% of the Assembly 23 (CADENZA pin geometry core) values.

The assemblies MZA and Zebra 22 are similar to each other in size and composition, although some of the particular plates used to make up the cores are different and the blankets differ, being composed of natural uranium in the case of the Cadenza cores. However, some of the differences between the keffective (C-E) values are surprisingly large (ranging from agreement for ENDF/B-VI v-4 and JEFF-3.1 up to differences in the range 0.4% dk to 0.5% dk for JEFF-2.2, JENDL-3.2 and JENDL-3.3).

4.3 Results of Spectral Characteristics Calculations. Central Spectral Indices

Central cell averaged reaction rate ratio calculations for MZA and MZB

(Note: the possible systematic uncertainties associated with the Zebra measurement techniques, proposed in Section 2.3, have not been included.)

Table 4.7 MONK/JEF-2.2 Spectral Indices

Reaction rate ratio	Calculated	Measured	$100\{(C/E) - 1\}$
MZA F28/F25	0.03232 ($\pm 0.97\%$)	0.03356 ($\pm 1.4\%$)	-3.7 (± 1.7)
MZA F25/F49	0.9970 ($\pm 0.87\%$)	0.978 ($\pm 1.9\%$)	+1.9 (± 2.1)
MZA C28/F49	0.1285 ($\pm 0.26\%$)	0.1291 ($\pm 1.4\%$)	-0.5 (± 1.4)
MZB F28/F25	0.02270 ($\pm 1.6\%$)	0.02283 ($\pm 1.2\%$)	-0.6 (± 2.0)
MZB F25/F49	1.0642 ($\pm 1.4\%$)	1.066 ($\pm 1.3\%$)	-0.2 (± 1.9)
MZB C28/F49	0.1435 ($\pm 0.5\%$)	0.1428 ($\pm 1.3\%$)	+0.5 (± 1.4)
	Cell average calculation	Chamber measurement	
MZA F40/F49 (Chamber)	0.2841 ($\pm 0.6\%$)	0.2565 ($\pm 4.7\%$)	(+10.8)* (± 4.7)
MZA F41/F49 (Chamber)	1.316 ($\pm 0.7\%$)	1.279 ($\pm 3.3\%$)	(+2.9)* (± 3.3)

* Chamber measurement compared with a cell average calculation

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Table 4.8 Results calculated for the CADENZA Core ZEBRA 22 (for comparison purposes)

Reaction rate ratio	Calculated (MONK/JEF-2.2)	Measured	100(C-E)/E%
F28/F25	0.03455 (± 0.57%)	0.03634 (± 1.3%)	-4.9 (± 1.4)
F25/F49	0.9655 (± 0.56%)	0.959 (± 1.6%)	+0.7 (± 1.7)
C28/F49	0.1236 (± 0.17%)	0.1266 (± 1.1%)	-2.4 (± 1.1)
	Cell average calculation	Chamber measurement	
F28/F25 (Chamber)	0.03455 (± 0.57%)	0.03483 (± 4.3%)	(-0.8) *
F25/F49 (Chamber)	0.9655 (± 0.56%)	0.960 (± 1.6%)	(+0.6) *
F40/F49 (Chamber)	0.2887 (± 0.4%)	0.2594 (± 4.6%)	(+11.3) *
F41/F49 (Chamber)	1.217 (± 0.5%)	1.217 (± 4.0%)	(0.0) *

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Table 4.9 Spectral Indices calculated using MONK/JENDL-3.2

Reaction rate ratio	Calculated	Measured	100{(C/E) - 1}
MZA F28/F25	0.03332 ($\pm$ 0.97%)	0.03356 ($\pm$ 1.4%)	-0.7 ($\pm$ 1.7)
MZA F25/F49	0.9788 ($\pm$ 0.89%)	0.978 ($\pm$ 1.9%)	0.1 ($\pm$ 2.1)
MZA C28/F49	0.1282 ($\pm$ 0.26%)	0.1291 ($\pm$ 1.4%)	-0.7 ($\pm$ 1.4)
MZB F28/F25	0.02273 ($\pm$ 1.6%)	0.02283 ($\pm$ 1.2%)	-0.4 ($\pm$ 2.0)
MZB F25/F49	1.0635 ($\pm$ 1.4%)	1.066 ($\pm$ 1.3%)	-0.3 ($\pm$ 1.9)
MZB C28/F49	0.1430 ($\pm$ 0.5%)	0.1428 ($\pm$ 1.3%)	0.1 ($\pm$ 1.3)
	Cell average calculation	Chamber measurement	
MZA F40/F49 (Chamber)	0.2818 ($\pm$ 0.6%)	0.2565 ($\pm$ 4.7%)	(10.3)* ($\pm$ 4.7)
MZA F41/F49 (Chamber)	1.335 ($\pm$ 0.7%)	1.279 ($\pm$ 3.3%)	(4.4)* ($\pm$ 3.3)

* Chamber measurement compared with a cell average calculation

Table 4.10 Results calculated for the CADENZA Core ZEBRA 22 (for comparison purposes)

Reaction rate ratio	Calculated (MONK/JENDL-3.2)	Measured	(C-E)/E%
F28/F25	0.03495 ($\pm$ 1.2%)	0.03634 ($\pm$ 1.3%)	-3.8 ($\pm$ 1.8)
F25/F49	0.974 ($\pm$ 1.1%)	0.959 ($\pm$ 1.6%)	+1.6 ($\pm$ 1.9)
C28/F49	0.1235 ($\pm$ 0.34%)	0.1266 ($\pm$ 1.1%)	-2.4 ($\pm$ 1.2)
	Cell average calculation	Chamber measurement	
F28/F25 (Chamber)	0.03495 ($\pm$ 1.2%)	0.03483 ($\pm$ 4.3%)	(+0.3) *
F25/F49 (Chamber)	0.974 ($\pm$ 1.1%)	0.960 ($\pm$ 1.6%)	(+1.4) *
F40/F49 (Chamber)	0.2908 ($\pm$ 0.75%)	0.2594 ($\pm$ 4.6%)	(+12.) *
F41/F49 (Chamber)	1.324 ($\pm$ 1.0%)	1.217 ($\pm$ 4.0%)	(+8.8) *

* Chamber measurement compared with a cell average calculation

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Table 4.11 Spectral Indices Calculated using MONK/ENDF/B-VI v-4

Reaction rate ratio	Calculated	Measured	{(C/E) - 1} %
MZA F28/F25	0.03319 ($\pm$ 0.95%)	0.03356 ($\pm$ 1.4%)	-1.1 ($\pm$ 1.7)
MZA F25/F49	0.980 ($\pm$ 0.87%)	0.978 ($\pm$ 1.9%)	+0.2 ($\pm$ 2.1)
MZA C28/F49	0.1286 ($\pm$ 0.26%)	0.1291 ($\pm$ 1.4%)	-0.4 ($\pm$ 1.3)
MZB F28/F25	0.02232 ($\pm$ 1.6%)	0.02283 ($\pm$ 1.2%)	-2.2 ($\pm$ 2.0)
MZB F25/F49	1.083 ($\pm$ 1.4%)	1.066 ($\pm$ 1.3%)	+1.7 ($\pm$ 1.9)
MZB C28/F49	0.1436 ($\pm$ 0.5%)	0.1428 ($\pm$ 1.3%)	+0.6 ($\pm$ 1.4)
	Cell average calculation	Chamber measurement	
MZA F40/F49 (Chamber)	0.2951 ($\pm$ 0.6%)	0.2565 ($\pm$ 4.7%)	(+15.0)* ($\pm$ 4.7)
MZA F41/F49 (Chamber)	1.322 ($\pm$ 0.7%)	1.279 ($\pm$ 3.3%)	(+3.4)* ($\pm$ 3.3)

* Chamber measurement compared with a cell average calculation

Table 4.12 Results calculated for the CADENZA Core ZEBRA 22 (for comparison purposes)

Reaction rate ratio	Calculated ENDF/B-VI v-4	Measured	(C-E)/E%
F28/F25	0.03481 ($\pm$ 0.7%)	0.03634 ($\pm$ 1.3%)	-4.2 ($\pm$ 1.5)
F25/F49	0.969 ($\pm$ 0.7%)	0.959 ($\pm$ 1.6%)	+1.0 ($\pm$ 1.7)
C28/F49	0.1229 ($\pm$ 0.2%)	0.1266 ($\pm$ 1.1%)	-3.0 ($\pm$ 1.1)
	Cell average calculation	Chamber measurement	
F28/F25 (Chamber)	0.03481 ($\pm$ 0.7%)	0.03483 ($\pm$ 4.3%)	(-0.1) *
F25/F49 (Chamber)	0.969 ($\pm$ 0.7%)	0.960 ($\pm$ 1.6%)	(+0.9) *
F40/F49 (Chamber)	0.3020 ($\pm$ 0.4%)	0.2594 ($\pm$ 4.6%)	(+16.4) *
F41/F49 (Chamber)	1.284 ($\pm$ 0.6%)	1.217 ($\pm$ 4.0%)	(5.5) *

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The C/E values calculated using JENDL-3.2 and ENDF/B-VI v4 for MZA and MZB are consistent with each other and are within (or close to) 1 s.d. of the measured value. The values calculated for MZB using JEF-2.2 are also in agreement with measurement but there is a discrepancy for MZA F28/F25. The Assembly 22 measured values for F28/F25 and C28/F49 look to be discrepant.

4.4 The Reactivity Worth Measurements

The original analyses can be found in the following MTNs:

Central and distributed reactivity worth measurements. MTN/96

Sodium voiding reactivity in MZB MTN/73 and 103

The methods of calculation used in these analyses, carried out in the early 1970s, involved cell calculations using the MURAL Cell Code (collision probabilities) and the 2000 group plus sub-group cross-section library FGL5 (see MTN/81). Whole reactor calculations were made using finite difference diffusion theory codes, and associated perturbation theory edits. The geometries treated included, RZ, XY with region and energy dependent axial bucklings, and XYZ. Finite difference Sn methods in one and two dimensions were used to obtain transport theory corrections to the diffusion theory results.

4.7 The Reaction Rate Distribution Measurements

The original analyses can be found in the following MTNs:

MTN/38, /45, /57, /63, /70, /71, /72, /105

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J. M. Stevenson, S. F. Swoboda	Revised Proposal for Mozart Assemblies	MTN1
J. E. Sanders	Outline Programme of Control Rod Measurements in MZC	MTN2
J. L. Butler	Proposals for the Kochel Programme of Energy-Deposition and Penetration Measurements on the Zebra Mozart Cores	MTN3
C. McCombie	Calculations in support of Spectrum Measurements in MZA	MTN4
J. M. Stevenson, S. F. Swoboda	Description of Subcritical and Standard Critical Loadings of Zebra 11 (MZA)	MTN5
J. Marshall, J. M. Stevenson, S. F. Swoboda	Control Rod Calibrations in Zebra 11 (MZA)	MTN6
T. Konishi, J. Marshall	Zebra Core 11 (MZA) Number Densities (Computer Print - Out) Volume 1, 2 And 3	MTN7
J. M. Stevenson, S. F. Swoboda	Further Information on the Experimental Reactivity of the 213 Core Element Loading of Zebra 11 (MZA)	MTN8
J. M. Stevenson, S. F. Swoboda	Further Information on the Experimental Reactivity of the 213 Core Element Loading Of Zebra 11 (MZA)	MTN8- ADD
J. M. Stevenson, S. F. Swoboda	Reactivity Measurements with Plate Samples in Zebra 11 (MZA)	MTN9
M. D. Carter, J. Samways	Spectrum Measurements with Proton -Recoil Counters In Zebra 11 (MZA)	MTN10
J. P. Hardiman, B. Franklin	Re-Evaluation of Time-Of-Flight Spectra in Zebra Core 11 (MZA)	MTN11
J. M. Stevenson	Experiment B10 (3) (Comparison of Reactivity Scales)	MTN12
J. M. Stevenson, S. F. Swoboda	Sodium Removal Reactivity Measurements in Zebra 11 (MZA)	MTN13
B. L. M. Burbidge, G. Ingram, D. Jowitt, Miss M. P. Smith, Miss P. A. Smart, D. Sweet	Central Reaction Rate Ratio Measurements in Zebra Core 11	MTN14
H. Yoshida	Analyses of Central Perturbation Measurements in Zebra 10	MTN15
J. M. Stevenson, S. F. Swoboda	The Final Design of MZB	MTN16
A. Sugawara	An Estimate of the MZC Reactivity Requirements and the Number of Outer Core Elements to be added to MZB	MTN17
J. M. Stevenson, S. F. Swoboda	Description of the Standard Loading of Zebra Assembly 12(1) - The First Version Of MZB	MTN18
H. Yoshida	Analysis of Sodium Removal Reactivity Measurements in Zebra 11 (MZA)	MTN19
H. Yoshida	Analysis Of Central Perturbation Measurements In Zebra 11 (Mza)	MTN20
A. K. McCracken, A. Packwood	Details of the Irradiations in the Kochel Programme on the MZB Core	MTN21
A. K. McCracken	MTN/21 Amendment 1	MTN21- AM1

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A. K. McCracken	MTN/21 Amendment 2	MTN21-AM2
M. D. Carter, J. Samways	Energy Uncertainties near 30 Kev in Proton Recoil Counter Spectrum Measurements in Zebra 11 (MZA)	MTN22
J. Marshall, J. M. Stevenson, S. F. Swoboda	Control Rod Calibrations in Zebra 12(1) - The First Version of MZB	MTN23
B. L. H. Burbidge, G. Ingram, D. W. Sweet, W. H. Taylor	Reaction Rate Scans Using Foils in Zebra Core 11	MTN24
J. M. Stevenson, S. F. Swoboda	The Experimental Reactivity of the Standard Loading of Zebra 12/1 - The First Version of MZB	MTN25
J. M. Stevenson, S. F. Swoboda	Additional Perturbation Measurements in MZB/1	MTN26
G. Ingram	Simulated Vapour Explosion and Melt Down Measurements in Zebra Core 12 (MZB/2)	MTN27
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J. E. Sanders	A Revised Programme of Control Rod Measurements in MZC	MTN34
A. Sugawara	Application of the Twotran(XY) Code to Fast Reactor Analysis	MTN35
J. M. Stevenson, S. F. Swoboda	Reactivity Worths of Special Assemblies in Various Radial Positions in Zebra Core 12 (Mzb)	MTN36
M. Nakano, R. W. Smith	Mural/FGL4 Cell Calculations For MZB (Zebra Core 12)	MTN37
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C. G. Campbell, S. Kobayashi	Data On PNC 90 % B4C And Ta Absorbers	MTN39
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B. M. Franklin, J. P. Hardiman	The Buckling of Zebra Core 11 (MZA)	MTN44
T. Konishi	Diffusion Theory Calculations of the Reactivity, Reaction Rate Ratios and Reaction Rate Distributions in MZA	MTN45
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APPENDIX A DATA INPUT FOR CALCULATIONS

A1. MONK Monte Carlo Models for MZA and MZB

MONK9a is a hyperfine group Monte Carlo code (Serco-Assurance, Winfrith, UK), the version used for earlier work being version 8b.

k_{eff} values, and central reaction rate ratios in MZA and MZB were calculated using MONK8b. Calculations were made using three MONK hyperfine group nuclear data sets, based respectively on JEF-2.2, JENDL-3.2 and ENDFB-VI-v3.

The Models used for the MONK8b calculations are as follows:

In Model A all of the plates in the core region are represented whereas in Model AS only one representative type of core element is represented.

In Model C there are further simplifications. The 5x5 array of elements is replaced by a uniform array and the element sheaths are smeared over the void regions outside the plates, filling the spaces between the plates and the uniform lattice mesh.

In the case of MZB/3 (uniform radial blanket), because of size limitations only Model C and Model AS are calculated (and not Model A).

Contents

MZA Model A (Pages X+2 to 1X+15)

MZA Model C (Pages X+16 to X+25)

MZB/3 Model C (Pages X+26 to X+43)

MZB/3 Model AS (Pages X+44 to X+64)

Note: the composition of the UO₂3R₄ uranium oxide plate used in the MZB inner core has been revised in the main document but the data given below were used in the calculations. Also, the gap between the groups of 5x5 lattice positions has been taken to be 0.2667 cm instead of the value given in the text of 0.2665 cm (this corresponds to the assumption of an overall average lattice spacing of 5.42544 cm (used in some Zebra documentation) instead of 5.4254 cm.

Construction of the MONK models.

The models are built up from PARTS (which are numbered sequentially. In the case of these Mozart Models a PART is either a NEST, an ARRAY or a CLUSTER. A nest begins with the inner region and outer regions are added sequentially (although some of the boundaries of an outer region can coincide with those of the next inner region).

The geometry of the component regions of a NEST or a CLUSTER can be either a BOX or a ZROD (in the case of these Mozart models, that is a cylinder with its axis in the Z direction).

The contents of a region can be either a Material (for which an M number is specified) or a Part (for which a P number is specified). Arrays consist of PARTS and so it is not necessary to include the letter P.

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The position and dimensions of a BOX (a rectangular parallelepiped) are specified by the six numbers which follow the material specification. The first three numbers are the coordinates of the corner having the lowest (x,y,z) coordinates and the second set of three numbers are the dimensions of the sides,(dx,dy,dz) of the box.

The positions and dimensions of a ZROD are specified by the three coordinates of the lower end of the axis (x,y,z) followed by the radius and the height

In the case of a CLUSTER the component regions are adjacent or can surround the previous set of regions.

An ARRAY is a three dimensional set of parts. The first three numbers give the numbers of components in the X, Y and Z directions. This is followed by the part numbers in the sequence they are in, in the array (starting from the lowest X Y and Z positions, in sequence0

Examples.

The plutonium metal plate. The plutonium is material M1 and the canning material is M2. The boxes are symmetrically placed, the lowest corner of the inner box being at (-dx/2, -dy/2, z= the thickness of the canning) It could equally well have been -dz/2.

```
* Plate 1, the Pu metal plate PUV8
PART 1 NEST
BOX      M1  -2.3355  -2.3355      0.04572      4.671      4.671
0.23506
BOX      M2  -2.5335  -2.5335      0.0      5.067      5.067      0.3265
```

The positions of the regions are only of significance within the specification of a PART. When PARTS are combined it is only the dimensions of the PART which is of significance, they can be piled up in ARRAYS or assembled in CLUSTERS or be regions of another PART.

A core cell is built as an ARRAY in the Z direction of the PARTS representing the plates. There are 14 plates in the cell, the dimensions of the array being X=1, Y=1, Z=14 (the first three numbers). These are followed by the PART numbers of the plates.

```
* Core Cell A
PART 23 ARRAY
1  1  14  3  2  3  1  4  2  3  3  2  5  1  3  2  3
```

An element is built as an ARRAY of cells, there being 24 cell PARTS in the element in the Z direction. The notation (27)*4 means that there are 4 x PART 27 sequentially

```
* The Core Element A
PART 36 ARRAY
1  1  24  35  34  (27)*4  (23)*12  (27)*4  29  35
*
```

The sheath has been added to this array and the void regions, M0, on either side of the sheath are introduced at this stage. Note, the outer BOX has the same X and Y dimensions as the inner region and so only adds material at the top and the bottom of the column (introduced to make all of the elements the same height).

```
* Sheath added and Element extended
*
```

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```
PART 37 NEST
BOX P36 -2.5335 -2.5335 -113.7514 5.067 5.067 227.5028
BOX M0 -2.5510 -2.5510 -113.7514 5.102 5.102 227.5028
BOX M19 -2.6272 -2.6272 -113.7514 5.2544 5.2544 227.5028
BOX M0 -2.68605 -2.68605 -113.7514 5.3721 5.3721 227.5028
BOX M14 -2.68605 -2.68605 -115.0 5.3721 5.3721 230.0
*
```

(The BOXES can contain either a PART, P36, or a material, M19)

An array of 5x5 elements is assembled (ARRAY dimensions 5, 5, 1) and the void region outside the groups of 5x5 elements is added.

```
*
PART 51 ARRAY
5 5 1 (50)*25
*
PART 52 NEST
BOX P51 -13.43025 -13.43025 -115.0 26.8605 26.8605
230.0
BOX M0 -13.5635 -13.5635 -115.0 27.127 27.127
230.0
*
```

The 5x5 blocks of elements are first assembled in rows along the X axis, there being 7 such blocks in Row 3.

```
* combine these arrays to form the row 3 array
PART 109 ARRAY
7 1 1 96 98 100 102 104 106 108
*
```

Finally the rows are put together as a non-overlapping CLUSTER of BOXES, surrounded by a ZROD cylinder of shielding material.

```
* Cluster of superlattice groups in a circle of shield material
PART 124 CLUSTER
BOX P123 -40.6905 67.8175 -115.0 81.381 16.3828 230.0
BOX P116 -67.8175 40.6905 -115.0 135.635 27.127 230.0
BOX P109 -84.2003 13.5635 -115.0 168.4006 27.127 230.0
BOX P94 -84.2003 -13.5635 -115.0 168.4006 27.127 230.0
BOX P81 -84.2003 -40.6905 -115.0 168.4006 27.127 230.0
BOX P70 -67.8175 -67.8175 -115.0 135.635 27.127 230.0
BOX P59 -40.6905 -84.2003 -115.0 81.381 16.3828 230.0
ZROD M14 0.0 0.0 -116.0 95.91 232.0
*
```

The statement:

COLUMNS 1 132

is to enlarge the length of the line which is recognised by the MONK program to 132 positions.

Features of the MONK calculations.

The numbers of histories involved in the MONK Monte Carlo calculations giving an accuracy of

$\pm 2.10^{-4}$ are 20 million, and for the accuracy of $\pm 1.10^{-4}$ are about 60 million.

The k_{eff} value calculated by MONK8b (called Kthree) is a weighted average of two k_{eff} estimates, Kcoll and Kscore, and the total leakage plus absorption estimate, A. In the course of a calculation several characteristics are computed in a series of stages called superhistories and their cumulative values are calculated:

H is the total number of neutrons tracked (called the Sample)

R is the total number of fission neutron children produced in all fission events (called the Children)

F is the expected number of fission neutrons produced in a collision, and is scored at each collision

L is the total number of neutrons leaking or absorbed

From these quantities estimates of k_{eff} are calculated:

$$K_{\text{coll}} = R/H$$

$$K_{\text{score}} = F/H$$

and also

$$A = L/H, \text{ which has an expectation value of unity.}$$

R, F and L are correlated and the correlation is taken into account in the calculation of Kthree:

$$K_{\text{three}} = \alpha.K_{\text{coll}} + (1 - \alpha).K_{\text{score}} + \beta.(1 - A)$$

where α and β are chosen to minimise the variance.

The two estimators, Kcoll and Kscore, in MONK differ by more than one standard deviation (on Kthree). The differences are systematically higher for the plate geometry cores and lower for the pin geometry cores. The k-effective differences between the plate and pin geometry cores would be systematically lower if based on the Kcoll values alone.

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*** MONK8B Input Listing for MZA Model A, Superlattice grid represented.**

```
* Assembly 11 is MZA the first core in the MOAZART Programme.
* Symmetry is assumed about the mid-plane
* Reactor structure: elements arranged on a square grid
* The 213 Core Elements contain Core Cells and an Axial Blanket Cell,
* enclosed in a stainless steel sheath and reflected in the midplane.
* The standard plates have a width of 5.067 cm.
* The Element sheath has an inner width 5.102 cm, outer width 5.2544 cm.
* The elements occupy a lattice area of 5.3721 cm square.
* Groups of 5x5 elements form the superlattice
*   There is a gap between these groups of elements of 0.2667 cm
* There are 408 Radial Blanket Elements
* The radial shielding elements consist of the Steel bar MST9F10
* which is about 300 cm high.
* These are represented explicitly within an outer radius and also
* homogenised (over the overall average lattice area) to fill the
* remaining space in the outer cylinder (pitch 5.4254 cm)
* The outer radius of the shielding region has been taken to be 95.91 cm
*   the enveloping circumference, rather than the value corresponding
*   to the area of shielding material
* Core Element structure (PART 26):
*   The element consists of combinations of the following cells:
*   Core Cell PART 19, Axial Blanket Cell PART 20 ,
*   Plenum Cell PART 21, element reflected in the mid-plane.
* Structure of the Radial Blanket element PART 28.
*   Central region PART 22, Upper region Cell PART 23 ,
*   Plenum Cell PART 21, element reflected in the mid-plane.
* Special Element in core centre region
*   (for reaction rate calculations) (PART 30):
*   This element contains the special cell PART 24
* All Enclosed in the stainless steel sheaths.
*****
* material 1 - Plutonium metal plate core
* material 2 - Plutonium metal clad
* material 3 - UO2 plate core
* material 4 - UO2 plate clad
* material 5 - Sodium plate core
* material 6 - Sodium plate clad
* material 7 - Steel STSTBR8
* material 8 - U8 natural uranium region
* material 9 - U2 natural uranium region
* material 10 - MST1
* material 11 - MST3 Steel block
* material 12 - MST8
* material 13 - Steel bar MST9F10 at actual density (width 5.08 cm)
* material 14 - Steel bar averaged over the mean spacing of 5.4254 cm
* material 15 - Plutonium metal plate core at reactor core centre
* material 16 - UO2 plate core at reactor core centre
* material 17 - GI8
* material 18 - GII8
* material 19 - Stainless steel sheath SHEATH
* material 20 - Smeared stainless steel sheath - actual lattice pitch
* material 21 - Smeared stainless steel sheath - average lattice pitch
* material 22 - MSTH the mild steelsheath
* material 23 - Smeared MSTH the mild steel sheath - actual pitch
* material 24 - Smeared MSTH the mild steel sheath - average pitch
* material 25 - STSTD8
* material 26 - ALSC3
* material 27 - ALG8
* material 28 - AL2O34
* material 29 - MST2
*
```

COLUMNS 1 132

BEGIN MATERIAL SPECIFICATION

NUMBER DENSITY

MATERIAL 1

H1	1.7475E-04	C	2.5027E-04	N	1.3413E-05	O16	5.0640E-05
AL	2.1760E-05	SI	2.3831E-05	CR	5.1941E-06	MN	1.0687E-06
FE	1.6610E-05	NI	1.1804E-05	GA	2.2424E-03	MO	1.9583E-06
U238	1.3318E-06	PU238	2.9103E-05	PU239	2.9328E-02		
PU240	6.7928E-03	PU241	1.0119E-03	PU242	1.6639E-04		
AM241	9.4236E-05						

MATERIAL 2

H1	1.3404E-05	C	9.2801E-05	SI	4.1625E-04	P	1.8432E-05

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S	9.3252E-06	CR	9.2549E-03	MN	7.5220E-04	FE	3.4310E-02
NI	4.5397E-03	CU	1.6626E-02				
MATERIAL 3							
H1	2.4503E-05	C	3.0842E-05	O16	4.5733E-02	SI	1.3190E-05
FE	6.6332E-06						
U234	1.1871E-06	U235	1.6462E-04	U238	2.2694E-02		
MATERIAL 4							
H1	1.7335E-05	C	1.4546E-04	SI	6.0964E-04	P	2.2563E-05
S	2.1792E-05	CR	1.2365E-02	MN	9.7951E-04	FE	4.3411E-02
NI	6.0134E-03	CU	8.1603E-04	AG	1.2368E-03		
MATERIAL 5							
H1	2.1098E-06	LI	3.8296E-07	B	1.4752E-07	O16	1.9937E-06
NA	2.3119E-02	K	4.6230E-07	CA	1.7244E-06	FE	3.8077E-08
MATERIAL 6							
H1	2.1496E-05	C	2.1646E-04	SI	6.0171E-04	P	2.7979E-05
S	2.7023E-05	CR	1.5000E-02	MN	1.0806E-03	FE	5.4056E-02
NI	7.2502E-03	NB	3.0316E-04				
MATERIAL 7							
H1	2.3265E-05	C	7.8091E-04	AL	1.7381E-04	SI	1.3358E-03
TI	2.9384E-04	CR	1.6325E-02	MN	9.3901E-04	FE	5.8278E-02
NI	7.7510E-03	CU	7.3801E-05	MO	9.7764E-05		
MATERIAL 8							
H1	4.4048E-05	C	4.9283E-04	SI	2.1076E-04	FE	1.0599E-04
U235	3.3369E-04	U238	4.6021E-02				
MATERIAL 9							
H1	4.3899E-05	C	4.6047E-04	SI	1.9692E-04	FE	9.9032E-05
U235	3.3962E-04	U238	4.6785E-02				
MATERIAL 10							
H1	2.8122E-05	C	5.1129E-04	AL	1.4007E-04	TI	3.9465E-05
CR	2.7256E-05	MN	3.2675E-04	FE	8.3911E-02	NI	4.8294E-05
CU	4.4603E-05	MO	9.8477E-06				
MATERIAL 11							
H1	2.8087E-05	C	5.1066E-04	AL	1.3989E-04	TI	3.9416E-05
CR	2.7222E-05	MN	3.2634E-04	FE	8.3806E-02	NI	4.8234E-05
CU	4.4548E-05	MO	9.8355E-06				
MATERIAL 12							
H1	2.7730E-05	C	5.0417E-04	AL	1.3812E-04	TI	3.8915E-05
CR	2.6876E-05	MN	3.2220E-04	FE	8.2742E-02	NI	4.7622E-05
CU	4.3982E-05	MO	9.7106E-06				
MATERIAL 13							
H1	4.6306E-05	C	6.8972E-04	SI	3.1158E-04	P	4.2944E-05
S	3.7110E-05	MN	7.1275E-04	FE	8.1432E-02		
MATERIAL 14							
H1	4.0597E-05	C	6.0468E-04	SI	2.7317E-04	P	3.7649E-05
S	3.2535E-05	MN	6.2488E-04	FE	7.1392E-02		
MATERIAL 15							
H1	1.7475E-04	C	2.5027E-04	N	1.3413E-05	O16	5.0640E-05
AL	2.1760E-05	SI	2.3831E-05	CR	5.1941E-06	MN	1.0687E-06
FE	1.6610E-05	NI	1.1804E-05	GA	2.2424E-03	MO	1.9583E-06
U238	1.3318E-06	PU238	2.9103E-05	PU239	2.9328E-02		
PU240	6.7928E-03	PU241	1.0119E-03	PU242	1.6639E-04		
AM241	9.4236E-05						
MATERIAL 16							
H1	2.4503E-05	C	3.0842E-05	O16	4.5733E-02	SI	1.3190E-05
FE	6.6332E-06						
U234	1.1871E-06	U235	1.6462E-04	U238	2.2694E-02		
MATERIAL 17							
H1	4.8551E-05	C	8.1417E-02	S	1.2207E-05	FE	6.1336E-06
MATERIAL 18							
H1	2.0286E-05	C	8.5101E-02	S	1.2751E-06	FE	1.8306E-06
MATERIAL 19							
H1	2.3206E-05	C	7.7892E-04	AL	3.4674E-04	SI	9.9934E-04
TI	2.9310E-04	V	9.1827E-05	CR	1.6104E-02	MN	1.1921E-03
FE	5.6622E-02	NI	9.0065E-03	CU	7.3613E-05	MO	1.4627E-04
MATERIAL 20							
H1	1.1500E-05	C	3.8600E-04	AL	1.7183E-04	SI	4.9522E-04
TI	1.4524E-04	V	4.5505E-05	CR	7.9802E-03	MN	5.9073E-04
FE	2.8059E-02	NI	4.4632E-03	CU	3.6479E-05	MO	7.2486E-05
MATERIAL 21							
H1	9.7398E-06	C	3.2692E-04	AL	1.4553E-04	SI	4.1943E-04
TI	1.2302E-04	V	3.8541E-05	CR	6.7589E-03	MN	5.0032E-04
FE	2.3765E-02	NI	3.7801E-03	CU	3.0896E-05	MO	6.1393E-05
MATERIAL 22							
H1	2.6058E-04	C	3.0978E-04	SI	4.6757E-05	P	1.4132E-05
S	4.6407E-05	MN	2.7489E-04	FE	7.7981E-02		
MATERIAL 23							

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H1 1.2913E-04 C 1.5351E-04 SI 2.3171E-05 P 7.0032E-06
S 2.2997E-05 MN 1.3622E-04 FE 3.8644E-02
MATERIAL 24
H1 1.0937E-04 C 1.3002E-04 SI 1.9624E-05 P 5.9314E-06
S 1.9478E-05 MN 1.1537E-04 FE 3.2730E-02
MATERIAL 25
H1 2.3115E-05 C 7.7587E-04 AL 1.7269E-04 SI 1.3272E-03
TI 2.9195E-04 CR 1.6220E-02 MN 9.3295E-04 FE 5.7902E-02
NI 7.7009E-03 CU 7.3324E-05 MO 9.7133E-05
MATERIAL 26
AL 4.7590E-02 SI 4.5790E-06 MN 9.3634E-07 FE 2.9936E-05
CU 1.8214E-06
MATERIAL 27
AL 2.6704E-02 SI 1.0296E-05 MN 6.5793E-07 FE 3.6374E-05
CU 4.5505E-07
MATERIAL 28
H1 5.1483E-05 B10 4.5063E-06 B11 1.6599E-05 O16 6.6386E-02
AL 4.4240E-02
MATERIAL 29
H1 2.7967E-05 C 5.0847E-04 AL 1.3930E-04 TI 3.9247E-05
CR 2.7106E-05 MN 3.2495E-04 FE 8.3448E-02 NI 4.8028E-05
CU 4.4357E-05 MO 9.7934E-06
END
*
*****
BEGIN MATERIAL GEOMETRY
*
*
* PLATES
*
*****
* Plate 1, the Pu metal plate PUV8
PART 1 NEST
BOX M1 -2.3355 -2.3355 0.04572 4.671 4.671 0.23506
BOX M2 -2.5335 -2.5185 0.0 5.067 5.067 0.3265
BOX M0 -2.5510 -2.5510 0.0 5.102 5.102 0.3265
BOX M19 -2.6272 -2.6272 0.0 5.2544 5.2544 0.3265
BOX M0 -2.68605 -2.68605 0.0 5.3721 5.3721 0.3265
*
* Plate 2, the UO2 plate UO24R4
PART 2 NEST
BOX M3 -2.4255 -2.4255 0.03683 4.851 4.851 0.55424
BOX M4 -2.5335 -2.5335 0.0 5.067 5.067 0.6279
BOX M0 -2.5510 -2.5510 0.0 5.102 5.102 0.6279
BOX M19 -2.6272 -2.6272 0.0 5.2544 5.2544 0.6279
BOX M0 -2.68605 -2.68605 0.0 5.3721 5.3721 0.6279
*
* Plate 3, the sodium plate NASTBR4
PART 3 NEST
BOX M5 -2.4815 -2.4815 0.03683 4.963 4.963 0.54234
BOX M6 -2.5335 -2.5335 0.0 5.067 5.067 0.616
BOX M0 -2.5510 -2.5510 0.0 5.102 5.102 0.616
BOX M19 -2.6272 -2.6272 0.0 5.2544 5.2544 0.616
BOX M0 -2.68605 -2.68605 0.0 5.3721 5.3721 0.616
*
* Plate 4, the steel plate STSTBR8
PART 4 NEST
BOX M7 -2.5335 -2.5335 0.0 5.067 5.067 0.3172
BOX M0 -2.5510 -2.5510 0.0 5.102 5.102 0.3172
BOX M19 -2.6272 -2.6272 0.0 5.2544 5.2544 0.3172
BOX M0 -2.68605 -2.68605 0.0 5.3721 5.3721 0.3172
*
* Plate 5, the graphite plate GI8
PART 5 NEST
BOX M17 -2.5335 -2.5335 0.0 5.067 5.067 0.3180
BOX M0 -2.5510 -2.5510 0.0 5.102 5.102 0.3180
BOX M19 -2.6272 -2.6272 0.0 5.2544 5.2544 0.3180
BOX M0 -2.68605 -2.68605 0.0 5.3721 5.3721 0.3180
*
* Axial blanket U8 plate
PART 6 NEST
BOX M8 -2.5335 -2.5335 0.0 5.067 5.067 0.3175
BOX M0 -2.5510 -2.5510 0.0 5.102 5.102 0.3175
BOX M19 -2.6272 -2.6272 0.0 5.2544 5.2544 0.3175
BOX M0 -2.68605 -2.68605 0.0 5.3721 5.3721 0.3175
*
* Plenum aluminium cylinder ALSC3

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PART 7 NEST
BOX    M26    -2.5335 -2.5335 0.0    5.067  5.067  7.62
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  7.62
BOX    M19    -2.6272 -2.6272 0.0    5.2544 5.2544 7.62
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 7.62
*
* Plenum plate MST1
PART 8 NEST
BOX    M10    -2.5335 -2.5335 0.0    5.067  5.067  2.5385
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  2.5385
BOX    M19    -2.6272 -2.6272 0.0    5.2544 5.2544 2.5385
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 2.5385
*
* Plenum plate MST3
PART 9 NEST
BOX    M11    -2.5335 -2.5335 0.0    5.067  5.067  7.6063
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  7.6063
BOX    M19    -2.6272 -2.6272 0.0    5.2544 5.2544 7.6063
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 7.6063
*
*
*****
*
*                               Radial blanket components
*
*****
* Uranium metal U2
PART 10 NEST
BOX    M9     -2.5335 -2.5335 0.0    5.067  5.067  1.2723
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  1.2723
BOX    M19    -2.6272 -2.6272 0.0    5.2544 5.2544 1.2723
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 1.2723
*
* Graphite GII8
PART 11 NEST
BOX    M18    -2.5335 -2.5335 0.0    5.067  5.067  0.31775
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  0.31775
BOX    M19    -2.6272 -2.6272 0.0    5.2544 5.2544 0.31775
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 0.31775
*
* Mild steel MST8
PART 12 NEST
BOX    M12    -2.5335 -2.5335 0.0    5.067  5.067  0.3147
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  0.3147
BOX    M19    -2.6272 -2.6272 0.0    5.2544 5.2544 0.3147
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 0.3147
*
* Stainless steel STSTD18
PART 13 NEST
BOX    M25    -2.5335 -2.5335 0.0    5.067  5.067  0.3236
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  0.3236
BOX    M19    -2.6272 -2.6272 0.0    5.2544 5.2544 0.3236
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 0.3236
*
* ALUMINIUM ALG8
PART 14 NEST
BOX    M27    -2.5335 -2.5335 0.0    5.067  5.067  0.3170
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  0.3170
BOX    M19    -2.6272 -2.6272 0.0    5.2544 5.2544 0.3170
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 0.3170
*
* Aluminium oxide AL2O34
PART 15 NEST
BOX    M28    -2.5335 -2.5335 0.0    5.067  5.067  0.6317
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  0.6317
BOX    M19    -2.6272 -2.6272 0.0    5.2544 5.2544 0.6317
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 0.6317
* Mild steel MST2
PART 16 NEST
BOX    M29    -2.5335 -2.5335 0.0    5.067  5.067  1.2718
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  1.2718
BOX    M19    -2.6272 -2.6272 0.0    5.2544 5.2544 1.2718
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 1.2718
*
*
*****

```

```
*Repeat of plate 1 and 2 for counting the fissions and captures
*in the central region
*
*****
* Plate 1, the Pu metal plate PUV8 in the central region
PART 17 NEST
BOX      M15   -2.3355  -2.3355  0.04572  4.671   4.671   0.23506
BOX      M2    -2.5335  -2.5185   0.0       5.067   5.067   0.3265
BOX      M0    -2.5510  -2.5510   0.0       5.102   5.102   0.3265
BOX      M19   -2.6272  -2.6272   0.0       5.2544  5.2544  0.3265
BOX      M0    -2.68605 -2.68605   0.0       5.3721  5.3721  0.3265
*
* Plate 2, the UO2 plate UO24R4 in the central region
PART 18 NEST
BOX      M16   -2.4255  -2.4255  0.03683  4.851   4.851   0.55424
BOX      M4    -2.5335  -2.5335   0.0       5.067   5.067   0.6279
BOX      M0    -2.5510  -2.5510   0.0       5.102   5.102   0.6279
BOX      M19   -2.6272  -2.6272   0.0       5.2544  5.2544  0.6279
BOX      M0    -2.68605 -2.68605   0.0       5.3721  5.3721  0.6279
*
*
*****
*
*
*                                CELLS
*
*****
* Core Cell
PART 19 ARRAY
1  1  14  3  2  3  1  4  2  3  3  2  5  1  3  2  3
*
* Axial blanket Cell
PART 20 ARRAY
1  1  20  3  6  5  3  4  6  3  5  3  4  6  3  5  3  6  4  3  5  6  3
*
* Upper Axial Plenum Cell
PART 21 ARRAY
1  1  5  7  9  7  8  7
*
* Radial blanket central region cell
PART 22 ARRAY
1  1  10  11  3  11  13  10  11  3  12  11  3
*
* Radial blanket outer region Cell
PART 23 ARRAY
1  1  20  14  14  15  11  14  10  14  11  15  16  14  11  14  14  10
15  14  11  12  14
*
* Core Cell in the central region, using parts 17 and 18
PART 24 ARRAY
1  1  14  3  18  3  17  4  18  3  3  18  5  17  3  18  3
*
*
*****
*
*
*                                ELEMENTS
*
*****
*
*
* The Core Element (half height)(reflected at Z=0)
* half-height = 44.9748 +34.9564 + 33.0048 = 112.936
* 2 cm Smeared steel region above (overall height = 115.0 cm)
*
PART 25 ARRAY
1  1  11  (19)*6  (20)*4  21
*
* Element extended
*
PART 26 NEST
BOX      P25   -2.68605 -2.68605  0.0       5.3721  5.3721  112.936
BOX      M14   -2.68605 -2.68605  0.0       5.3721  5.3721  115.0
*
*The Radial Blanket element (half height)(reflected at Z = 0)
* half-height = 50.296 + 30.4506 + 33.0048 = 113.7514
* (0.813 cm higher than the core)
```


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*
PART 27 ARRAY
1 1 14 (22)*10 (23)*3 21
*
PART 28 NEST
BOX P27 -2.68605 -2.68605 0.0 5.3721 5.3721 113.7514
BOX M14 -2.68605 -2.68605 0.0 5.3721 5.3721 115.0
*
* The Special Core Element (half height) (reflected at Z=0)
*
PART 29 ARRAY
1 1 11 (24)*3 (19)*3 (20)*4 21
*
* Element extended
*
PART 30 NEST
BOX P29 -2.68605 -2.68605 0.0 5.3721 5.3721 112.936
BOX M14 -2.68605 -2.68605 0.0 5.3721 5.3721 115.0
*
* Half-height steel bar
PART 31 NEST
BOX M13 -2.54 -2.54 0.0 5.08 5.08 115.0
BOX M0 -2.68605 -2.68605 0.0 5.3721 5.3721 115.0
*
*****
*
* ARRAYS OF ELEMENTS
*
*****
* Uniform groups of 5x5 elements surrounded by the superlattice gap
*
*****
* Core array
*
PART 32 ARRAY
5 5 1 (26)*25
*
PART 33 OVERLAP
BOX P32 -13.43025 -13.43025 0.0 26.8605 26.8605 115.0
BOX M13 -13.5635 -13.5635 50.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 115.0
*
* 5x5 Special core centre region for reaction rate data.
PART 34 ARRAY
5 5 1 (30)*25
*
PART 35 OVERLAP
BOX P34 -13.43025 -13.43025 0.0 26.8605 26.8605 115.0
BOX M13 -13.5635 -13.5635 50.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 115.0
*
*
* 5x5 Radial blanket arrays:
*
PART 36 ARRAY
5 5 1 (28)*25
*
PART 37 OVERLAP
BOX P36 -13.43025 -13.43025 0.0 26.8605 26.8605 115.0
BOX M13 -13.5635 -13.5635 50.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 115.0
*
*
*****
* ROW 1
*****
*
* Row 1, the bottom set of groups of size 5x3 (5 along the x axis)
* 3 arrays
* Left side
PART 38 ARRAY
5 3 1 (31)*12 (28)*3
PART 39 OVERLAP
BOX P38 -13.43025 -8.05815 0.0 26.8605 16.1163 115.0
BOX M13 -13.5635 -8.1914 50.2 27.127 16.3828 30.4

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

BOX      M0    -13.5635  -8.1914   0.0  27.127  16.3828  115.0
* Centre
PART 40 ARRAY
5  3  1  (31)*6 (28)*3 31 (28)*5
PART 41 OVERLAP
BOX      P40   -13.43025 -8.05815  0.0  26.8605 16.1163 115.0
BOX      M13   -13.5635  -8.1914  50.2  27.127 16.3828 30.4
BOX      M0    -13.5635  -8.1914   0.0  27.127 16.3828 115.0
* Right side
PART 42 ARRAY
5  3  1  (31)*10 (28)*3 (31)*2
PART 43 OVERLAP
BOX      P42   -13.43025 -8.05815  0.0  26.8605 16.1163 115.0
BOX      M13   -13.5635  -8.1914  50.2  27.127 16.3828 30.4
BOX      M0    -13.5635  -8.1914   0.0  27.127 16.3828 115.0
*
* combine these arrays to form the row 1 array
PART 44 ARRAY
3  1  1  39  41  43
*
*
*****
*                                     ROW 2
*****
* 5 arrays of elements
*
* Bottom left corner group
PART 45 ARRAY
5  5  1  (31)*9  28  (31)*3  (28)*2  (31)*2  (28)*3  31  (28)*4
*
PART 46 OVERLAP
BOX      P45   -13.43025 -13.43025  0.0  26.8605 26.8605 115.0
BOX      M13   -13.5635  -13.5635  50.2          27.127 27.127 30.4
BOX      M0    -13.5635  -13.5635  0.0  27.127 27.127 115.0
*
* Central group
PART 47 ARRAY
5  5  1  (28)*21 (26)*3  28
*
PART 48 OVERLAP
BOX      P47   -13.43025 -13.43025  0.0  26.8605 26.8605 115.0
BOX      M13   -13.5635  -13.5635  50.2          27.127 27.127 30.4
BOX      M0    -13.5635  -13.5635  0.0  27.127 27.127 115.0
*
* Bottom right corner group
PART 49 ARRAY
5  5  1  (31)*5  28  (31)*4  (28)*2 (31)*3  (28)*3  (31)*2  (28)*4  31
*
PART 50 OVERLAP
BOX      P49   -13.43025 -13.43025  0.0  26.8605 26.8605 115.0
BOX      M13   -13.5635  -13.5635  50.2          27.127 27.127 30.4
BOX      M0    -13.5635  -13.5635  0.0  27.127 27.127 115.0
*
* combine these arrays to form the row 2 array
PART 51 ARRAY
5  1  1  46  37  48  37  50
*
*****
*                                     ROW 3
*****
* 7 arrays of elements, the left and right hand ones being 3x5 arrays
*
* Left side
PART 52 ARRAY
3  5  1  (31)*8  28  (31)*2  28  (31)*2  28
PART 53 OVERLAP
BOX      P52   -8.05815  -13.43025  0.0  16.1163 26.8605 115.0
BOX      M13   -8.1914  -13.5635  50.2          16.3828 27.127 30.4
BOX      M0    -8.1914  -13.5635  0.0  16.3828 27.127 115.0
* Centre left
PART 54 ARRAY
5  5  1  (28)*3  (26)*2  (28)*2  (26)*3  28  (26)*14
*
PART 55 OVERLAP
BOX      P54   -13.43025 -13.43025  0.0  26.8605 26.8605 115.0
BOX      M13   -13.5635  -13.5635  50.2          27.127 27.127 30.4

```

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CRIT-BUCK-SPEC-REAC-RRATE

```

BOX      M0      -13.5635  -13.5635   0.0 27.127  27.127 115.0
*
* Centre right
PART 56 ARRAY
5  5  1      (26)*2  (28)*3  (26)*3  (28)*2  (26)*4  28  (26)*10
*
PART 57 OVERLAP
BOX      P56     -13.43025 -13.43025   0.0 26.8605 26.8605 115.0
BOX      M13     -13.5635  -13.5635   50.2      27.127 27.127  30.4
BOX      M0      -13.5635  -13.5635   0.0 27.127  27.127 115.0
* Right side
PART 58 ARRAY
3  5  1      (31)*6  28  (31)*2  28  (31)*2  28  (31)*2
PART 59 OVERLAP
BOX      P58     -8.05815  -13.43025   0.0 16.1163 26.8605 115.0
BOX      M13     -8.1914  -13.5635   50.2      16.3828 27.127  30.4
BOX      M0      -8.1914  -13.5635   0.0 16.3828 27.127  115.0
*
* combine these arrays to form the row 3 array
PART 60 ARRAY
7  1  1  53  37  55  33  57  37  59
*
*
*****
*                                     ROW 4
*****
* The middle row
* 7 arrays of elements, the left and right hand ones being 3x5 arrays
*
* Left side
PART 61 ARRAY
3  5  1      (31)*2  28  31  (28)*2  31  (28)*2  31  (28)*2  (31)*2  28
PART 62 OVERLAP
BOX      P61     -8.05815  -13.43025   0.0 16.1163 26.8605 115.0
BOX      M13     -8.1914  -13.5635   50.2      16.3828 27.127  30.4
BOX      M0      -8.1914  -13.5635   0.0 16.3828 27.127  115.0
* Blanket left
PART 63 ARRAY
5  5  1      (28)*9  26  (28)*4  26  (28)*4  26  (28)*5
*
PART 64 OVERLAP
BOX      P63     -13.43025 -13.43025   0.0 26.8605 26.8605 115.0
BOX      M13     -13.5635  -13.5635   50.2      27.127 27.127  30.4
BOX      M0      -13.5635  -13.5635   0.0 27.127  27.127 115.0
*
* Blanket right
PART 65 ARRAY
5  5  1      (28)*5  26  (28)*4  26  (28)*4  26  (28)*4  (28)*5
*
PART 66 OVERLAP
BOX      P65     -13.43025 -13.43025   0.0 26.8605 26.8605 115.0
BOX      M13     -13.5635  -13.5635   50.2      27.127 27.127  30.4
BOX      M0      -13.5635  -13.5635   0.0 27.127  27.127 115.0
* Right side
PART 67 ARRAY
3  5  1  28  (31)*2  (28)*2  31  (28)*2  31  (28)*2  31  28  (31)*2
PART 68 OVERLAP
BOX      P67     -8.05815  -13.43025   0.0 16.1163 26.8605 115.0
BOX      M13     -8.1914  -13.5635   50.2      16.3828 27.127  30.4
BOX      M0      -8.1914  -13.5635   0.0 16.3828 27.127  115.0
*
* combine these arrays to form the row 4 array
PART 69 ARRAY
7  1  1  62  64  33  35  33  66  68
*
*
*****
*                                     ROW 5
*****
* 7 arrays of elements, the left and right hand ones being 3x5 arrays
*
* Left side
PART 70 ARRAY
3  5  1      (31)*2  28  (31)*2  28  (31)*2  28  (31)*6
PART 71 OVERLAP
BOX      P70     -8.05815  -13.43025   0.0 16.1163 26.8605 115.0

```

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CRIT-BUCK-SPEC-REAC-RRATE

```

BOX    M13    -8.1914  -13.5635   50.2      16.3828  27.127   30.4
BOX    M0     -8.1914  -13.5635    0.0  16.3828  27.127   115.0
*
* Centre left
PART 72 ARRAY
5  5  1  (26)*10  28  (26)*4  (28)*2  (26)*3  (28)*3  (26)*2
*
PART 73 OVERLAP
BOX    P72   -13.43025 -13.43025   0.0  26.8605  26.8605  115.0
BOX    M13   -13.5635  -13.5635   50.2      27.127  27.127   30.4
BOX    M0    -13.5635  -13.5635    0.0  27.127  27.127   115.0
*
* Centre right
PART 74 ARRAY
5  5  1  (26)*14  28  (26)*3  (28)*2  (26)*2  (28)*3
*
PART 75 OVERLAP
BOX    P74   -13.43025 -13.43025   0.0  26.8605  26.8605  115.0
BOX    M13   -13.5635  -13.5635   50.2      27.127  27.127   30.4
BOX    M0    -13.5635  -13.5635    0.0  27.127  27.127   115.0
*
* Right side
PART 76 ARRAY
3  5  1  28  (31)*2  28  (31)*2  28  (31)*2  (31)*6
PART 77 OVERLAP
BOX    P76   -8.05815  -13.43025   0.0  16.1163  26.8605  115.0
BOX    M13   -8.1914  -13.5635   50.2      16.3828  27.127   30.4
BOX    M0    -8.1914  -13.5635    0.0  16.3828  27.127   115.0
*
* combine these arrays to form the row 5 array
PART 78 ARRAY
7  1  1  71  37  73  33  75  37  77
*
*
*****
*
*
* 5 arrays of 5x5 elements
*
* Top left corner group
PART 79 ARRAY
5  5  1  31  (28)*4  (31)*2  (28)*3  (31)*3  (28)*2  (31)*4  28  (31)*5
*
PART 80 OVERLAP
BOX    P79   -13.43025 -13.43025   0.0  26.8605  26.8605  115.0
BOX    M13   -13.5635  -13.5635   50.2      27.127  27.127   30.4
BOX    M0    -13.5635  -13.5635    0.0  27.127  27.127   115.0
*
* Top Central group
PART 81 ARRAY
5  5  1  28  (26)*3  (28)*21
*
PART 82 OVERLAP
BOX    P81   -13.43025 -13.43025   0.0  26.8605  26.8605  115.0
BOX    M13   -13.5635  -13.5635   50.2      27.127  27.127   30.4
BOX    M0    -13.5635  -13.5635    0.0  27.127  27.127   115.0
*
* Top right corner group
PART 83 ARRAY
5  5  1  (28)*4  31  (28)*3  (31)*2  (28)*2  (31)*3  28  (31)*9
*
PART 84 OVERLAP
BOX    P83   -13.43025 -13.43025   0.0  26.8605  26.8605  115.0
BOX    M13   -13.5635  -13.5635   50.2      27.127  27.127   30.4
BOX    M0    -13.5635  -13.5635    0.0  27.127  27.127   115.0
*
* combine these arrays to form the row 2 array
PART 85 ARRAY
5  1  1  80  37  82  37  84
*
*****
*
*
*
* Row 7, the top set of groups of size 5x3 (5 along the x axis)

```

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```

* 3 arrays
* Left side
PART 86 ARRAY
5 3 1 (31)*2 (28)*3 (31)*10
PART 87 OVERLAP
BOX P86 -13.43025 -8.05815 0.0 26.8605 16.1163 115.0
BOX M13 -13.5635 -8.1914 50.2 27.127 16.3828 30.4
BOX M0 -13.5635 -8.1914 0.0 27.127 16.3828 115.0
* Centre
PART 88 ARRAY
5 3 1 (28)*5 31 (28)*3 (31)*6
PART 89 OVERLAP
BOX P88 -13.43025 -8.05815 0.0 26.8605 16.1163 115.0
BOX M13 -13.5635 -8.1914 50.2 27.127 16.3828 30.4
BOX M0 -13.5635 -8.1914 0.0 27.127 16.3828 115.0
* Right side
PART 90 ARRAY
5 3 1 (28)*3 (31)*12
PART 91 OVERLAP
BOX P90 -13.43025 -8.05815 0.0 26.8605 16.1163 115.0
BOX M13 -13.5635 -8.1914 50.2 27.127 16.3828 30.4
BOX M0 -13.5635 -8.1914 0.0 27.127 16.3828 115.0
*
* combine these arrays to form the row 7 array
PART 92 ARRAY
3 1 1 87 89 91
*
*****
*
* Cluster of superlattice groups in a circle of shield material
*
*****
* Cluster of superlattice groups in a circle of shield material
PART 93 CLUSTER
BOX P92 -40.6905 67.8175 0.0 81.381 16.3828 115.0
BOX P85 -67.8175 40.6905 0.0 135.635 27.127 115.0
BOX P78 -84.2003 13.5635 0.0 168.4006 27.127 115.0
BOX P69 -84.2003 -13.5635 0.0 168.4006 27.127 115.0
BOX P60 -84.2003 -40.6905 0.0 168.4006 27.127 115.0
BOX P51 -67.8175 -67.8175 0.0 135.635 27.127 115.0
BOX P44 -40.6905 -84.2003 0.0 81.381 16.3828 115.0
ZROD M14 0.0 0.0 0.0 95.91 116.0
*
*****
* Albedo for free boundaries at side and top and reflection at bottom
*
ALBEDO 0.0 0.0 1.0
END
*
*****
*
BEGIN CONTROL DATA
STAGES -50 2400 5000 STDV 0.0002
END
*
*****
*
BEGIN SOURCE GEOMETRY
ZONEMAT
ALL / MATERIAL 1
END
*
*****
*
BEGIN ACTION TALLIES
NONORM
END
*
*****

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

*** MONK8B Input Listing for MZA Model CS, sheath material smeared**

```

* Uniform lattice mesh assumed
* Assembly 11 is MZA the first core in the MOZART Programme.
* Symmetry is assumed about the mid-plane
* Reactor structure: elements arranged on a square grid
* The 213 Core Elements contain Core Cells and an Axial Blanket Cell,
* enclosed in a stainless steel sheath and reflected in the midplane.
* The standard plates have a width of 5.067 cm.
* The Element sheath has an inner width 5.102 cm, outer width 5.2544 cm.
* The elements occupy a lattice area of 5.3721 cm square.
* Groups of 5x5 elements form the superlattice
*   There is a gap between these groups of elements of 0.2667 cm
* In this model a uniform lattice spacing is assumed of 5.4254 cm
* There are 408 Radial Blanket Elements
* The radial shielding elements consist of the Steel bar MST9F10
* which is about 300 cm high.
* These are represented explicitly within an outer radius and also
* homogenised (over the overall average lattice area) to fill the
* remaining space in the outer cylinder (pitch 5.4254 cm)
* The outer radius of the shielding region has been taken to be 95.91 cm
*   the enveloping circumference, rather than the value corresponding
*   to the area of shielding material
* Core Element structure (PART 26):
*   The element consists of combinations of the following cells:
*   Core Cell PART 19, Axial Blanket Cell PART 20 ,
*   Plenum Cell PART 21, element reflected in the mid-plane.
* Structure of the Radial Blanket element PART 28.
*   Central region PART 22, Upper region Cell PART 23 ,
*   Plenum Cell PART 21, element reflected in the mid-plane.
* Special Element in core centre region
*   (for reaction rate calculations) (PART 30):
*   This element contains the special cell PART 24
* All Enclosed in the stainless steel sheaths.
*****
* material 1 - Plutonium metal plate core
* material 2 - Plutonium metal clad
* material 3 - UO2 plate core
* material 4 - UO2 plate clad
* material 5 - Sodium plate core
* material 6 - Sodium plate clad
* material 7 - Steel STSTBR8
* material 8 - U8 natural uranium region
* material 9 - U2 natural uranium region
* material 10 - MST1
* material 11 - MST3 Steel block
* material 12 - MST8
* material 13 - Steel bar MST9F10 at actual density (width 5.08 cm)
* material 14 - Steel bar averaged over the mean spacing of 5.4254 cm
* material 15 - Plutonium metal plate core at reactor core centre
* material 16 - UO2 plate core at reactor core centre
* material 17 - GI8
* material 18 - GII8
* material 19 - STSTDL8
* material 20 - MST2
* material 21 - Smeared stainless steel sheath - average lattice pitch
* material 22 - ALSC3
* material 23 - ALG8
* material 24 - AL2034
*
*****
COLUMNS 1 132
BEGIN MATERIAL SPECIFICATION
NUMBER DENSITY
MATERIAL 1
H1 1.7475E-04 C 2.5027E-04 N 1.3413E-05 O16 5.0640E-05
AL 2.1760E-05 SI 2.3831E-05 CR 5.1941E-06 MN 1.0687E-06
FE 1.6610E-05 NI 1.1804E-05 GA 2.2424E-03 MO 1.9583E-06
U238 1.3318E-06 PU238 2.9103E-05 PU239 2.9328E-02
PU240 6.7928E-03 PU241 1.0119E-03 PU242 1.6639E-04
AM241 9.4236E-05
MATERIAL 2
H1 1.3404E-05 C 9.2801E-05 SI 4.1625E-04 P 1.8432E-05
S 9.3252E-06 CR 9.2549E-03 MN 7.5220E-04 FE 3.4310E-02
NI 4.5397E-03 CU 1.6626E-02
MATERIAL 3

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CRIT-BUCK-SPEC-REAC-RRATE

H1 2.4503E-05 C 3.0842E-05 O16 4.5733E-02 SI 1.3190E-05
FE 6.6332E-06
U234 1.1871E-06 U235 1.6462E-04 U238 2.2694E-02
MATERIAL 4
H1 1.7335E-05 C 1.4546E-04 SI 6.0964E-04 P 2.2563E-05
S 2.1792E-05 CR 1.2365E-02 MN 9.7951E-04 FE 4.3411E-02
NI 6.0134E-03 CU 8.1603E-04 AG 1.2368E-03
MATERIAL 5
H1 2.1098E-06 LI 3.8296E-07 B 1.4752E-07 O16 1.9937E-06
NA 2.3119E-02 K 4.6230E-07 CA 1.7244E-06 FE 3.8077E-08
MATERIAL 6
H1 2.1496E-05 C 2.1646E-04 SI 6.0171E-04 P 2.7979E-05
S 2.7023E-05 CR 1.5000E-02 MN 1.0806E-03 FE 5.4056E-02
NI 7.2502E-03 NB 3.0316E-04
MATERIAL 7
H1 2.3265E-05 C 7.8091E-04 AL 1.7381E-04 SI 1.3358E-03
TI 2.9384E-04 CR 1.6325E-02 MN 9.3901E-04 FE 5.8278E-02
NI 7.7510E-03 CU 7.3801E-05 MO 9.7764E-05
MATERIAL 8
H1 4.4048E-05 C 4.9283E-04 SI 2.1076E-04 FE 1.0599E-04
U235 3.3369E-04 U238 4.6021E-02
MATERIAL 9
H1 4.3899E-05 C 4.6047E-04 SI 1.9692E-04 FE 9.9032E-05
U235 3.3962E-04 U238 4.6785E-02
MATERIAL 10
H1 2.8122E-05 C 5.1129E-04 AL 1.4007E-04 TI 3.9465E-05
CR 2.7256E-05 MN 3.2675E-04 FE 8.3911E-02 NI 4.8294E-05
CU 4.4603E-05 MO 9.8477E-06
MATERIAL 11
H1 2.8087E-05 C 5.1066E-04 AL 1.3989E-04 TI 3.9416E-05
CR 2.7222E-05 MN 3.2634E-04 FE 8.3806E-02 NI 4.8234E-05
CU 4.4548E-05 MO 9.8355E-06
MATERIAL 12
H1 2.7730E-05 C 5.0417E-04 AL 1.3812E-04 TI 3.8915E-05
CR 2.6876E-05 MN 3.2220E-04 FE 8.2742E-02 NI 4.7622E-05
CU 4.3982E-05 MO 9.7106E-06
MATERIAL 13
H1 4.6306E-05 C 6.8972E-04 SI 3.1158E-04 P 4.2944E-05
S 3.7110E-05 MN 7.1275E-04 FE 8.1432E-02
MATERIAL 14
H1 4.0597E-05 C 6.0468E-04 SI 2.7317E-04 P 3.7649E-05
S 3.2535E-05 MN 6.2488E-04 FE 7.1392E-02
MATERIAL 15
H1 1.7475E-04 C 2.5027E-04 N 1.3413E-05 O16 5.0640E-05
AL 2.1760E-05 SI 2.3831E-05 CR 5.1941E-06 MN 1.0687E-06
FE 1.6610E-05 NI 1.1804E-05 GA 2.2424E-03 MO 1.9583E-06
U238 1.3318E-06 PU238 2.9103E-05 PU239 2.9328E-02
PU240 6.7928E-03 PU241 1.0119E-03 PU242 1.6639E-04
AM241 9.4236E-05
MATERIAL 16
H1 2.4503E-05 C 3.0842E-05 O16 4.5733E-02 SI 1.3190E-05
FE 6.6332E-06
U234 1.1871E-06 U235 1.6462E-04 U238 2.2694E-02
MATERIAL 17
H1 4.8551E-05 C 8.1417E-02 S 1.2207E-05 FE 6.1336E-06
MATERIAL 18
H1 2.0286E-05 C 8.5101E-02 S 1.2751E-06 FE 1.8306E-06
MATERIAL 19
H1 2.3115E-05 C 7.7587E-04 AL 1.7269E-04 SI 1.3272E-03
TI 2.9195E-04 CR 1.6220E-02 MN 9.3295E-04 FE 5.7902E-02
NI 7.7009E-03 CU 7.3324E-05 MO 9.7133E-05
MATERIAL 20
H1 2.7967E-05 C 5.0847E-04 AL 1.3930E-04 TI 3.9247E-05
CR 2.7106E-05 MN 3.2495E-04 FE 8.3448E-02 NI 4.8028E-05
CU 4.4357E-05 MO 9.7934E-06
MATERIAL 21
H1 9.7398E-06 C 3.2692E-04 AL 1.4553E-04 SI 4.1943E-04
TI 1.2302E-04 V 3.8541E-05 CR 6.7589E-03 MN 5.0032E-04
FE 2.3765E-02 NI 3.7801E-03 CU 3.0896E-05 MO 6.1393E-05
MATERIAL 22
AL 4.7590E-02 SI 4.5790E-06 MN 9.3634E-07 FE 2.9936E-05
CU 1.8214E-06
MATERIAL 23
AL 2.6704E-02 SI 1.0296E-05 MN 6.5793E-07 FE 3.6374E-05
CU 4.5505E-07
MATERIAL 24

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LIQUID METAL FAST REACTOR - LMFR
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H1 5.1483E-05 B10 4.5063E-06 B11 1.6599E-05 O16 6.6386E-02
AL 4.4240E-02
END
*

BEGIN MATERIAL GEOMETRY

*

*

PLATES

*

* Plate 1, the Pu metal plate PUV8

PART 1 NEST

BOX	M1	-2.3355	-2.3355	0.04572	4.671	4.671	0.23506

BOX	M2	-2.5335	-2.5335	0.0	5.067	5.067	0.3265

BOX	M21	-2.7127	-2.7127	0.0	5.4254	5.4254	0.3265

*

* Plate 2, the UO2 plate UO24R4

PART 2 NEST

BOX	M3	-2.4255	-2.4255	0.03683	4.851	4.851	0.55424

BOX	M4	-2.5335	-2.5335	0.0	5.067	5.067	0.6279

BOX	M21	-2.7127	-2.7127	0.0	5.4254	5.4254	0.6279

*

* Plate 3, the sodium plate NASTBR4

PART 3 NEST

BOX	M5	-2.4815	-2.4815	0.03683	4.963	4.963	0.54234

BOX	M6	-2.5335	-2.5335	0.0	5.067	5.067	0.616

BOX	M21	-2.7127	-2.7127	0.0	5.4254	5.4254	0.616

*

* Plate 4, the steel plate STSTBR8

PART 4 NEST

BOX	M7	-2.5335	-2.5335	0.0	5.067	5.067	0.3172

BOX	M21	-2.7127	-2.7127	0.0	5.4254	5.4254	0.3172

*

* Plate 5, the graphite plate GI8

PART 5 NEST

BOX	M17	-2.5335	-2.5335	0.0	5.067	5.067	0.3180

BOX	M21	-2.7127	-2.7127	0.0	5.4254	5.4254	0.3180

*

* Axial blanket U8 plate

PART 6 NEST

BOX	M8	-2.5335	-2.5335	0.0	5.067	5.067	0.3175

BOX	M21	-2.7127	-2.7127	0.0	5.4254	5.4254	0.3175

*

* Plenum aluminium cylinder ALSC3

PART 7 NEST

BOX	M22	-2.5335	-2.5335	0.0	5.067	5.067	7.62

BOX	M21	-2.7127	-2.7127	0.0	5.4254	5.4254	7.62

*

* Plenum plate MST1

PART 8 NEST

BOX	M10	-2.5335	-2.5335	0.0	5.067	5.067	2.5385

BOX	M21	-2.7127	-2.7127	0.0	5.4254	5.4254	2.5385

*

* Plenum plate MST3

PART 9 NEST

BOX	M11	-2.5335	-2.5335	0.0	5.067	5.067	7.6063

BOX	M21	-2.7127	-2.7127	0.0	5.4254	5.4254	7.6063

*

*

*

Radial blanket components

*

* Uranium metal U2

PART 10 NEST

BOX	M9	-2.5335	-2.5335	0.0	5.067	5.067	1.2723

BOX	M21	-2.7127	-2.7127	0.0	5.4254	5.4254	1.2723

*

* Graphite GII8

PART 11 NEST

BOX	M18	-2.5335	-2.5335	0.0	5.067	5.067	0.31775

BOX	M21	-2.7127	-2.7127	0.0	5.4254	5.4254	0.31775

*

* Mild steel MST8

PART 12 NEST


```

*
* Stainless steel STSTD8
PART 13 NEST
BOX M12 -2.5335 -2.5335 0.0 5.067 5.067 0.3147
BOX M21 -2.7127 -2.7127 0.0 5.4254 5.4254 0.3147
*
* ALUMINIUM ALG8
PART 14 NEST
BOX M23 -2.5335 -2.5335 0.0 5.067 5.067 0.3170
BOX M21 -2.7127 -2.7127 0.0 5.4254 5.4254 0.3170
*
* Aluminium oxide AL2O3
PART 15 NEST
BOX M24 -2.5335 -2.5335 0.0 5.067 5.067 0.6317
BOX M21 -2.7127 -2.7127 0.0 5.4254 5.4254 0.6317
* Mild steel MST2
PART 16 NEST
BOX M20 -2.5335 -2.5335 0.0 5.067 5.067 1.2718
BOX M21 -2.7127 -2.7127 0.0 5.4254 5.4254 1.2718
*
*
*****
* Repeat of plate 1 and 2 for counting the fissions and captures
* in the central region
*
*****
* Plate 1, the Pu metal plate PUV8 in the central region
PART 17 NEST
BOX M15 -2.3355 -2.3355 0.04572 4.671 4.671 0.23506
BOX M2 -2.5335 -2.5335 0.0 5.067 5.067 0.3265
BOX M21 -2.7127 -2.7127 0.0 5.4254 5.4254 0.3265
*
* Plate 2, the UO2 plate UO24R4 in the central region
PART 18 NEST
BOX M16 -2.4255 -2.4255 0.03683 4.851 4.851 0.55424
BOX M4 -2.5335 -2.5335 0.0 5.067 5.067 0.6279
BOX M21 -2.7127 -2.7127 0.0 5.4254 5.4254 0.6279
*
*
*****
*
* CELLS
*
*****
* Core Cell
PART 19 ARRAY
1 1 14 3 2 3 1 4 2 3 3 2 5 1 3 2 3
*
* Axial blanket Cell
PART 20 ARRAY
1 1 20 3 6 5 3 4 6 3 5 3 4 6 3 5 3 6 4 3 5 6 3
*
* Upper Axial Plenum Cell
PART 21 ARRAY
1 1 5 7 9 7 8 7
*
* Radial blanket central region cell
PART 22 ARRAY
1 1 10 11 3 11 13 10 11 3 12 11 3
*
* Radial blanket outer region Cell
PART 23 ARRAY
1 1 20 14 14 15 11 14 10 14 11 15 16 14 11 14 14 10
15 14 11 12 14
*
* Core Cell in the central region, using parts 17 and 18
PART 24 ARRAY
1 1 14 3 18 3 17 4 18 3 3 18 5 17 3 18 3
*
*
*****
*
* ELEMENTS

```

```

*****
*
* The Core Element (half height)(reflected at Z=0)
* half-height = 44.9748 +34.9564 + 33.0048 = 112.936
* 2 cm Smeared steel region above (overall height = 115.0 cm)
*
PART 25 ARRAY
1 1 11 (19)*6 (20)*4 21
*
* Element extended
*
PART 26 NEST
BOX P25 -2.7127 -2.7127 0.0 5.4254 5.4254 112.936
BOX M14 -2.7127 -2.7127 0.0 5.4254 5.4254 115.0
*
*The Radial Blanket element (half height)(reflected at Z = 0)
* half-height = 50.296 + 30.4506 + 33.0048 = 113.7514
* (0.813 cm higher than the core)
*
PART 27 ARRAY
1 1 14 (22)*10 (23)*3 21
*
PART 28 NEST
BOX P27 -2.7127 -2.7127 0.0 5.4254 5.4254 113.7514
BOX M14 -2.7127 -2.7127 0.0 5.4254 5.4254 115.0
*
* The Special Core Element (half height)(reflected at Z=0)
*
PART 29 ARRAY
1 1 11 (24)*3 (19)*3 (20)*4 21
*
* Element extended
*
PART 30 NEST
BOX P29 -2.7127 -2.7127 0.0 5.4254 5.4254 112.936
BOX M14 -2.7127 -2.7127 0.0 5.4254 5.4254 115.0
*
* Half-height steel bar
PART 31 NEST
BOX M13 -2.54 -2.54 0.0 5.08 5.08 115.0
BOX M0 -2.7127 -2.7127 0.0 5.4254 5.4254 115.0
*
*****
*
*
* ARRAYS OF ELEMENTS
*
*****
*
* Uniform groups of 5x5 elements
*
*****
*
* Core array
*
PART 32 ARRAY
5 5 1 (26)*25
*
*
* 5x5 Special core centre region for reaction rate data.
PART 33 ARRAY
5 5 1 (30)*25
*
*
* 5x5 Radial blanket arrays:
*
PART 34 ARRAY
5 5 1 (28)*25
*
*****
*
* ROW 1
*****
*
* Row 1, the bottom set of groups of size 5x3 (5 along the x axis)
* 3 arrays
*

```

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```

* Left side
PART 35 ARRAY
5 3 1 (31)*12 (28)*3
*
* Centre
PART 36 ARRAY
5 3 1 (31)*6 (28)*3 31 (28)*5
*
* Right side
PART 37 ARRAY
5 3 1 (31)*10 (28)*3 (31)*2
*
* combine these arrays to form the row 1 array
PART 38 ARRAY
3 1 1 35 36 37
*
*
*****
*
*
*****
* 5 arrays of elements
*
* Bottom left corner group
PART 39 ARRAY
5 5 1 (31)*9 28 (31)*3 (28)*2 (31)*2 (28)*3 31 (28)*4
*
* Central group
PART 40 ARRAY
5 5 1 (28)*21 (26)*3 28
*
* Bottom right corner group
PART 41 ARRAY
5 5 1 (31)*5 28 (31)*4 (28)*2 (31)*3 (28)*3 (31)*2 (28)*4 31
*
* combine these arrays to form the row 2 array
PART 42 ARRAY
5 1 1 39 34 40 34 41
*
*****
*
*
*****
* 7 arrays of elements, the left and right hand ones being 3x5 arrays
*
* Left side
PART 43 ARRAY
3 5 1 (31)*8 28 (31)*2 28 (31)*2 28
*
* Centre left
PART 44 ARRAY
5 5 1 (28)*3 (26)*2 (28)*2 (26)*3 28 (26)*14
*
* Centre right
PART 45 ARRAY
5 5 1 (26)*2 (28)*3 (26)*3 (28)*2 (26)*4 28 (26)*10
*
* Right side
PART 46 ARRAY
3 5 1 (31)*6 28 (31)*2 28 (31)*2 28 (31)*2
*
* combine these arrays to form the row 3 array
PART 47 ARRAY
7 1 1 43 34 44 32 45 34 46
*
*
*****
*
*
*****
* The middle row
* 7 arrays of elements, the left and right hand ones being 3x5 arrays
*
* Left side
PART 48 ARRAY
3 5 1 (31)*2 28 31 (28)*2 31 (28)*2 31 (28)*2 (31)*2 28
*
* Blanket left
PART 49 ARRAY

```

```

5   5   1   (28)*9   26   (28)*4   26   (28)*4   26   (28)*4   (28)*5
*
* Blanket right
PART 50 ARRAY
5   5   1   (28)*5   26   (28)*4   26   (28)*4   26   (28)*4   (28)*5
*
* Right side
PART 51 ARRAY
3   5   1   28   (31)*2   (28)*2   31   (28)*2   31   (28)*2   31   28   (31)*2
*
* combine these arrays to form the row 4 array
PART 52 ARRAY
7   1   1   48   49   32   33   32   50   51
*
*
*****
*                                                                 ROW 5
*****
* 7 arrays of elements, the left and right hand ones being 3x5 arrays
*
* Left side
PART 53 ARRAY
3   5   1   (31)*2   28   (31)*2   28   (31)*2   28   (31)*6
*
* Centre left
PART 54 ARRAY
5   5   1   (26)*10   28   (26)*4   (28)*2   (26)*3   (28)*3   (26)*2
*
* Centre right
PART 55 ARRAY
5   5   1   (26)*14   28   (26)*3   (28)*2   (26)*2   (28)*3
*
*
* Right side
PART 56 ARRAY
3   5   1   28   (31)*2   28   (31)*2   28   (31)*2   (31)*6
*
* combine these arrays to form the row 5 array
PART 57 ARRAY
7   1   1   53   34   54   32   55   34   56
*
*
*****
*                                                                 ROW 6
*****
* 5 arrays of 5x5 elements
*
* Top left corner group
PART 58 ARRAY
5   5   1   31   (28)*4   (31)*2   (28)*3   (31)*3   (28)*2   (31)*4   28   (31)*5
*
* Top Central group
PART 59 ARRAY
5   5   1   28   (26)*3   (28)*21
*
* Top right corner group
PART 60 ARRAY
5   5   1   (28)*4   31   (28)*3   (31)*2   (28)*2   (31)*3   28   (31)*9
*
* combine these arrays to form the row 6 array
PART 61 ARRAY
5   1   1   58   34   59   34   60
*
*
*****
*                                                                 ROW 7
*****
*
* Row 7, the top set of groups of size 5x3 (5 along the x axis)
* 3 arrays
*
* Left side
PART 62 ARRAY
5   3   1   (31)*2   (28)*3   (31)*10
*
* Centre
PART 63 ARRAY

```

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```

5 3 1 (28)*5 31 (28)*3 (31)*6
*
* Right side
PART 64 ARRAY
5 3 1 (28)*3 (31)*12
*
* combine these arrays to form the row 7 array
PART 65 ARRAY
3 1 1 62 63 64
*
*****
*
* Cluster of superlattice groups in a circle of shield material
*
*****
* Cluster of superlattice groups in a circle of shield material
PART 66 CLUSTER
BOX P65 -40.6905 67.8175 0.0 81.381 16.2762 115.0
BOX P61 -67.8175 40.6905 0.0 135.635 27.127 115.0
BOX P57 -84.0937 13.5635 0.0 168.1874 27.127 115.0
BOX P52 -84.0937 -13.5635 0.0 168.1874 27.127 115.0
BOX P47 -84.0937 -40.6905 0.0 168.1874 27.127 115.0
BOX P42 -67.8175 -67.8175 0.0 135.635 27.127 115.0
BOX P38 -40.6905 -84.0937 0.0 81.381 16.2762 115.0
ZROD M14 0.0 0.0 0.0 95.91 116.0
*
*****
* Albedo for free boundaries at side and top and reflection at bottom
*
ALBEDO 0.0 0.0 1.0
END
*
*****
*
BEGIN CONTROL DATA
STAGES -50 2400 5000 STDV 0.0002
END
*
*****
*
BEGIN SOURCE GEOMETRY
ZONEMAT
ALL / MATERIAL 1
END
*
*****
*
BEGIN ACTION TALLIES
NONORM
END
*
*****

```

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*** MONK8B Input Listing for MZB/3 Model C, all core elements represented**

* Assembly 12 is MZB the second core in the MOZART Programme.
* Version 3 has the approximately uniform radial blanket
* containing the natural uranium metal plates
* Reactor structure: elements arranged on a uniform square grid
* The Core Elements contain Core Cells and an Axial Blanket Cell,
* enclosed in a stainless steel sheath and reflected in the midplane.
* The standard plates have a width of 5.067 cm.
* The Element sheath has an inner width 5.102 cm, outer width 5.2544 cm.
* The elements occupy a lattice area of 5.3721 cm square.
* Groups of 5x5 elements form the superlattice
* There is a gap between these groups of elements of 0.2667 cm
* There are 408 Radial Blanket Elements
* The radial shielding elements consist of the Steel bar MST9F10
* which is about 300 cm high.
* These are represented explicitly within an outer radius and also
* homogenised (over the overall average lattice area) to fill the
* remaining space in the outer cylinder (pitch 5.4254 cm)
* The outer radius of the shielding region has been taken to be 95.91 cm
* the enveloping circumference, rather than the value corresponding
* to the area of shielding material
* Core Element structure (PART 26):
* The element consists of combinations of the following cells:
* Core Cell PART 19, Axial Blanket Cell PART 20 ,
* Plenum Cell PART 21, element reflected in the mid-plane.
* Structure of the Radial Blanket element PART 28.
* Central region PART 22, Upper region Cell PART 23 ,
* Plenum Cell PART 21, element reflected in the mid-plane.
* Special Element in core centre region
* (for reaction rate calculations) (PART 30):
* This element contains the special cell PART 24
* All Enclosed in the stainless steel sheaths.

* material 1 - U/Pu oxide plate core
* material 2 - U/Pu plate clad
* material 3 - PUIX8 Plutonium metal plate core
* material 4 - PUIX8 Plutonium metal clad
* material 5 - PUVI8 Plutonium metal plate core
* material 6 - PUVI8 Plutonium metal clad
* material 7 - UO2 plate core UO23R4
* material 8 - UO2 plate clad UO23R4
* material 9 - UO2 plate core UO24R4
* material 10 - UO2 plate clad UO24R4
* material 11 - U8 natural uranium region
* material 12 - U2 natural uranium region
* material 13 - Sodium plate core NASTDL4
* material 14 - Sodium plate clad NASTDL4
* material 15 - Sodium plate core NASTBR4
* material 16 - Sodium plate clad NASTBR4
* material 17 - Steel STSTBR8
* material 18 - Steel STSTD8
* material 19 - MST1
* material 20 - MST2
* material 21 - MST3 Steel block
* material 22 - MST8
* material 23 - Steel bar MST9F10 at actual density (width 5.08 cm)
* material 24 - Steel bar averaged over the mean spacing of 5.4254 cm
* material 25 - GI8
* material 26 - GII8
* material 27 - GIII8
* material 28 - Smeared stainless steel sheath - average lattice pitch
* material 29 - Smeared mild steel sheath - average lattice pitch
* material 30 - ALSC3
* material 31 - ALG8
* material 32 - AL2O34
* material 33 - U/Pu oxide plate core at reactor core centre
* material 34 - PUIX8 plate core at reactor core centre
* material 35 - UO23R4 plate core at reactor core centre
* material 36 - PUX8 Plutonium metal plate core
* material 37 - PUX8 Plutonium metal clad
* material 38 - PUXI8 Plutonium metal plate core
* material 39 - PUXI8 Plutonium metal clad
* material 40 - Sodium plate core NASTDM4
* material 41 - Sodium plate can NASTDM4
* material 42 - PUV8 Plutonium metal plate core

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* material 43 - PUV8 Plutonium metal clad
* material 44 - PUVII8 Plutonium metal plate core
* material 45 - PUVII8 Plutonium metal clad
* material 46 - PUVIII8 Plutonium metal plate core
* material 47 - PUVIII8 Plutonium metal clad
* material 48 - PUXII8 Plutonium metal plate core
* material 49 - PUXII8 Plutonium metal clad
*

COLUMNS 1 132
BEGIN MATERIAL SPECIFICATION
NUMBER DENSITY
MATERIAL 1
C 6.2771E-05 O16 4.2860E-02 AL 2.7943E-05 SI 2.6845E-05
FE 1.3500E-05 NI 1.2846E-05
U234 7.4340E-07 U235 1.1548E-04 U238 1.5938E-02
NP237 2.4466E-07 PU239 4.7730E-03 PU240 5.3344E-04
PU241 5.0303E-05 PU242 4.7919E-06 AM241 2.6204E-05
MATERIAL 2
H1 2.0111E-05 C 1.6876E-04 SI 5.9180E-04 P 2.6177E-05
S 2.5282E-05 CR 1.3956E-02 MN 1.0995E-03 FE 5.0428E-02
NI 6.9005E-03 NB 2.8363E-04
MATERIAL 3
H1 1.5145E-04 C 2.8155E-04 N 9.2216E-06 O16 5.7245E-05
AL 2.3065E-05 SI 2.8430E-05 CR 6.0974E-06 MN 1.7099E-06
FE 1.3036E-05 NI 2.6810E-05 GA 2.1190E-03
U238 5.2779E-06 PU238 3.5515E-05 PU239 2.8995E-02
PU240 6.9474E-03 PU241 1.1413E-03 PU242 1.8046E-04
AM241 5.9252E-05
MATERIAL 4
H1 1.3771E-05 C 1.1312E-04 SI 3.6529E-04 P 1.3425E-05
CR 9.3855E-03 MN 8.5801E-04 FE 3.5483E-02 NI 4.1575E-03
CU 1.6626E-02
MATERIAL 5
H1 1.0485E-04 C 2.2876E-04 N 2.4312E-05 O16 3.5962E-05
AL 1.7408E-05 CR 3.1616E-06 MN 1.0687E-06 FE 1.9344E-05
NI 6.8024E-06 GA 2.2555E-03
U238 2.4663E-07 PU238 3.6995E-05 PU239 2.8972E-02
PU240 7.3421E-03 PU241 1.1537E-03 PU242 2.0132E-04
AM241 8.6769E-05
MATERIAL 6
H1 1.3955E-05 C 1.1413E-04 SI 3.6853E-04 P 1.3545E-05
CR 9.4688E-03 MN 8.6563E-04 FE 3.5798E-02 NI 4.1944E-03
CU 1.6626E-02
MATERIAL 7
H1 3.0915E-05 C 1.1933E-05 O16 4.6151E-02 AL 3.4645E-06
SI 2.3076E-05 MN 1.1343E-07 FE 1.3390E-06 NI 1.2742E-06
MO 3.2478E-07
U235 1.6595E-04 U238 2.2908E-02
MATERIAL 8
H1 1.9528E-05 C 1.2651E-04 SI 6.3619E-04 P 3.4607E-04
S 3.5596E-05 CR 1.3636E-02 MN 8.4422E-04 FE 4.7664E-02
NI 8.3138E-03
MATERIAL 9
H1 2.4503E-05 C 3.0842E-05 O16 4.5733E-02 SI 1.3190E-05
FE 6.6332E-06
U234 1.1871E-06 U235 1.6462E-04 U238 2.2694E-02
MATERIAL 10
H1 1.7335E-05 C 1.4546E-04 SI 6.0964E-04 P 2.2563E-05
S 2.1792E-05 CR 1.2365E-02 MN 9.7951E-04 FE 4.3411E-02
NI 6.0134E-03 CU 8.1603E-04 AG 1.2368E-03
MATERIAL 11
H1 4.4048E-05 C 4.9283E-04 SI 2.1076E-04 FE 1.0599E-04
U235 3.3369E-04 U238 4.6021E-02
MATERIAL 12
H1 4.3899E-05 C 4.6047E-04 SI 1.9692E-04 FE 9.9032E-05
U235 3.3962E-04 U238 4.6785E-02
MATERIAL 13
H1 1.3418E-05 O16 5.6353E-06 NA 2.3168E-02 CA 3.5994E-06
FE 1.6144E-07
MATERIAL 14
H1 2.4319E-05 C 2.8978E-04 SI 6.0218E-04 P 3.2445E-05
S 3.2865E-05 CR 1.4602E-02 MN 1.3425E-03 FE 5.4467E-02
NI 7.0225E-03 NB 3.0815E-04
MATERIAL 15
H1 2.1098E-06 LI 3.8296E-07 B 1.4752E-07 O16 1.9937E-06

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NA 2.3119E-02 K 4.6230E-07 CA 1.7244E-06 FE 3.8077E-08
MATERIAL 16
H1 2.1496E-05 C 2.1646E-04 SI 6.0171E-04 P 2.7979E-05
S 2.7023E-05 CR 1.5000E-02 MN 1.0806E-03 FE 5.4056E-02
NI 7.2502E-03 NB 3.0316E-04
MATERIAL 17
H1 2.3265E-05 C 7.8091E-04 AL 1.7381E-04 SI 1.3358E-03
TI 2.9384E-04 CR 1.6325E-02 MN 9.3901E-04 FE 5.8278E-02
NI 7.7510E-03 CU 7.3801E-05 MO 9.7764E-05
MATERIAL 18
H1 2.3115E-05 C 7.7587E-04 AL 1.7269E-04 SI 1.3272E-03
TI 2.9195E-04 CR 1.6220E-02 MN 9.3295E-04 FE 5.7902E-02
NI 7.7009E-03 CU 7.3324E-05 MO 9.7133E-05
MATERIAL 19
H1 2.8122E-05 C 5.1129E-04 AL 1.4007E-04 TI 3.9465E-05
CR 2.7256E-05 MN 3.2675E-04 FE 8.3911E-02 NI 4.8294E-05
CU 4.4603E-05 MO 9.8477E-06
MATERIAL 20
H1 2.7967E-05 C 5.0847E-04 AL 1.3930E-04 TI 3.9247E-05
CR 2.7106E-05 MN 3.2495E-04 FE 8.3448E-02 NI 4.8028E-05
CU 4.4357E-05 MO 9.7934E-06
MATERIAL 21
H1 2.8087E-05 C 5.1066E-04 AL 1.3989E-04 TI 3.9416E-05
CR 2.7222E-05 MN 3.2634E-04 FE 8.3806E-02 NI 4.8234E-05
CU 4.4548E-05 MO 9.8355E-06
MATERIAL 22
H1 2.7730E-05 C 5.0417E-04 AL 1.3812E-04 TI 3.8915E-05
CR 2.6876E-05 MN 3.2220E-04 FE 8.2742E-02 NI 4.7622E-05
CU 4.3982E-05 MO 9.7106E-06
MATERIAL 23
H1 4.6306E-05 C 6.8972E-04 SI 3.1158E-04 P 4.2944E-05
S 3.7110E-05 MN 7.1275E-04 FE 8.1432E-02
MATERIAL 24
H1 4.0597E-05 C 6.0468E-04 SI 2.7317E-04 P 3.7649E-05
S 3.2535E-05 MN 6.2488E-04 FE 7.1392E-02
MATERIAL 25
H1 4.8551E-05 C 8.1417E-02 S 1.2207E-05 FE 6.1336E-06
MATERIAL 26
H1 2.0286E-05 C 8.5101E-02 S 1.2751E-06 FE 1.8306E-06
MATERIAL 27
H1 1.9906E-05 C 8.3507E-02 FE 2.3351E-06
MATERIAL 28
H1 9.7398E-06 C 3.2692E-04 AL 1.4553E-04 SI 4.1943E-04
TI 1.2302E-04 V 3.8541E-05 CR 6.7589E-03 MN 5.0032E-04
FE 2.3765E-02 NI 3.7801E-03 CU 3.0896E-05 MO 6.1393E-05
MATERIAL 29
H1 1.0937E-04 C 1.3002E-04 SI 1.9624E-05 P 5.9314E-06
S 1.9478E-05 MN 1.1537E-04 FE 3.2730E-02
MATERIAL 30
AL 4.7590E-02 SI 4.5790E-06 MN 9.3634E-07 FE 2.9936E-05
CU 1.8214E-06
MATERIAL 31
AL 2.6704E-02 SI 1.0296E-05 MN 6.5793E-07 FE 3.6374E-05
CU 4.5505E-07
MATERIAL 32
H1 5.1483E-05 B10 4.5063E-06 B11 1.6599E-05 O16 6.6386E-02
AL 4.4240E-02
MATERIAL 33
C 6.2771E-05 O16 4.2860E-02 AL 2.7943E-05 SI 2.6845E-05
FE 1.3500E-05 NI 1.2846E-05
U234 7.4340E-07 U235 1.1548E-04 U238 1.5938E-02
NP237 2.4466E-07 PU239 4.7730E-03 PU240 5.3344E-04
PU241 5.0303E-05 PU242 4.7919E-06 AM241 2.6204E-05
MATERIAL 34
H1 1.5145E-04 C 2.8155E-04 N 9.2216E-06 O16 5.7245E-05
AL 2.3065E-05 SI 2.8430E-05 CR 6.0974E-06 MN 1.7099E-06
FE 1.3036E-05 NI 2.6810E-05 GA 2.1190E-03
U238 5.2779E-06 PU238 3.5515E-05 PU239 2.8995E-02
PU240 6.9474E-03 PU241 1.1413E-03 PU242 1.8046E-04
AM241 5.9252E-05
MATERIAL 35
H1 3.0915E-05 C 1.1933E-05 O16 4.6151E-02 AL 3.4645E-06
SI 2.3076E-05 MN 1.1343E-07 FE 1.3390E-06 NI 1.2742E-06
MO 3.2478E-07
U235 1.6595E-04 U238 2.2908E-02
MATERIAL 36

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H1 1.0485E-04 C 2.9524E-04 N 1.0060E-05 O16 4.5503E-05
AL 2.1760E-05 SI 1.5887E-05 CR 4.2908E-06 MN 1.0687E-06
FE 1.4928E-05 NI 1.6206E-05 GA 2.2417E-03
U238 1.4305E-06 PU238 3.4035E-05 PU239 2.9107E-02
PU240 6.9117E-03 PU241 1.1359E-03 PU242 1.8531E-04
AM241 3.3658E-05
MATERIAL 37
H1 1.3587E-05 C 1.2050E-04 SI 5.2025E-04 P 2.6701E-05
S 1.5471E-05 TI 5.7590E-06 CR 9.9679E-03 MN 8.5308E-04
FE 3.3844E-02 NI 4.8383E-03 CU 1.6868E-02
MATERIAL 38
H1 1.7475E-04 C 2.2876E-04 N 1.1737E-05 O16 4.1833E-05
AL 1.8713E-05 SI 1.8396E-05 CR 6.0974E-06 MN 1.0687E-06
FE 2.2287E-05 NI 1.7606E-05 GA 2.2490E-03
U238 6.9057E-07 PU238 3.7488E-05 PU239 2.8990E-02
PU240 6.9709E-03 PU241 1.1546E-03 PU242 1.8482E-04
AM241 3.0855E-05
MATERIAL 39
H1 1.3404E-05 C 1.1825E-04 SI 5.1057E-04 P 2.6205E-05
S 1.5188E-05 TI 5.6508E-06 CR 9.7825E-03 MN 8.3722E-04
FE 3.3215E-02 NI 4.7483E-03 CU 1.6868E-02
MATERIAL 40
H1 1.3418E-05 O16 5.6353E-06 NA 2.3168E-02 CA 3.5994E-06
FE 1.6144E-07
MATERIAL 41
H1 2.1522E-05 C 2.1672E-04 SI 7.8781E-04 P 3.2216E-05
S 1.6234E-05 CR 1.5953E-02 MN 1.2635E-03 FE 5.2254E-02
NI 7.8948E-03 NB 3.4089E-04
MATERIAL 42
H1 1.7475E-04 C 2.5027E-04 N 1.3413E-05 O16 5.0640E-05
AL 2.1760E-05 SI 2.3831E-05 CR 5.1941E-06 MN 1.0687E-06
FE 1.6610E-05 NI 1.1804E-05 GA 2.2424E-03 MO 1.9583E-06
U238 1.3318E-06 PU238 2.9103E-05 PU239 2.9328E-02
PU240 6.7928E-03 PU241 9.8832E-04 PU242 1.6639E-04
AM241 1.1785E-04
MATERIAL 43
H1 1.3404E-05 C 9.2801E-05 SI 4.1625E-04 P 1.8432E-05
S 9.3252E-06 CR 9.2549E-03 MN 7.5220E-04 FE 3.4310E-02
NI 4.5397E-03 CU 1.6626E-02
MATERIAL 44
H1 1.3980E-04 C 2.0335E-04 N 6.7066E-06 O16 5.4310E-05
AL 1.6973E-05 SI 1.0870E-05 CR 4.0649E-06 MN 8.5494E-07
FE 1.0513E-05 NI 9.0032E-06 GA 2.0492E-03
U238 9.3720E-07 PU238 3.1569E-05 PU239 2.9028E-02
PU240 6.9606E-03 PU241 1.1208E-03 PU242 1.8725E-04
AM241 8.0243E-05
MATERIAL 45
H1 1.3771E-05 C 1.1357E-04 SI 3.6675E-04 P 1.3479E-05
CR 9.4231E-03 MN 8.6145E-04 FE 3.5625E-02 NI 4.1742E-03
CU 1.6626E-02
MATERIAL 46
H1 1.2815E-04 C 4.2429E-04 N 2.4312E-05 O16 8.8804E-05
AL 2.3065E-05 SI 1.4215E-05 CR 3.6133E-06 MN 1.4962E-06
FE 1.6400E-05 NI 8.6031E-06 GA 2.0247E-03
U238 6.9057E-07 PU238 3.0583E-05 PU239 2.9035E-02
PU240 6.9371E-03 PU241 1.1304E-03 PU242 1.8773E-04
AM241 7.1186E-05
MATERIAL 47
H1 1.3771E-05 C 1.1340E-04 SI 3.6619E-04 P 1.3461E-05
CR 9.4087E-03 MN 8.6013E-04 FE 3.5570E-02 NI 4.1678E-03
CU 1.6626E-02
MATERIAL 48
H1 1.7475E-04 C 2.6298E-04 N 6.7066E-06 O16 4.1833E-05
AL 1.7408E-05 SI 2.2159E-05 CR 9.2590E-06 MN 8.5494E-07
FE 1.4928E-05 NI 2.3809E-05 GA 2.3032E-03
U238 1.6771E-06 PU238 3.6995E-05 PU239 2.9064E-02
PU240 6.8990E-03 PU241 1.1606E-03 PU242 1.7997E-04
AM241 2.7359E-05
MATERIAL 49
H1 1.3220E-05 C 1.1685E-04 SI 5.0450E-04 P 2.5895E-05
S 1.5004E-05 TI 5.5851E-06 CR 9.6661E-03 MN 8.2726E-04
FE 3.2820E-02 NI 4.6918E-03 CU 1.6868E-02
END
*

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BEGIN MATERIAL GEOMETRY

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*

*

PLATES

* Plate 1, the Pu metal plate UPU024

PART 1 NEST

BOX	M1	-2.4765	-2.4765	0.03734	4.953		4.953	0.55312
BOX	M2	-2.5335	-2.5335	0.0	5.067	5.067	0.6278	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.6278	

*

* Plate 2, the Pu metal plate PUIX8

PART 2 NEST

BOX	M3	-2.3355	-2.3355	0.04572	4.671	4.671	0.23506	
BOX	M4	-2.5335	-2.5335	0.0	5.067	5.067	0.3265	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.3265	

*

* Plate 3, the Pu metal plate PUVI8

PART 3 NEST

BOX	M5	-2.3355	-2.3355	0.04572	4.671	4.671	0.23506	
BOX	M6	-2.5335	-2.5335	0.0	5.067	5.067	0.3265	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.3265	

*

* Plate 4, the UO2 plate UO23R4

PART 4 NEST

BOX	M7	-2.4255	-2.4255	0.03683	4.851	4.851	0.55424	
BOX	M8	-2.5335	-2.5335	0.0	5.067	5.067	0.6279	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.6279	

*

* Plate 5, the UO2 plate UO24R4

PART 5 NEST

BOX	M9	-2.4255	-2.4255	0.03683	4.851	4.851	0.55424	
BOX	M10	-2.5335	-2.5335	0.0	5.067	5.067	0.6279	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.6279	

*

* Central region cells for calculating reaction rate ratios

* Plate 6, the special Pu metal plate UPU024

PART 6 NEST

BOX	M33	-2.4765	-2.4765	0.03734	4.953		4.953	0.55312
BOX	M2	-2.5335	-2.5335	0.0	5.067	5.067	0.6278	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.6278	

*

* Plate 7, the special Pu metal plate PUIX8

PART 7 NEST

BOX	M34	-2.3355	-2.3355	0.04572	4.671	4.671	0.23506	
BOX	M4	-2.5335	-2.5335	0.0	5.067	5.067	0.3265	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.3265	

*

* Plate 8, the special UO2 plate UO23R4

PART 8 NEST

BOX	M35	-2.4255	-2.4255	0.03683	4.851	4.851	0.55424	
BOX	M8	-2.5335	-2.5335	0.0	5.067	5.067	0.6279	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.6279	

*

* Plate 9, the sodium plate NASTDL4

PART 9 NEST

BOX	M13	-2.4815	-2.4815	0.03683	4.963	4.963	0.54234	
BOX	M14	-2.5335	-2.5335	0.0	5.067	5.067	0.616	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.616	

*

* Plate 10, the sodium plate NASTBR4

PART 10 NEST

BOX	M15	-2.4815	-2.4815	0.03683	4.963	4.963	0.54234	
BOX	M16	-2.5335	-2.5335	0.0	5.067	5.067	0.616	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.616	

*

* Plate 11, the graphite plate GII8 (modified from GIII8)

PART 11 NEST

BOX	M26	-2.5335	-2.5335	0.0	5.067	5.067	0.31775	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.31775	

*

* Axial blanket U8 plate

PART 12 NEST

BOX	M11	-2.5335	-2.5335	0.0	5.067	5.067	0.3175	
BOX	M28	-2.7127	-2.7127	0.0	5.4254	5.4254	0.3175	

*

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* Plate 13, the steel plate STSTBR8
PART 13 NEST
BOX      M17    -2.5335  -2.5335  0.0      5.067  5.067  0.3172
BOX      M28    -2.7127  -2.7127  0.0      5.4254 5.4254 0.3172
*
* Plate 14, the graphite plate GI8
PART 14 NEST
BOX      M25    -2.5335  -2.5335  0.0      5.067  5.067  0.3180
BOX      M28    -2.7127  -2.7127  0.0      5.4254 5.4254 0.3180
*
* Plenum aluminium cylinder ALSC3
PART 15 NEST
BOX      M29     -2.5335 -2.5335  0.0      5.067  5.067  7.62
BOX      M28    -2.7127  -2.7127  0.0      5.4254 5.4254 7.62
*
* Plenum plate MST1
PART 16 NEST
BOX      M19     -2.5335 -2.5335  0.0      5.067  5.067  2.5385
BOX      M28    -2.7127  -2.7127  0.0      5.4254 5.4254 2.5385
*
* Plenum plate MST3
PART 17 NEST
BOX      M21     -2.5335 -2.5335  0.0      5.067  5.067  7.6063
BOX      M28    -2.7127  -2.7127  0.0      5.4254 5.4254 7.6063
*
*****
*
*                               Radial blanket components
*
*****
* Uranium metal U2
PART 18 NEST
BOX      M12     -2.5335 -2.5335  0.0      5.067  5.067  1.2723
BOX      M28    -2.7127  -2.7127  0.0      0.0    5.4254 5.4254 1.2723
*
* Graphite GII8
PART 19 NEST
BOX      M26     -2.5335 -2.5335  0.0      5.067  5.067  0.31775
BOX      M28    -2.7127  -2.7127  0.0      5.4254 5.4254 0.31775
*
* Mild steel MST8
PART 20 NEST
BOX      M22     -2.5335 -2.5335  0.0      5.067  5.067  0.3147
BOX      M28    -2.7127  -2.7127  0.0      5.4254 5.4254 0.3147
*
* Stainless steel STSTD18
PART 21 NEST
BOX      M18     -2.5335 -2.5335  0.0      5.067  5.067  0.3236
BOX      M28    -2.7127  -2.7127  0.0      5.4254 5.4254 0.3236
*
* ALUMINIUM ALG8
PART 22 NEST
BOX      M31     -2.5335 -2.5335  0.0      5.067  5.067  0.3170
BOX      M28    -2.7127  -2.7127  0.0      5.4254 5.4254 0.3170
*
* Aluminium oxide AL2O34
PART 23 NEST
BOX      M32     -2.5335 -2.5335  0.0      5.067  5.067  0.6317
BOX      M28    -2.7127  -2.7127  0.0      5.4254 5.4254 0.6317
*
*
* Mild steel MST2
PART 24 NEST
BOX      M20     -2.5335 -2.5335  0.0      5.067  5.067  1.2718
BOX      M28    -2.7127  -2.7127  0.0      5.4254 5.4254 1.2718
*
*****
*
*                               CELLS
*
*****
* Inner Core Cell
PART 25 ARRAY
1  1  14  9  4  9  2  9  4  9  13  4  9  1  9  4  9

```

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```

*
* Outer Core Cell 1B
PART 26 ARRAY
1 1 14 9 5 9 3 13 5 9 9 5 14 3 9 5 9
*
* Axial blanket Cell 1A
PART 27 ARRAY
1 1 20 9 12 14 9 13 12 9 14 9 13
12 9 14 9 12 13 9 14 12 9
*
* Upper Axial Plenum Cell
PART 28 ARRAY
1 1 5 15 17 15 16 15
*
* Lower Axial Plenum Cell
PART 29 ARRAY
1 1 5 15 16 15 17 15
*
* Radial blanket central region cell
PART 30 ARRAY
1 1 10 19 10 19 21 18 11 10 20 19 10
*
* Radial blanket outer region Cell
PART 31 ARRAY
1 1 20 22 22 23 14 22 18 22 14 23 24
22 14 22 22 18 23 22 14 20 22
*
* Core Cell in the central region,
PART 32 ARRAY
1 1 14 9 8 9 7 9 8 9 13 8 9 6 9 8 9
*
* Steel packing pieces to line up the elements
*
* Inner core packing
PART 33 NEST
BOX M17 -2.7127 -2.7127 0.0 5.4254 5.4254 2.51575
*
* Outer core packing
PART 34 NEST
BOX M17 -2.7127 -2.7127 0.0 5.4254 5.4254 2.064
*
* radial blanket element packing (reduced by 0.003)
PART 35 NEST
BOX M17 -2.7127 -2.7127 0.0 5.4254 5.4254 1.2456
*
*****
*
*
* ELEMENTS
*
*****
*
* The Inner Core Element
* height =  $89.0461 + 2 \times (34.9564 + 33.0048) = 224.9685$ 
* 2.51575 cm Smeared steel region above and below (height = 230.0 cm)
*
PART 36 ARRAY
1 1 23 33 29 (27)*4 (25)*11 (27)*4 28 33
*
* The Outer Core Element
* height =  $2 \times (44.9748 + 34.9564 + 33.0048) = 2 \times 112.936 = 225.872$ 
* 2.064 cm Smeared steel region above and below (height = 115.0 cm)
*
PART 37 ARRAY
1 1 24 34 29 (27)*4 (26)*12 (27)*4 28 34
*
*The Radial Blanket element 1B
* height =  $2 \times (50.296 + 30.4506 + 33.0048) = 2 \times 113.7514 = 227.5028$ 
* (1.2486 cm Smeared steel region above and below)
*
PART 38 ARRAY
1 1 30 35 29 (31)*3 (30)*20 (31)*3 28 35
*
* The Special Inner Core Element
*
PART 39 ARRAY

```

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```

1  1  23  33  29  (27)*4  (25)*3  (32)*5  (25)*3  (27)*4  28  33
*
*
* steel bar
PART 40 NEST
BOX    M23  -2.54  -2.54    0.0    5.08    5.08    230.0
BOX    M0   -2.7127 -2.7127    0.0    5.4254  5.4254  230.0
*
*****
*
*                                     ALTERNATIVE INNER CORE CELLS AND ELEMENTS
*
*****
* Plate 41, the Pu metal plate PUX8
PART 41 NEST
BOX    M36  -2.3355 -2.3355  0.04572  4.671    4.671    0.23506
BOX    M37  -2.5335 -2.5335  0.0        5.067    5.067    0.3265
BOX    M28  -2.7127 -2.7127    0.0        5.4254  5.4254    0.3265
*
* Plate 42, the Pu metal plate PUXI8
PART 42 NEST
BOX    M38  -2.3355 -2.3355  0.04572  4.671    4.671    0.23506
BOX    M39  -2.5335 -2.5335  0.0        5.067    5.067    0.3265
BOX    M28  -2.7127 -2.7127    0.0        5.4254  5.4254    0.3265
*
* Plate 43, the sodium plate NASTDM4
PART 43 NEST
BOX    M40  -2.4815 -2.4815  0.03683  4.963    4.963    0.54234
BOX    M41  -2.5335 -2.5335  0.0        5.067    5.067    0.616
BOX    M28  -2.7127 -2.7127    0.0        5.4254  5.4254    0.616
*
*
*****
*
* Alternative Inner Core Cells
* Cell 30B
PART 44 ARRAY
1  1  14  9  4  9  41  9  4  9  13  4  9  1  9  4  9
*
* Cell 30BG
PART 45 ARRAY
1  1  14  43  4  43  41  43  4  43  13  4  43  1  43  4  43
*
* Cell 30D
PART 46 ARRAY
1  1  14  43  4  43  42  43  4  43  13  4  43  1  43  4  43
*
* Alternative Axial blanket Cell 30G
PART 47 ARRAY
1  1  20  43  12  14  43  13  12  43  14  43  13
12  43  14  43  12  13  43  14  12  43
*
* Alternative inner core elements
*
* Element C12-30B
PART 48 ARRAY
1  1  23  33  29  (27)*4  (44)*11  (27)*4  28  33
*
* Element C12-30BG
PART 49 ARRAY
1  1  23  33  29  (47)*4  (45)*11  (47)*4  28  33
*
* Element C12-30D
PART 50 ARRAY
1  1  23  33  29  (47)*4  (46)*11  (47)*4  28  33
*
*
*****
*
*                                     ALTERNATIVE OUTER CORE CELLS AND ELEMENTS
*
*****
*

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*
* Plate 51, the Pu metal plate PUV8
PART 51 NEST
BOX      M42  -2.3355  -2.3355  0.04572  4.671  4.671  0.23506
BOX      M43  -2.5335  -2.5335  0.0       5.067  5.067  0.3265
BOX      M28  -2.7127  -2.7127  0.0       5.4254  5.4254  0.3265
*
* Plate 52, the Pu metal plate PUVII8
PART 52 NEST
BOX      M44  -2.3355  -2.3355  0.04572  4.671  4.671  0.23506
BOX      M45  -2.5335  -2.5335  0.0       5.067  5.067  0.3265
BOX      M28  -2.7127  -2.7127  0.0       5.4254  5.4254  0.3265
*
* Plate 53, the Pu metal plate PUVIII8
PART 53 NEST
BOX      M46  -2.3355  -2.3355  0.04572  4.671  4.671  0.23506
BOX      M47  -2.5335  -2.5335  0.0       5.067  5.067  0.3265
BOX      M28  -2.7127  -2.7127  0.0       5.4254  5.4254  0.3265
*
* Plate 54, the Pu metal plate PUVIII8
PART 54 NEST
BOX      M48  -2.3355  -2.3355  0.04572  4.671  4.671  0.23506
BOX      M49  -2.5335  -2.5335  0.0       5.067  5.067  0.3265
BOX      M28  -2.7127  -2.7127  0.0       5.4254  5.4254  0.3265
*
*
* Outer Core Cell 1A
PART 55 ARRAY
1  1  14  10  5  10  51  13  5  10  10  5  14  51  10  5  10
*
*
* Outer Core Cell 1BG
PART 56 ARRAY
1  1  14  43  5  43  3  13  5  43  43  5  14  3  43  5  43
*
*
* Outer Core Cell 1C
PART 57 ARRAY
1  1  14  9  5  9  52  13  5  9  9  5  14  52  9  5  9
*
* Outer Core Cell 1D
PART 58 ARRAY
1  1  14  9  5  9  53  13  5  9  9  5  14  53  9  5  9
*
*
* Outer Core Cell 1DG
PART 59 ARRAY
1  1  14  43  5  43  53  13  5  43  43  5  14  53  43  5  43
*
*
* Outer Core Cell 1G
PART 60 ARRAY
1  1  14  43  5  43  54  13  5  43  43  5  14  54  43  5  43
*
*
* Axial blanket Cell 1
PART 61 ARRAY
1  1  20  10  12  14  10  13  12  10  14  10  13
12  10  14  10  12  13  10  14  12  10
*
*
* Axial blanket Cell 1AG
PART 62 ARRAY
1  1  20  43  12  14  43  13  12  43  14  43  13
12  43  14  43  12  13  43  14  12  43
*
* The Outer Core Element 1A
*
PART 63 ARRAY
1  1  24  34  29  (61)*4  (55)*12  (61)*4  28  34
*
*
* The Outer Core Element 1BG
*
PART 64 ARRAY
1  1  24  34  29  (62)*4  (56)*12  (62)*4  28  34

```

```

*
* The Outer Core Element 1C
*
PART 65 ARRAY
1 1 24 34 29 (27)*4 (57)*12 (27)*4 28 34
*
*
* The Outer Core Element 1D
*
PART 66 ARRAY
1 1 24 34 29 (27)*4 (58)*12 (27)*4 28 34
*
*
* The Outer Core Element 1DG
*
PART 67 ARRAY
1 1 24 34 29 (62)*4 (59)*12 (62)*4 28 34
*
*
* The Outer Core Element 1G
*
PART 68 ARRAY
1 1 24 34 29 (62)*4 (60)*12 (62)*4 28 34
*
*
*****
*
* ARRAYS OF ELEMENTS
*
* Uniform group of 5x5 elements
*
*****
* Inner Core array
*
* 5x5 Special core centre region for reaction rate data.
PART 69 ARRAY
5 5 1 (39)*25
*
*
*****
*
* ROW 1
*****
*
* Row 1, the bottom set of groups of size 3x4 and 5x4 (5 along x axis)
* 5 arrays
*
* Left side
PART 70 ARRAY
3 4 1 (40)*9 40 (38)*2
*
* Left centre
PART 71 ARRAY
5 4 1 (40)*5 (40)*4 38 (38)*10
*
* Centre
PART 72 ARRAY
5 4 1 (40)*5 (38)*15
*
* Right centre
PART 73 ARRAY
5 4 1 (40)*5 38 (40)*4 (38)*10
*
* Right side
PART 74 ARRAY
3 4 1 (40)*9 (38)*2 40
*
* combine these arrays to form the row 1 array
PART 75 ARRAY
5 1 1 70 71 72 73 74
*
*
*****
*
* ROW 2
*****
*
* 7 arrays of elements
*

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
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```

* Bottom left outer group
PART 76 ARRAY
5 5 1 (40)*10 (40)*4 38 (40)*3 (38)*2 (40)*2 (38)*3
*
* Bottom left second group
PART 77 ARRAY
5 5 1 40 (38)*4 (38)*20
*
* Bottom left centre group
PART 78 ARRAY
5 5 1 (38)*15 (38)*3 68 67 68 67 (66)*2 65
*
* Central group
PART 79 ARRAY
5 5 1 (38)*15 (66)*5 (65)*5
*
* Bottom right centre group
PART 80 ARRAY
5 5 1 (38)*15 67 68 (38)*3 65 (66)*3 38
*
* Bottom next right group
PART 81 ARRAY
5 5 1 (38)*4 40 (38)*20
*
* Bottom right outer group
PART 82 ARRAY
5 5 1 (40)*10 38 (40)*4 (38)*2 (40)*3 (38)*3 (40)*2
*
* combine these 7 arrays to form the row 2 array
PART 83 ARRAY
7 1 1 76 77 78 79 80 81 82
*
*****
*                                     ROW 3
*****
* 9 arrays of elements, the left and right hand ones being 4x5 arrays
*
* Left side
PART 84 ARRAY
4 5 1 (40)*12 (40)*3 38 (40)*3 38
*
* Outer left
PART 85 ARRAY
5 5 1 40 (38)*4 (38)*20
*
* Left Centre
PART 86 ARRAY
5 5 1 (38)*4 67 (38)*3 (66)*2 (38)*2 66 65 37
38 66 65 37 63 68 65 37 63 50
*
* Core left
PART 87 ARRAY
5 5 1 66 (65)*2 (37)*2 65 37 (63)*2 50 37 63 (50)*3
63 (50)*4 (50)*2 (49)*2 48
*
* Core centre
PART 88 ARRAY
5 5 1 37 (63)*3 37 (50)*10 (49)*5 (48)*5
*
* Core right
PART 89 ARRAY
5 5 1 (37)*2 (65)*2 66 50 (63)*2 37 65 (50)*3 63 37
(50)*4 63 48 49 (50)*3
*
* Right Centre
PART 90 ARRAY
5 5 1 68 (38)*4 65 66 (38)*3 64 65 66 (38)*2
63 37 65 66 38 50 63 65 66 67
*
* Outer right
PART 91 ARRAY
5 5 1 (38)*4 40 (38)*20
*
* Right side
PART 92 ARRAY
4 5 1 (40)*12 38 (40)*3 38 (40)*3

```


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```

*
* combine these arrays to form the row 3 array
PART 93 ARRAY
9 1 1 84 85 86 87 88 89 90 91 92
*
*
*****
*
*
*****
* 9 arrays of elements, the left and right hand ones being 4x5 arrays
*
* Left side
PART 94 ARRAY
4 5 1 (40)*2 (38)*2 (40)*2 (38)*2 (40)*2 (38)*2
(40)*2 (38)*2 40 (38)*3
*
* Outer left
PART 95 ARRAY
5 5 1 (38)*5 (38)*4 66 (38)*4 66 (38)*3 68 66
(38)*3 67 65
*
* Left Core
PART 96 ARRAY
5 5 1 66 65 37 63 50 65 37 63 (50)*2 65 63 (50)*3
37 63 (50)*3 37 (50)*3 48
*
* Centre Left
PART 97 ARRAY
5 5 1 50 49 (48)*3 49 (48)*4 (48)*3 (36)*2 (48)*2 (36)*3
48 (36)*4
*
* Centre
PART 98 ARRAY
5 5 1 (48)*5 (36)*20
*
* Centre right
PART 99 ARRAY
5 5 1 (48)*3 49 50 36 (48)*3 49 (36)*2 (48)*3 (36)*3 (48)*2
(36)*3 (48)*2
*
* Right Core
PART 100 ARRAY
5 5 1 50 63 37 65 66 (50)*2 63 37 65 (50)*3 63 65
(50)*3 63 37 48 (50)*3 37
*
* Outer right
PART 101 ARRAY
5 5 1 68 (38)*4 67 (38)*4 66 (38)*4 66 68 (38)*3
65 67 (38)*3
*
* Right side
PART 102 ARRAY
4 5 1 (38)*2 (40)*2 (38)*2 (40)*2 (38)*2 (40)*2 (38)*2 (40)*2
(38)*3 40
*
* combine these arrays to form the row 3 array
PART 103 ARRAY
9 1 1 94 95 96 97 98 99 100 101 102
*
*
*****
* The middle row
*
*****
* 9 arrays of elements, the left and right hand ones being 4x5 arrays
*
* Left side
PART 104 ARRAY
4 5 1 40 (38)*3 40 (38)*3 40 (38)*3 40 (38)*3 40 (38)*3
*
* Outer left
PART 105 ARRAY
5 5 1 (38)*3 66 65 (38)*3 66 65 (38)*3 66 65
(38)*3 66 65 (38)*3 66 65
*
* Left Core
PART 106 ARRAY

```

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```

5 5 1 63 (50)*2 49 48 63 (50)*2 49 48 63 (50)*2 49 48
63 (50)*2 49 48 63 (50)*2 49 48
*
* Centre Left
PART 107 ARRAY
5 5 1 48 (36)*4 48 (36)*4 48 (36)*4 48 (36)*4 48 (36)*4
*
* Centre right
PART 108 ARRAY
5 5 1 (36)*4 48 (36)*4 48 (36)*4 48 (36)*4 48 (36)*4 48
*
* Right Core
PART 109 ARRAY
5 5 1 48 49 (50)*2 37 48 49 (50)*2 63 48 49 (50)*2 63
48 49 (50)*2 63 48 49 (50)*2 37
*
* Outer right
PART 110 ARRAY
5 5 1 65 66 (38)*3 65 66 (38)*3 65 66 (38)*3 65 66 (38)*3
65 66 (38)*3
*
* Right side
PART 111 ARRAY
4 5 1 (38)*3 40 (38)*3 40 (38)*3 40 (38)*3 40 (38)*3 40
*
* combine these arrays to form the row 3 array
PART 112 ARRAY
9 1 1 104 105 106 107 69 108 109 110 111
*
*
*****
*
* ROW 6
*****
* 9 arrays of elements, the left and right hand ones being 4x5 arrays
*
* Left side
PART 113 ARRAY
4 5 1 40 (38)*3 (40)*2 (38)*2 (40)*2 (38)*2 (40)*2 (38)*2
(40)*2 (38)*2
*
* Outer left
PART 114 ARRAY
5 5 1 (38)*3 67 65 (38)*3 68 66 (38)*4 66 (38)*4 67
(38)*4 68
*
*
* Left Core
PART 115 ARRAY
5 5 1 37 (50)*3 48 37 63 (50)*3 65 63 (50)*3
65 37 63 (50)*2 66 65 37 63 50
*
* Centre Left
PART 116 ARRAY
5 5 1 (48)*2 (36)*3 (48)*2 (36)*3 (48)*3 (36)*2
49 (48)*3 36 50 49 (48)*3
*
* Centre
PART 117 ARRAY
5 5 1 (36)*20 (48)*5
*
* Centre right
PART 118 ARRAY
5 5 1 (36)*4 48 (36)*3 (48)*2 (36)*2 (48)*3 (48)*4 49
(48)*3 49 50
*
* Right Core
PART 119 ARRAY
5 5 1 48 (50)*3 37 (50)*3 63 37 (50)*3 63 65
(50)*2 63 37 65 50 63 37 65 66
*
* Outer right
PART 120 ARRAY
5 5 1 65 67 (38)*3 66 68 (38)*3 66 (38)*4 66 (38)*4
(38)*5
*
* Right side

```

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```

PART 121 ARRAY
4 5 1 (38)*3 40 (38)*2 (40)*2 (38)*2 (40)*2 (38)*2 (40)*2
(38)*2 (40)*2
*
* combine these arrays to form the row 3 array
PART 122 ARRAY
9 1 1 113 114 115 116 117 118 119 120 121
*
*
*****
*
*
*****
*
* 9 arrays of elements, the left and right hand ones being 4x5 arrays
*
* Left side
PART 123 ARRAY
4 5 1 (40)*3 38 (40)*3 38 (40)*12
*
* Outer left
PART 124 ARRAY
5 5 1 (38)*20 40 (38)*4
*
* Left Centre
PART 125 ARRAY
5 5 1 67 66 65 63 50 38 66 65 37 63 (38)*2 66 65 64
(38)*3 66 65 (38)*4 68
*
* Core left
PART 126 ARRAY
5 5 1 (50)*3 49 48 63 (50)*4 37 63 (50)*3 65 37 (63)*2 50
66 (65)*2 (37)*2
*
* Core centre
PART 127 ARRAY
5 5 1 (48)*5 (49)*5 (50)*10 37 (63)*3 37
*
* Core right
PART 128 ARRAY
5 5 1 48 (49)*2 (50)*2 (50)*4 63 (50)*3 63 37
50 (63)*2 37 65 (37)*2 (65)*2 66
*
* Right centre
PART 129 ARRAY
5 5 1 50 63 37 66 68 63 37 65 66 38 37 65 66 (38)*2
(66)*2 (38)*3 67 (38)*4
*
* Outer right
PART 130 ARRAY
5 5 1 (38)*20 (38)*4 40
*
* Right side
PART 131 ARRAY
4 5 1 38 (40)*3 38 (40)*3 (40)*12
*
* combine these arrays to form the row 7 array
PART 132 ARRAY
9 1 1 123 124 125 126 127 128 129 130 131
*
*
*****
*
*
*****
*
* 7 arrays of elements
*
* left outer group
PART 133 ARRAY
5 5 1 (40)*2 (38)*3 (40)*3 (38)*2 (40)*4 38 (40)*10
*
* left second group
PART 134 ARRAY
5 5 1 (38)*20 40 (38)*4
*
* left centre group
PART 135 ARRAY
5 5 1 38 (66)*3 65 (38)*3 68 67 (38)*15

```

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```

*
* Central group
PART 136 ARRAY
5 5 1 (65)*5 (66)*5 (38)*15
*
* right centre group
PART 137 ARRAY
5 5 1 65 (66)*2 67 68 67 68 (38)*3 (38)*15
*
* next right group
PART 138 ARRAY
5 5 1 (38)*20 (38)*4 40
*
* right outer group
PART 139 ARRAY
5 5 1 (38)*3 (40)*2 (38)*2 (40)*3 38 (40)*4 (40)*10
*
* combine these 7 arrays to form the row 2 array
PART 140 ARRAY
7 1 1 133 134 135 136 137 138 139
*
*
*****
*
* Row 9, the top set of groups of size 3x4 and 5x4 (5 along the x axis)
* 5 arrays
*
* Left side
PART 141 ARRAY
3 4 1 40 (38)*2 (40)*9
*
* Left centre
PART 142 ARRAY
5 4 1 (38)*10 (40)*4 38 (40)*5
*
* Centre
PART 143 ARRAY
5 4 1 (38)*15 (40)*5
*
* Right centre
PART 144 ARRAY
5 4 1 (38)*10 38 (40)*4 (40)*5
*
* Right side
PART 145 ARRAY
3 4 1 (38)*2 40 (40)*9
*
* combine these arrays to form the row 9 array
PART 146 ARRAY
5 1 1 141 142 143 144 145
*
*
*****
*
* Cluster of superlattice groups in a circle of shield material
*****
* Cluster of superlattice groups in a circle of shield material
PART 147 CLUSTER
BOX P146 -56.9667 94.9445 -115.0 113.9334 21.7016 230.0
BOX P140 -94.9445 67.8175 -115.0 189.889 27.127 230.0
BOX P132 -116.6461 40.6905 -115.0 233.2922 27.127 230.0
BOX P122 -116.6461 13.5635 -115.0 233.2922 27.127 230.0
BOX P112 -116.6461 -13.5635 -115.0 233.2922 27.127 230.0
BOX P103 -116.6461 -40.6905 -115.0 233.2922 27.127 230.0
BOX P93 -116.6461 -67.8175 -115.0 233.2922 27.127 230.0
BOX P83 -94.9445 -94.9445 -115.0 189.889 27.127 230.0
BOX P75 -56.9667 -116.6461 -115.0 113.9334 21.7016 230.0
ZROD M24 0.0 0.0 -116.0 135.0 232.0
*
*****
* Albedo for free boundaries at side and top and reflection at bottom
*
ALBEDO 0.0 0.0 0.0

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-*BUCK*-SPEC-REAC-RRATE

```
END
*
*****
*
BEGIN CONTROL DATA
STAGES -50  2400  5000  STDV 0.0002
END
*
*****
*
BEGIN SOURCE GEOMETRY
ZONEMAT
ALL / MATERIAL 1
END
*
*****
*
BEGIN ACTION TALLIES
  NONORM
  NO ACTION TALLIES
  NOPRINT FLUXES  SCEDST  BNDXNG MATACT REGACT  NPARAM  SYSCAT
  SGUIDE HOLACT
END
*
*****
```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

*** MONK8B Input Listing for MZB/3 Model AS,**

```
* Assembly 12 is MZB the second core in the MOZART Programme.
* Version 3 has the approximately uniform radial blanket
* containing the natural uranium metal plates
* Reactor structure: elements arranged on a square grid
* The Core Elements contain Core Cells and an Axial Blanket Cell,
* enclosed in a stainless steel sheath and reflected in the midplane.
* The standard plates have a width of 5.067 cm.
* The Element sheath has an inner width 5.102 cm, outer width 5.2544 cm.
* The elements occupy a lattice area of 5.3721 cm square.
* Groups of 5x5 elements form the superlattice
*   There is a gap between these groups of elements of 0.2667 cm
* There are 408 Radial Blanket Elements
* The radial shielding elements consist of the Steel bar MST9F10
* which is about 300 cm high.
* These are represented explicitly within an outer radius and also
* homogenised (over the overall average lattice area) to fill the
* remaining space in the outer cylinder (pitch 5.4254 cm)
* The outer radius of the shielding region has been taken to be 95.91 cm
*   the enveloping circumference, rather than the value corresponding
*   to the area of shielding material
* Core Element structure (PART 26):
*   The element consists of combinations of the following cells:
*   Core Cell PART 19, Axial Blanket Cell PART 20 ,
*   Plenum Cell PART 21, element reflected in the mid-plane.
* Structure of the Radial Blanket element PART 28.
*   Central region PART 22, Upper region Cell PART 23 ,
*   Plenum Cell PART 21, element reflected in the mid-plane.
* Special Element in core centre region
*   (for reaction rate calculations) (PART 30):
*   This element contains the special cell PART 24
* All Enclosed in the stainless steel sheaths.
*****
* material 1 - U/Pu oxide plate core
* material 2 - U/Pu plate clad
* material 3 - PUIX8 Plutonium metal plate core
* material 4 - PUIX8 Plutonium metal clad
* material 5 - PUVI8 Plutonium metal plate core
* material 6 - PUVI8 Plutonium metal clad
* material 7 - UO2 plate core UO23R4
* material 8 - UO2 plate clad UO23R4
* material 9 - UO2 plate core UO24R4
* material 10 - UO2 plate clad UO24R4
* material 11 - U8 natural uranium region
* material 12 - U2 natural uranium region
* material 13 - Sodium plate core NASTDL4
* material 14 - Sodium plate clad NASTDL4
* material 15 - Sodium plate core NASTBR4
* material 16 - Sodium plate clad NASTBR4
* material 15 - Sodium plate core NAJII4
* material 16 - Sodium plate clad NAJII4
* material 17 - Steel STSTBR8
* material 18 - Steel STSTD8
* material 19 - MST1
* material 20 - MST2
* material 21 - MST3 Steel block
* material 22 - MST8
* material 23 - Steel bar MST9F10 at actual density (width 5.08 cm)
* material 24 - Steel bar averaged over the mean spacing of 5.4254 cm
* material 25 - GI8
* material 26 - GII8
* material 27 - GIII8 ???
* material 28 - stainless steel sheath - actual density
* material 29 - ALSC3
* material 30 - ALG8
* material 31 - AL2O34
* material 32 - U/Pu oxide plate core at reactor core centre
* material 33 - PUIX8 plate core at reactor core centre
* material 34 - UO23R4 plate core at reactor core centre
*
*****
COLUMNS 1 132
BEGIN MATERIAL SPECIFICATION
NUMBER DENSITY
MATERIAL 1
```

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C 6.2771E-05 O16 4.2860E-02 AL 2.7943E-05 SI 2.6845E-05
FE 1.3500E-05 NI 1.2846E-05
U234 7.4340E-07 U235 1.1548E-04 U238 1.5938E-02
NP237 2.4466E-07 PU239 4.7730E-03 PU240 5.3344E-04
PU241 5.0303E-05 PU242 4.7919E-06 AM241 2.6204E-05

MATERIAL 2
H1 2.0111E-05 C 1.6876E-04 SI 5.9180E-04 P 2.6177E-05
S 2.5282E-05 CR 1.3956E-02 MN 1.0995E-03 FE 5.0428E-02
NI 6.9005E-03 NB 2.8363E-04

MATERIAL 3
H1 1.5145E-04 C 2.8155E-04 N 9.2216E-06 O16 5.7245E-05
AL 2.3065E-05 SI 2.8430E-05 CR 6.0974E-06 MN 1.7099E-06
FE 1.3036E-05 NI 2.6810E-05 GA 2.1190E-03
U238 5.2779E-06 PU238 3.5515E-05 PU239 2.8995E-02
PU240 6.9474E-03 PU241 1.1413E-03 PU242 1.8046E-04
AM241 5.9252E-05

MATERIAL 4
H1 1.3771E-05 C 1.1312E-04 SI 3.6529E-04 P 1.3425E-05
CR 9.3855E-03 MN 8.5801E-04 FE 3.5483E-02 NI 4.1575E-03
CU 1.6626E-02

MATERIAL 5
H1 1.0485E-04 C 2.2876E-04 N 2.4312E-05 O16 3.5962E-05
AL 1.7408E-05 CR 3.1616E-06 MN 1.0687E-06 FE 1.9344E-05
NI 6.8024E-06 GA 2.2555E-03
U238 2.4663E-07 PU238 3.6995E-05 PU239 2.8972E-02
PU240 7.3421E-03 PU241 1.1537E-03 PU242 2.0132E-04
AM241 8.6769E-05

MATERIAL 6
H1 1.3955E-05 C 1.1413E-04 SI 3.6853E-04 P 1.3545E-05
CR 9.4688E-03 MN 8.6563E-04 FE 3.5798E-02 NI 4.1944E-03
CU 1.6626E-02

MATERIAL 7
H1 3.0915E-05 C 1.1933E-05 O16 4.6151E-02 AL 3.4645E-06
SI 2.3076E-05 MN 1.1343E-07 FE 1.3390E-06 NI 1.2742E-06
MO 3.2478E-07
U235 1.6595E-04 U238 2.2908E-02

MATERIAL 8
H1 1.9528E-05 C 1.2651E-04 SI 6.3619E-04 P 3.4607E-04
S 3.5596E-05 CR 1.3636E-02 MN 8.4422E-04 FE 4.7664E-02
NI 8.3138E-03

MATERIAL 9
H1 2.4503E-05 C 3.0842E-05 O16 4.5733E-02 SI 1.3190E-05
FE 6.6332E-06
U234 1.1871E-06 U235 1.6462E-04 U238 2.2694E-02

MATERIAL 10
H1 1.7335E-05 C 1.4546E-04 SI 6.0964E-04 P 2.2563E-05
S 2.1792E-05 CR 1.2365E-02 MN 9.7951E-04 FE 4.3411E-02
NI 6.0134E-03 CU 8.1603E-04 AG 1.2368E-03

MATERIAL 11
H1 4.4048E-05 C 4.9283E-04 SI 2.1076E-04 FE 1.0599E-04
U235 3.3369E-04 U238 4.6021E-02

MATERIAL 12
H1 4.3899E-05 C 4.6047E-04 SI 1.9692E-04 FE 9.9032E-05
U235 3.3962E-04 U238 4.6785E-02

MATERIAL 13
H1 1.3418E-05 O16 5.6353E-06 NA 2.3168E-02 CA 3.5994E-06
FE 1.6144E-07

MATERIAL 14
H1 2.4319E-05 C 2.8978E-04 SI 6.0218E-04 P 3.2445E-05
S 3.2865E-05 CR 1.4602E-02 MN 1.3425E-03 FE 5.4467E-02
NI 7.0225E-03 NB 3.0815E-04

MATERIAL 15
H1 2.1098E-06 LI 3.8296E-07 B 1.4752E-07 O16 1.9937E-06
NA 2.3119E-02 K 4.6230E-07 CA 1.7244E-06 FE 3.8077E-08

MATERIAL 16
H1 2.1496E-05 C 2.1646E-04 SI 6.0171E-04 P 2.7979E-05
S 2.7023E-05 CR 1.5000E-02 MN 1.0806E-03 FE 5.4056E-02
NI 7.2502E-03 NB 3.0316E-04

MATERIAL 17
H1 2.3265E-05 C 7.8091E-04 AL 1.7381E-04 SI 1.3358E-03
TI 2.9384E-04 CR 1.6325E-02 MN 9.3901E-04 FE 5.8278E-02
NI 7.7510E-03 CU 7.3801E-05 MO 9.7764E-05

MATERIAL 18
H1 2.3115E-05 C 7.7587E-04 AL 1.7269E-04 SI 1.3272E-03
TI 2.9195E-04 CR 1.6220E-02 MN 9.3295E-04 FE 5.7902E-02
NI 7.7009E-03 CU 7.3324E-05 MO 9.7133E-05

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```

MATERIAL 19
H1 2.8122E-05 C 5.1129E-04 AL 1.4007E-04 TI 3.9465E-05
CR 2.7256E-05 MN 3.2675E-04 FE 8.3911E-02 NI 4.8294E-05
CU 4.4603E-05 MO 9.8477E-06
MATERIAL 20
H1 2.7967E-05 C 5.0847E-04 AL 1.3930E-04 TI 3.9247E-05
CR 2.7106E-05 MN 3.2495E-04 FE 8.3448E-02 NI 4.8028E-05
CU 4.4357E-05 MO 9.7934E-06
MATERIAL 21
H1 2.8087E-05 C 5.1066E-04 AL 1.3989E-04 TI 3.9416E-05
CR 2.7222E-05 MN 3.2634E-04 FE 8.3806E-02 NI 4.8234E-05
CU 4.4548E-05 MO 9.8355E-06
MATERIAL 22
H1 2.7730E-05 C 5.0417E-04 AL 1.3812E-04 TI 3.8915E-05
CR 2.6876E-05 MN 3.2220E-04 FE 8.2742E-02 NI 4.7622E-05
CU 4.3982E-05 MO 9.7106E-06
MATERIAL 23
H1 4.6306E-05 C 6.8972E-04 SI 3.1158E-04 P 4.2944E-05
S 3.7110E-05 MN 7.1275E-04 FE 8.1432E-02
MATERIAL 24
H1 4.0597E-05 C 6.0468E-04 SI 2.7317E-04 P 3.7649E-05
S 3.2535E-05 MN 6.2488E-04 FE 7.1392E-02
MATERIAL 25
H1 4.8551E-05 C 8.1417E-02 S 1.2207E-05 FE 6.1336E-06
MATERIAL 26
H1 2.0286E-05 C 8.5101E-02 S 1.2751E-06 FE 1.8306E-06
MATERIAL 27
H1 1.9906E-05 C 8.3507E-02 FE 2.3351E-06
MATERIAL 28
H1 2.3206E-05 C 7.7892E-04 AL 3.4674E-04 SI 9.9934E-04
TI 2.9310E-04 V 9.1827E-05 CR 1.6104E-02 MN 1.1921E-03
FE 5.6622E-02 NI 9.0065E-03 CU 7.3613E-05 MO 1.4627E-04
MATERIAL 29
H1 1.0937E-04 C 1.3002E-04 SI 1.9624E-05 P 5.9314E-06
S 1.9478E-05 MN 1.1537E-04 FE 3.2730E-02
MATERIAL 30
AL 4.7590E-02 SI 4.5790E-06 MN 9.3634E-07 FE 2.9936E-05
CU 1.8214E-06
MATERIAL 31
AL 2.6704E-02 SI 1.0296E-05 MN 6.5793E-07 FE 3.6374E-05
CU 4.5505E-07
MATERIAL 32
H1 5.1483E-05 B10 4.5063E-06 B11 1.6599E-05 O16 6.6386E-02
AL 4.4240E-02
MATERIAL 33
C 6.2771E-05 O16 4.2860E-02 AL 2.7943E-05 SI 2.6845E-05
FE 1.3500E-05 NI 1.2846E-05
U234 7.4340E-07 U235 1.1548E-04 U238 1.5938E-02
NP237 2.4466E-07 PU239 4.7730E-03 PU240 5.3344E-04
PU241 5.0303E-05 PU242 4.7919E-06 AM241 2.6204E-05
MATERIAL 34
H1 1.5145E-04 C 2.8155E-04 N 9.2216E-06 O16 5.7245E-05
AL 2.3065E-05 SI 2.8430E-05 CR 6.0974E-06 MN 1.7099E-06
FE 1.3036E-05 NI 2.6810E-05 GA 2.1190E-03
U238 5.2779E-06 PU238 3.5515E-05 PU239 2.8995E-02
PU240 6.9474E-03 PU241 1.1413E-03 PU242 1.8046E-04
AM241 5.9252E-05
MATERIAL 35
H1 3.0915E-05 C 1.1933E-05 O16 4.6151E-02 AL 3.4645E-06
SI 2.3076E-05 MN 1.1343E-07 FE 1.3390E-06 NI 1.2742E-06
MO 3.2478E-07
U235 1.6595E-04 U238 2.2908E-02
END
*
*****
BEGIN MATERIAL GEOMETRY
*
*
*
*****
* Plate 1, the Pu oxide plate UPU024
PART 1 NEST
BOX M1 -2.4765 -2.4765 0.03734 4.953 4.953 0.55312
BOX M2 -2.5335 -2.5335 0.0 5.067 5.067 0.6278
BOX M0 -2.5510 -2.5510 0.0 5.102 5.102 0.6278
BOX M28 -2.6272 -2.6272 0.0 5.2544 5.2544 0.6278

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```

BOX      M0  -2.68605 -2.68605 0.0      5.3721 5.3721 0.6278
*
* Plate 2, the Pu metal plate PUIX8
PART 2 NEST
BOX      M3  -2.3355  -2.3355 0.04572 4.671  4.671  0.23506
BOX      M4  -2.5335  -2.5335 0.0      5.067  5.067  0.3265
BOX      M0  -2.5510  -2.5510 0.0      5.102  5.102  0.3265
BOX      M28 -2.6272  -2.6272 0.0      5.2544 5.2544 0.3265
BOX      M0  -2.68605 -2.68605 0.0      5.3721 5.3721 0.3265
*
* Plate 3, the Pu metal plate PUVI8
PART 3 NEST
BOX      M5  -2.3355  -2.3355 0.04572 4.671  4.671  0.23506
BOX      M6  -2.5335  -2.5335 0.0      5.067  5.067  0.3265
BOX      M0  -2.5510  -2.5510 0.0      5.102  5.102  0.3265
BOX      M28 -2.6272  -2.6272 0.0      5.2544 5.2544 0.3265
BOX      M0  -2.68605 -2.68605 0.0      5.3721 5.3721 0.3265
*
* Plate 4, the UO2 plate UO23R4
PART 4 NEST
BOX      M7  -2.4255  -2.4255 0.03683 4.851  4.851  0.55424
BOX      M8  -2.5335  -2.5335 0.0      5.067  5.067  0.6279
BOX      M0  -2.5510  -2.5510 0.0      5.102  5.102  0.6279
BOX      M28 -2.6272  -2.6272 0.0      5.2544 5.2544 0.6279
BOX      M0  -2.68605 -2.68605 0.0      5.3721 5.3721 0.6279
*
* Plate 5, the UO2 plate UO24R4
PART 5 NEST
BOX      M9  -2.4255  -2.4255 0.03683 4.851  4.851  0.55424
BOX      M10 -2.5335  -2.5335 0.0      5.067  5.067  0.6279
BOX      M0  -2.5510  -2.5510 0.0      5.102  5.102  0.6279
BOX      M28 -2.6272  -2.6272 0.0      5.2544 5.2544 0.6279
BOX      M0  -2.68605 -2.68605 0.0      5.3721 5.3721 0.6279
*
* Central region cells for calculating reaction rate ratios
* Plate 6, the special Pu metal plate UPUO24
PART 6 NEST
BOX      M33 -2.4765  -2.4765 0.03734 4.953      4.953  0.55312
BOX      M2  -2.5335  -2.5335 0.0      5.067  5.067  0.6278
BOX      M0  -2.5510  -2.5510 0.0      5.102  5.102  0.6278
BOX      M28 -2.6272  -2.6272 0.0      5.2544 5.2544 0.6278
BOX      M0  -2.68605 -2.68605 0.0      5.3721 5.3721 0.6278
*
* Plate 7, the special Pu metal plate PUIX8
PART 7 NEST
BOX      M34 -2.3355  -2.3355 0.04572 4.671  4.671  0.23506
BOX      M4  -2.5335  -2.5335 0.0      5.067  5.067  0.3265
BOX      M0  -2.5510  -2.5510 0.0      5.102  5.102  0.3265
BOX      M28 -2.6272  -2.6272 0.0      5.2544 5.2544 0.3265
BOX      M0  -2.68605 -2.68605 0.0      5.3721 5.3721 0.3265
*
* Plate 8, the special UO2 plate UO23R4
PART 8 NEST
BOX      M35 -2.4255  -2.4255 0.03683 4.851  4.851  0.55424
BOX      M8  -2.5335  -2.5335 0.0      5.067  5.067  0.6279
BOX      M0  -2.5510  -2.5510 0.0      5.102  5.102  0.6279
BOX      M28 -2.6272  -2.6272 0.0      5.2544 5.2544 0.6279
BOX      M0  -2.68605 -2.68605 0.0      5.3721 5.3721 0.6279
*
* Plate 9, the sodium plate NASTDL4
PART 9 NEST
BOX      M13 -2.4815  -2.4815 0.03683 4.963  4.963  0.54234
BOX      M14 -2.5335  -2.5335 0.0      5.067  5.067  0.616
BOX      M0  -2.5510  -2.5510 0.0      5.102  5.102  0.616
BOX      M28 -2.6272  -2.6272 0.0      5.2544 5.2544 0.616
BOX      M0  -2.68605 -2.68605 0.0      5.3721 5.3721 0.616
*
* Plate 10, the sodium plate NASTBR4
PART 10 NEST
BOX      M15 -2.4815  -2.4815 0.03683 4.963  4.963  0.54234
BOX      M16 -2.5335  -2.5335 0.0      5.067  5.067  0.616
BOX      M0  -2.5510  -2.5510 0.0      5.102  5.102  0.616
BOX      M28 -2.6272  -2.6272 0.0      5.2544 5.2544 0.616
BOX      M0  -2.68605 -2.68605 0.0      5.3721 5.3721 0.616
*
* Plate 11, the graphite plate GII8 (modified from GIII8)

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PART 11 NEST
BOX      M26  -2.5335  -2.5335  0.0      5.067  5.067  0.31775
BOX      M0   -2.5510  -2.5510  0.0      5.102  5.102  0.31775
BOX      M28  -2.6272  -2.6272  0.0      5.2544 5.2544 0.31775
BOX      M0   -2.68605 -2.68605 0.0      5.3721 5.3721 0.31775
*
* Axial blanket U8 plate
PART 12 NEST
BOX      M11   -2.5335 -2.5335 0.0      5.067  5.067  0.3175
BOX      M0   -2.5510  -2.5510 0.0      5.102  5.102  0.3175
BOX      M28  -2.6272  -2.6272 0.0      5.2544 5.2544 0.3175
BOX      M0   -2.68605 -2.68605 0.0      5.3721 5.3721 0.3175
*
* Plate 13, the steel plate STSTBR8
PART 13 NEST
BOX      M17  -2.5335  -2.5335 0.0      5.067  5.067  0.3172
BOX      M0   -2.5510  -2.5510 0.0      5.102  5.102  0.3172
BOX      M28  -2.6272  -2.6272 0.0      5.2544 5.2544 0.3172
BOX      M0   -2.68605 -2.68605 0.0      5.3721 5.3721 0.3172
*
* Plate 14, the graphite plate GI8
PART 14 NEST
BOX      M25  -2.5335  -2.5335 0.0      5.067  5.067  0.3180
BOX      M0   -2.5510  -2.5510 0.0      5.102  5.102  0.3180
BOX      M28  -2.6272  -2.6272 0.0      5.2544 5.2544 0.3180
BOX      M0   -2.68605 -2.68605 0.0      5.3721 5.3721 0.3180
*
* Plenum aluminium cylinder ALSC3
PART 15 NEST
BOX      M29  -2.5335 -2.5335 0.0      5.067  5.067  7.62
BOX      M0   -2.5510  -2.5510 0.0      5.102  5.102  7.62
BOX      M28  -2.6272  -2.6272 0.0      5.2544 5.2544 7.62
BOX      M0   -2.68605 -2.68605 0.0      5.3721 5.3721 7.62
*
* Plenum plate MST1
PART 16 NEST
BOX      M19  -2.5335 -2.5335 0.0      5.067  5.067  2.5385
BOX      M0   -2.5510  -2.5510 0.0      5.102  5.102  2.5385
BOX      M28  -2.6272  -2.6272 0.0      5.2544 5.2544 2.5385
BOX      M0   -2.68605 -2.68605 0.0      5.3721 5.3721 2.5385
*
* Plenum plate MST3
PART 17 NEST
BOX      M21  -2.5335 -2.5335 0.0      5.067  5.067  7.6063
BOX      M0   -2.5510  -2.5510 0.0      5.102  5.102  7.6063
BOX      M28  -2.6272  -2.6272 0.0      5.2544 5.2544 7.6063
BOX      M0   -2.68605 -2.68605 0.0      5.3721 5.3721 7.6063
*
*
*****
*
*
* Radial blanket components
*
*****
* Uranium metal U2
PART 18 NEST
BOX      M12  -2.5335  -2.5335 0.0      5.067  5.067  1.2723
BOX      M0   -2.5510  -2.5510 0.0      5.102  5.102  1.2723
BOX      M28  -2.6272  -2.6272 0.0      5.2544 5.2544 1.2723
BOX      M0   -2.68605 -2.68605 0.0      5.3721 5.3721 1.2723
*
* Graphite GII8
PART 19 NEST
BOX      M26  -2.5335 -2.5335 0.0      5.067  5.067  0.31775
BOX      M0   -2.5510  -2.5510 0.0      5.102  5.102  0.31775
BOX      M28  -2.6272  -2.6272 0.0      5.2544 5.2544 0.31775
BOX      M0   -2.68605 -2.68605 0.0      5.3721 5.3721 0.31775
*
* Mild steel MST8
PART 20 NEST
BOX      M22  -2.5335 -2.5335 0.0      5.067  5.067  0.3147
BOX      M0   -2.5510  -2.5510 0.0      5.102  5.102  0.3147
BOX      M28  -2.6272  -2.6272 0.0      5.2544 5.2544 0.3147
BOX      M0   -2.68605 -2.68605 0.0      5.3721 5.3721 0.3147
*
* Stainless steel STSTD8

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PART 21 NEST
BOX    M18    -2.5335 -2.5335 0.0    5.067  5.067  0.3236
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  0.3236
BOX    M28    -2.6272 -2.6272 0.0    5.2544 5.2544 0.3236
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 0.3236
*
* ALUMINIUM ALG8
PART 22 NEST
BOX    M31    -2.5335 -2.5335 0.0    5.067  5.067  0.3170
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  0.3170
BOX    M28    -2.6272 -2.6272 0.0    5.2544 5.2544 0.3170
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 0.3170
*
* Aluminium oxide AL2O34
PART 23 NEST
BOX    M32    -2.5335 -2.5335 0.0    5.067  5.067  0.6317
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  0.6317
BOX    M28    -2.6272 -2.6272 0.0    5.2544 5.2544 0.6317
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 0.6317
*
*
* Mild steel MST2
PART 24 NEST
BOX    M20    -2.5335 -2.5335 0.0    5.067  5.067  1.2718
BOX    M0     -2.5510 -2.5510 0.0    5.102  5.102  1.2718
BOX    M28    -2.6272 -2.6272 0.0    5.2544 5.2544 1.2718
BOX    M0     -2.68605 -2.68605 0.0    5.3721 5.3721 1.2718
*
*****
*
*
*
*****
* Inner Core Cell
PART 25 ARRAY
1  1  14  9  4  9  2  9  4  9  13  4  9  1  9  4  9
*
* Outer Core Cell
PART 26 ARRAY
1  1  14  9  5  9  3  13  5  9  9  5  14  3  9  5  9
*
* Axial blanket Cell
PART 27 ARRAY
1  1  20  9  12  14  9  13  12  9  14  9  13
12  9  14  9  12  13  9  14  12  9
*
* Upper Axial Plenum Cell
PART 28 ARRAY
1  1  5  15  17  15  16  15
*
* Lower Axial Plenum Cell
PART 29 ARRAY
1  1  5  15  16  15  17  15
*
* Radial blanket central region cell
PART 30 ARRAY
1  1  10  19  10  19  21  18  11  10  20  19  10
*
* Radial blanket outer region Cell
PART 31 ARRAY
1  1  20  22  22  23  14  22  18  22  14  23  24
22  14  22  22  18  23  22  14  20  22
*
* Core Cell in the central region,
PART 32 ARRAY
1  1  14  9  8  9  7  9  8  9  13  8  9  6  9  8  9
*
* Steel packing pieces to line up the elements
*
*
* Inner core packing
PART 33 NEST
BOX    M17    -2.68605 -2.68605 0.0    5.3721 5.3721 2.51575
*
* Outer core packing

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PART 34 NEST
BOX      M17  -2.68605 -2.68605 0.0      5.3721  5.3721 2.064
*
* radial blanket element packing (reduced by 0.003)
PART 35 NEST
BOX      M17  -2.68605 -2.68605 0.0      5.3721  5.3721 1.2456
*
*****
*
*                                     ELEMENTS
*
*****
* The Inner Core Element
* height = 89.0461 + 2*(34.9564 + 33.0048) =224.9685
* 2.51575 cm Smeared steel region above and below (height = 230.0 cm)
*
PART 36 ARRAY
1  1  23  33  29  (27)*4  (25)*11  (27)*4  28  33
*
* The Outer Core Element
* height = 2*(44.9748 +34.9564 + 33.0048) = 2* 112.936 =225.872
* 2.064 cm Smeared steel region above and below (height = 115.0 cm)
*
PART 37 ARRAY
1  1  24  34  29  (27)*4  (26)*12  (27)*4  28  34
*
*The Radial Blanket element
* height = 2*(50.296 + 30.4506 + 33.0048) = 2*113.7514 = 227.5028
* (1.2486 cm Smeared steel region above and below)
*
PART 38 ARRAY
1  1  30  35  29  (31)*3  (30)*20  (31)*3  28  35
*
* The Special Inner Core Element
*
PART 39 ARRAY
1  1  23  33  29  (27)*4  (25)*3  (32)*5  (25)*3  (27)*4  28  33
*
*
* steel bar
PART 40 NEST
BOX      M23  -2.54    -2.54    0.0      5.08    5.08   230.0
BOX      M0   -2.68605 -2.68605 0.0      5.3721  5.3721 230.0
*
*****
*
*                                     ARRAYS OF ELEMENTS
*
*****
* Uniform groups of 5x5 elements
*
*****
* Inner Core array
*
PART 41 ARRAY
5  5  1  (36)*25
*
*
PART 42 OVERLAP
BOX      P41  -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX      M23  -13.5635  -13.5635  34.4      27.127  27.127  30.4
BOX      M23  -13.5635  -13.5635 165.2  27.127  27.127  30.4
BOX      M0   -13.5635  -13.5635 0.0 27.127  27.127  230.0
*
*
* 5x5 Special core centre region for reaction rate data.
PART 43 ARRAY
5  5  1  (39)*25
*
*
PART 44 OVERLAP
BOX      P43  -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX      M23  -13.5635  -13.5635  34.4      27.127  27.127  30.4
BOX      M23  -13.5635  -13.5635 165.2  27.127  27.127  30.4
BOX      M0   -13.5635  -13.5635 0.0 27.127  27.127  230.0

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```

*
*
*****
*
*                               ROW 1
*****
*
* Row 1, the bottom set of groups of size 3x4 and 5x4 (5 along the x axis)
* 5 arrays
*
* Left side
PART 45 ARRAY
3 4 1 (40)*9 40 (38)*2
*
PART 46 OVERLAP
BOX P45 -8.05815 -10.7442 0.0 16.1163 21.4884 230.0
BOX M23 -8.1381 -10.8508 34.4 16.2762 21.7016 30.4
BOX M23 -8.1381 -10.8508 165.2 16.2762 21.7016 30.4
BOX M0 -8.1381 -10.8508 0.0 16.2762 21.7016 230.0
*
*
* Left centre
PART 47 ARRAY
5 4 1 (40)*5 (40)*4 38 (38)*10
*
PART 48 OVERLAP
BOX P47 -13.43025 -10.7442 0.0 26.8605 21.4884 230.0
BOX M23 -13.5635 -10.8508 34.4 27.127 21.7016 30.4
BOX M23 -13.5635 -10.8508 165.2 27.127 21.7016 30.4
BOX M0 -13.5635 -10.8508 0.0 27.127 21.7016 230.0
*
*
* Centre
PART 49 ARRAY
5 4 1 (40)*5 (38)*15
*
PART 50 OVERLAP
BOX P49 -13.43025 -10.7442 0.0 26.8605 21.4884 230.0
BOX M23 -13.5635 -10.8508 34.4 27.127 21.7016 30.4
BOX M23 -13.5635 -10.8508 165.2 27.127 21.7016 30.4
BOX M0 -13.5635 -10.8508 0.0 27.127 21.7016 230.0
*
*
* Right centre
PART 51 ARRAY
5 4 1 (40)*5 38 (40)*4 (38)*10
*
PART 52 OVERLAP
BOX P51 -13.43025 -10.7442 0.0 26.8605 21.4884 230.0
BOX M23 -13.5635 -10.8508 34.4 27.127 21.7016 30.4
BOX M23 -13.5635 -10.8508 165.2 27.127 21.7016 30.4
BOX M0 -13.5635 -10.8508 0.0 27.127 21.7016 230.0
*
*
* Right side
PART 53 ARRAY
3 4 1 (40)*9 (38)*2 40
*
PART 54 OVERLAP
BOX P53 -8.05815 -10.7442 0.0 16.1163 21.4884 230.0
BOX M23 -8.1381 -10.8508 34.4 16.2762 21.7016 30.4
BOX M23 -8.1381 -10.8508 165.2 16.2762 21.7016 30.4
BOX M0 -8.1381 -10.8508 0.0 16.2762 21.7016 230.0
*
*
* combine these arrays to form the row 1 array
PART 55 ARRAY
5 1 1 46 48 50 52 54
*
*
*****
*
*                               ROW 2
*****
* 7 arrays of elements
*
* Bottom left outer group
PART 56 ARRAY

```

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```

5 5 1 (40)*10 (40)*4 38 (40)*3 (38)*2 (40)*2 (38)*3
*
PART 57 OVERLAP
BOX P56 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Bottom left second group
PART 58 ARRAY
5 5 1 40 (38)*4 (38)*20
*
PART 59 OVERLAP
BOX P58 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Bottom left centre group
PART 60 ARRAY
5 5 1 (38)*15 (38)*3 (37)*2 (37)*5
*
PART 61 OVERLAP
BOX P60 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Central group
PART 62 ARRAY
5 5 1 (38)*15 (37)*10
*
PART 63 OVERLAP
BOX P62 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Bottom right centre group
PART 64 ARRAY
5 5 1 (38)*15 (37)*2 (38)*3 (37)*4 38
*
PART 65 OVERLAP
BOX P64 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Bottom next right group
PART 66 ARRAY
5 5 1 (38)*4 40 (38)*20
*
PART 67 OVERLAP
BOX P66 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Bottom right outer group
PART 68 ARRAY
5 5 1 (40)*10 38 (40)*4 (38)*2 (40)*3 (38)*3 (40)*2
*
PART 69 OVERLAP
BOX P68 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* combine these 7 arrays to form the row 2 array

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

PART 70 ARRAY
7 1 1 57 59 61 63 65 67 69
*
*****
*
*                               ROW 3
*****
* 9 arrays of elements, the left and right hand ones being 4x5 arrays
*
* Left side
PART 71 ARRAY
4 5 1 (40)*12 (40)*3 38 (40)*3 38
*
PART 72 OVERLAP
BOX P71 -10.7442 -13.43025 0.0 21.4884 26.8605 230.0
BOX M23 -10.8508 -13.5635 34.4 21.7016 27.127 30.4
BOX M23 -10.8508 -13.5635 165.2 21.7016 27.127 30.4
BOX M0 -10.8508 -13.5635 0.0 21.7016 27.127 230.0
*
*
* Outer left
PART 73 ARRAY
5 5 1 40 (38)*4 (38)*20
*
PART 74 OVERLAP
BOX P73 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Left Centre
PART 75 ARRAY
5 5 1 (38)*4 37 (38)*3 (37)*2 (38)*2 (37)*3 38 (37)*4
(37)*4 36
*
PART 76 OVERLAP
BOX P75 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Core left
PART 77 ARRAY
5 5 1 (37)*5 (37)*4 36 (37)*2 (36)*3 37 (36)*4 (36)*5
*
PART 78 OVERLAP
BOX P77 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Core centre
PART 79 ARRAY
5 5 1 (37)*5 (36)*20
*
PART 80 OVERLAP
BOX P79 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Core right
PART 81 ARRAY
5 5 1 (37)*5 36 (37)*4 (36)*3 (37)*2 (36)*4 37 (36)*5
*
PART 82 OVERLAP
BOX P81 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Right Centre

```

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LIQUID METAL FAST REACTOR - LMFR
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```

PART 83 ARRAY
5 5 1 37 (38)*4 (37)*2 (38)*3 (37)*3 (38)*2 (37)*4 38
36 (37)*4
*
PART 84 OVERLAP
BOX P83 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Outer right
PART 85 ARRAY
5 5 1 (38)*4 40 (38)*20
*
PART 86 OVERLAP
BOX P85 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Right side
PART 87 ARRAY
4 5 1 (40)*12 38 (40)*3 38 (40)*3
*
PART 88 OVERLAP
BOX P87 -10.7442 -13.43025 0.0 21.4884 26.8605 230.0
BOX M23 -10.8508 -13.5635 34.4 21.7016 27.127 30.4
BOX M23 -10.8508 -13.5635 165.2 21.7016 27.127 30.4
BOX M0 -10.8508 -13.5635 0.0 21.7016 27.127 230.0
*
*
* combine these arrays to form the row 3 array
PART 89 ARRAY
9 1 1 72 74 76 78 80 82 84 86 88
*
*****
*
*
*****
* 9 arrays of elements, the left and right hand ones being 4x5 arrays
*
* Left side
PART 90 ARRAY
4 5 1 (40)*2 (38)*2 (40)*2 (38)*2 (40)*2 (38)*2
(40)*2 (38)*2 40 (38)*3
*
PART 91 OVERLAP
BOX P90 -10.7442 -13.43025 0.0 21.4884 26.8605 230.0
BOX M23 -10.8508 -13.5635 34.4 21.7016 27.127 30.4
BOX M23 -10.8508 -13.5635 165.2 21.7016 27.127 30.4
BOX M0 -10.8508 -13.5635 0.0 21.7016 27.127 230.0
*
*
* Outer left
PART 92 ARRAY
5 5 1 (38)*5 (38)*4 37 (38)*4 37 (38)*3 (37)*2
(38)*3 (37)*2
*
PART 93 OVERLAP
BOX P92 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Left Core
PART 94 ARRAY
5 5 1 (37)*4 36 (37)*3 (36)*2 (37)*2 (36)*3 (37)*2 (36)*3
37 (36)*4
*
PART 95 OVERLAP
BOX P94 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0

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```

*
*
* Right Core
PART 96 ARRAY
5 5 1 36 (37)*4 (36)*2 (37)*3 (36)*3 (37)*2 (36)*3 (37)*2
(36)*4 37
*
PART 97 OVERLAP
BOX P96 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Outer right
PART 98 ARRAY
5 5 1 37 (38)*4 37 (38)*4 37 (38)*4 (37)*2 (38)*3
(37)*2 (38)*3
*
PART 99 OVERLAP
BOX P98 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Right side
PART 100 ARRAY
4 5 1 (38)*2 (40)*2 (38)*2 (40)*2 (38)*2 (40)*2 (38)*2 (40)*2
(38)*3 40
*
PART 101 OVERLAP
BOX P100 -10.7442 -13.43025 0.0 21.4884 26.8605 230.0
BOX M23 -10.8508 -13.5635 34.4 21.7016 27.127 30.4
BOX M23 -10.8508 -13.5635 165.2 21.7016 27.127 30.4
BOX M0 -10.8508 -13.5635 0.0 21.7016 27.127 230.0
*
*
* combine these arrays to form the row 3 array
PART 102 ARRAY
9 1 1 91 93 95 (42)*3 97 99 101
*
*
*****
* The middle row ROW 5
*****
* 9 arrays of elements, the left and right hand ones being 4x5 arrays
*
* Left side
PART 103 ARRAY
4 5 1 40 (38)*3 40 (38)*3 40 (38)*3 40 (38)*3 40 (38)*3
*
PART 104 OVERLAP
BOX P103 -10.7442 -13.43025 0.0 21.4884 26.8605 230.0
BOX M23 -10.8508 -13.5635 34.4 21.7016 27.127 30.4
BOX M23 -10.8508 -13.5635 165.2 21.7016 27.127 30.4
BOX M0 -10.8508 -13.5635 0.0 21.7016 27.127 230.0
*
*
* Outer left
PART 105 ARRAY
5 5 1 (38)*3 (37)*2 (38)*3 (37)*2 (38)*3 (37)*2 (38)*3 (37)*2
(38)*3 (37)*2
*
PART 106 OVERLAP
BOX P105 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Left Core
PART 107 ARRAY
5 5 1 37 (36)*4 37 (36)*4 37 (36)*4 37 (36)*4 37 (36)*4
*
PART 108 OVERLAP

```

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```

BOX    P107  -13.43025      -13.43025  0.0 26.8605 26.8605 230.0
BOX    M23   -13.5635     -13.5635   34.4      27.127  27.127  30.4
BOX    M23   -13.5635     -13.5635  165.2   27.127  27.127  30.4
BOX    M0    -13.5635     -13.5635   0.0 27.127  27.127  230.0
*
*
* Right Core
PART 109 ARRAY
5  5  1  (36)*4  37  (36)*4  37  (36)*4  37  (36)*4  37  (36)*4  37
*
PART 110 OVERLAP
BOX    P109  -13.43025      -13.43025  0.0 26.8605 26.8605 230.0
BOX    M23   -13.5635     -13.5635   34.4      27.127  27.127  30.4
BOX    M23   -13.5635     -13.5635  165.2   27.127  27.127  30.4
BOX    M0    -13.5635     -13.5635   0.0 27.127  27.127  230.0
*
*
* Outer right
PART 111 ARRAY
5  5  1  (37)*2  (38)*3  (37)*2  (38)*3  (37)*2  (38)*3  (37)*2  (38)*3
(37)*2  (38)*3
*
PART 112 OVERLAP
BOX    P111  -13.43025      -13.43025  0.0 26.8605 26.8605 230.0
BOX    M23   -13.5635     -13.5635   34.4      27.127  27.127  30.4
BOX    M23   -13.5635     -13.5635  165.2   27.127  27.127  30.4
BOX    M0    -13.5635     -13.5635   0.0 27.127  27.127  230.0
*
*
* Right side
PART 113 ARRAY
4  5  1  (38)*3  40  (38)*3  40  (38)*3  40  (38)*3  40  (38)*3  40
*
PART 114 OVERLAP
BOX    P113  -10.7442     -13.43025  0.0 21.4884 26.8605 230.0
BOX    M23   -10.8508     -13.5635   34.4      21.7016  27.127  30.4
BOX    M23   -10.8508     -13.5635  165.2   21.7016  27.127  30.4
BOX    M0    -10.8508     -13.5635   0.0 21.7016 27.127  230.0
*
*
* combine these arrays to form the row 3 array
PART 115 ARRAY
9  1  1  104  106  108  42  44  42  110  112  114
*
*
*****
*
*
*****
* 9 arrays of elements, the left and right hand ones being 4x5 arrays
*
* Left side
PART 116 ARRAY
4  5  1  40  (38)*3  (40)*2  (38)*2  (40)*2  (38)*2  (40)*2  (38)*2
(40)*2  (38)*2
*
PART 117 OVERLAP
BOX    P116  -10.7442     -13.43025  0.0 21.4884 26.8605 230.0
BOX    M23   -10.8508     -13.5635   34.4      21.7016  27.127  30.4
BOX    M23   -10.8508     -13.5635  165.2   21.7016  27.127  30.4
BOX    M0    -10.8508     -13.5635   0.0 21.7016 27.127  230.0
*
*
* Outer left
PART 118 ARRAY
5  5  1  (38)*3  (37)*2  (38)*3  (37)*2  (38)*4  37  (38)*4  37
(38)*4  37
*
PART 119 OVERLAP
BOX    P118  -13.43025      -13.43025  0.0 26.8605 26.8605 230.0
BOX    M23   -13.5635     -13.5635   34.4      27.127  27.127  30.4
BOX    M23   -13.5635     -13.5635  165.2   27.127  27.127  30.4
BOX    M0    -13.5635     -13.5635   0.0 27.127  27.127  230.0
*
*
* Left Core
PART 120 ARRAY

```

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```

5 5 1 37 (36)*4 (37)*2 (36)*3 (37)*2 (36)*3 (37)*3 (36)*2
(37)*4 36
*
PART 121 OVERLAP
BOX P120 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Right Core
PART 122 ARRAY
5 5 1 (36)*4 37 (36)*3 (37)*2 (36)*3 (37)*2 (36)*2 (37)*3
36 (37)*4
*
PART 123 OVERLAP
BOX P122 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Outer right
PART 124 ARRAY
5 5 1 (37)*2 (38)*3 (37)*2 (38)*3 37 (38)*4 37 (38)*4
(38)*5
*
PART 125 OVERLAP
BOX P124 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4
BOX M0 -13.5635 -13.5635 0.0 27.127 27.127 230.0
*
*
* Right side
PART 126 ARRAY
4 5 1 (38)*3 40 (38)*2 (40)*2 (38)*2 (40)*2 (38)*2 (40)*2
(38)*2 (40)*2
*
PART 127 OVERLAP
BOX P126 -10.7442 -13.43025 0.0 21.4884 26.8605 230.0
BOX M23 -10.8508 -13.5635 34.4 21.7016 27.127 30.4
BOX M23 -10.8508 -13.5635 165.2 21.7016 27.127 30.4
BOX M0 -10.8508 -13.5635 0.0 21.7016 27.127 230.0
*
*
* combine these arrays to form the row 3 array
PART 128 ARRAY
9 1 1 117 119 121 (42)*3 123 125 127
*
*
*****
*
* ROW 7
*****
*
* 9 arrays of elements, the left and right hand ones being 4x5 arrays
*
* Left side
PART 129 ARRAY
4 5 1 (40)*3 38 (40)*3 38 (40)*12
*
PART 130 OVERLAP
BOX P129 -10.7442 -13.43025 0.0 21.4884 26.8605 230.0
BOX M23 -10.8508 -13.5635 34.4 21.7016 27.127 30.4
BOX M23 -10.8508 -13.5635 165.2 21.7016 27.127 30.4
BOX M0 -10.8508 -13.5635 0.0 21.7016 27.127 230.0
*
*
* Outer left
PART 131 ARRAY
5 5 1 (38)*20 40 (38)*4
*
PART 132 OVERLAP
BOX P131 -13.43025 -13.43025 0.0 26.8605 26.8605 230.0
BOX M23 -13.5635 -13.5635 34.4 27.127 27.127 30.4
BOX M23 -13.5635 -13.5635 165.2 27.127 27.127 30.4

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```

BOX      M0      -13.5635  -13.5635   0.0 27.127 27.127 230.0
*
*
* Left Centre
PART 133 ARRAY
5 5 1      (37)*4  36 38  (37)*4  (38)*2  (37)*3  (38)*3  (37)*2
(38)*4  37
*
PART 134 OVERLAP
BOX      P133  -13.43025          -13.43025  0.0 26.8605 26.8605 230.0
BOX      M23  -13.5635  -13.5635   34.4          27.127 27.127 30.4
BOX      M23  -13.5635  -13.5635  165.2 27.127 27.127 30.4
BOX      M0   -13.5635  -13.5635   0.0 27.127 27.127 230.0
*
*
* Core left
PART 135 ARRAY
5 5 1      (36)*5  37 (36)*4  (37)*2  (36)*3  (37)*4  36 (37)*5
*
PART 136 OVERLAP
BOX      P135  -13.43025          -13.43025  0.0 26.8605 26.8605 230.0
BOX      M23  -13.5635  -13.5635   34.4          27.127 27.127 30.4
BOX      M23  -13.5635  -13.5635  165.2 27.127 27.127 30.4
BOX      M0   -13.5635  -13.5635   0.0 27.127 27.127 230.0
*
*
* Core centre
PART 137 ARRAY
5 5 1      (36)*20 (37)*5
*
PART 138 OVERLAP
BOX      P137  -13.43025          -13.43025  0.0 26.8605 26.8605 230.0
BOX      M23  -13.5635  -13.5635   34.4          27.127 27.127 30.4
BOX      M23  -13.5635  -13.5635  165.2 27.127 27.127 30.4
BOX      M0   -13.5635  -13.5635   0.0 27.127 27.127 230.0
*
*
* Core right
PART 139 ARRAY
5 5 1      (36)*5  (36)*4  37 (36)*3  (37)*2  36 (37)*4  (37)*5
*
PART 140 OVERLAP
BOX      P139  -13.43025          -13.43025  0.0 26.8605 26.8605 230.0
BOX      M23  -13.5635  -13.5635   34.4          27.127 27.127 30.4
BOX      M23  -13.5635  -13.5635  165.2 27.127 27.127 30.4
BOX      M0   -13.5635  -13.5635   0.0 27.127 27.127 230.0
*
*
* Right centre
PART 141 ARRAY
5 5 1 36 (37)*4 (37)*4 38 (37)*3 (38)*2 (37)*2 (38)*3
37 (38)*4
*
PART 142 OVERLAP
BOX      P141  -13.43025          -13.43025  0.0 26.8605 26.8605 230.0
BOX      M23  -13.5635  -13.5635   34.4          27.127 27.127 30.4
BOX      M23  -13.5635  -13.5635  165.2 27.127 27.127 30.4
BOX      M0   -13.5635  -13.5635   0.0 27.127 27.127 230.0
*
*
* Outer right
PART 143 ARRAY
5 5 1      (38)*20 (38)*4 40
*
PART 144 OVERLAP
BOX      P143  -13.43025          -13.43025  0.0 26.8605 26.8605 230.0
BOX      M23  -13.5635  -13.5635   34.4          27.127 27.127 30.4
BOX      M23  -13.5635  -13.5635  165.2 27.127 27.127 30.4
BOX      M0   -13.5635  -13.5635   0.0 27.127 27.127 230.0
*
*
* Right side
PART 145 ARRAY
4 5 1      38 (40)*3 38 (40)*3 (40)*12
*
PART 146 OVERLAP

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BOX    P145  -10.7442 -13.43025  0.0 21.4884 26.8605 230.0
BOX    M23  -10.8508 -13.5635   34.4          21.7016 27.127  30.4
BOX    M23  -10.8508 -13.5635  165.2  21.7016 27.127  30.4
BOX    M0   -10.8508 -13.5635   0.0 21.7016 27.127  230.0
*
*
* combine these arrays to form the row 3 array
PART 147 ARRAY
9  1  1  130  132  134  136  138  140  142  144  146
*
*
*****
*                                     ROW 8
*****
* 7 arrays of elements
*
* left outer group
PART 148 ARRAY
5  5  1  (40)*2 (38)*3 (40)*3 (38)*2 (40)*4  38  (40)*10
*
PART 149 OVERLAP
BOX    P148  -13.43025          -13.43025  0.0 26.8605 26.8605 230.0
BOX    M23  -13.5635 -13.5635   34.4          27.127 27.127  30.4
BOX    M23  -13.5635 -13.5635  165.2  27.127 27.127  30.4
BOX    M0   -13.5635 -13.5635   0.0 27.127 27.127  230.0
*
*
* left second group
PART 150 ARRAY
5  5  1  (38)*20  40  (38)*4
*
PART 151 OVERLAP
BOX    P150  -13.43025          -13.43025  0.0 26.8605 26.8605 230.0
BOX    M23  -13.5635 -13.5635   34.4          27.127 27.127  30.4
BOX    M23  -13.5635 -13.5635  165.2  27.127 27.127  30.4
BOX    M0   -13.5635 -13.5635   0.0 27.127 27.127  230.0
*
*
* left centre group
PART 152 ARRAY
5  5  1  38  (37)*4  (38)*3  (37)*2  (38)*15
*
PART 153 OVERLAP
BOX    P152  -13.43025          -13.43025  0.0 26.8605 26.8605 230.0
BOX    M23  -13.5635 -13.5635   34.4          27.127 27.127  30.4
BOX    M23  -13.5635 -13.5635  165.2  27.127 27.127  30.4
BOX    M0   -13.5635 -13.5635   0.0 27.127 27.127  230.0
*
*
* Central group
PART 154 ARRAY
5  5  1  (37)*10  (38)*15
*
PART 155 OVERLAP
BOX    P154  -13.43025          -13.43025  0.0 26.8605 26.8605 230.0
BOX    M23  -13.5635 -13.5635   34.4          27.127 27.127  30.4
BOX    M23  -13.5635 -13.5635  165.2  27.127 27.127  30.4
BOX    M0   -13.5635 -13.5635   0.0 27.127 27.127  230.0
*
*
* right centre group
PART 156 ARRAY
5  5  1  (37)*5  (37)*2  (38)*3  (38)*15
*
PART 157 OVERLAP
BOX    P156  -13.43025          -13.43025  0.0 26.8605 26.8605 230.0
BOX    M23  -13.5635 -13.5635   34.4          27.127 27.127  30.4
BOX    M23  -13.5635 -13.5635  165.2  27.127 27.127  30.4
BOX    M0   -13.5635 -13.5635   0.0 27.127 27.127  230.0
*
*
* next right group
PART 158 ARRAY
5  5  1  (38)*20  (38)*4  40
*
PART 159 OVERLAP

```

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LIQUID METAL FAST REACTOR - LMFR
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```

BOX    P158  -13.43025      -13.43025  0.0 26.8605 26.8605 230.0
BOX    M23   -13.5635     -13.5635   34.4      27.127  27.127  30.4
BOX    M23   -13.5635     -13.5635  165.2   27.127  27.127  30.4
BOX    M0    -13.5635     -13.5635   0.0 27.127  27.127  230.0
*
*
*   right outer group
PART 160 ARRAY
5  5  1  (38)*3  (40)*2  (38)*2  (40)*3  38  (40)*4  (40)*10
*
PART 161 OVERLAP
BOX    P160  -13.43025      -13.43025  0.0 26.8605 26.8605 230.0
BOX    M23   -13.5635     -13.5635   34.4      27.127  27.127  30.4
BOX    M23   -13.5635     -13.5635  165.2   27.127  27.127  30.4
BOX    M0    -13.5635     -13.5635   0.0 27.127  27.127  230.0
*
*
*   combine these 7 arrays to form the row 2 array
PART 162 ARRAY
7  1  1  149  151  153  155  157  159  161
*
*
*****
*                                     ROW 9
*****
*
*   Row 9, the top set of groups of size 3x4 and 5x4 (5 along the x axis)
*   5 arrays
*
*   Left side
PART 163 ARRAY
3  4  1  40 (38)*2  (40)*9
*
PART 164 OVERLAP
BOX    P163  -8.05815  -10.7442  0.0 16.1163 21.4884 230.0
BOX    M23   -8.1381  -10.8508  34.4 16.2762 21.7016 30.4
BOX    M23   -8.1381  -10.8508  165.2 16.2762 21.7016 30.4
BOX    M0    -8.1381  -10.8508   0.0 16.2762 21.7016 230.0
*
*
*   Left centre
PART 165 ARRAY
5  4  1  (38)*10  (40)*4  38  (40)*5
*
PART 166 OVERLAP
BOX    P165  -13.43025      -10.7442  0.0 26.8605 21.4884 230.0
BOX    M23   -13.5635     -10.8508  34.4 27.127  21.7016 30.4
BOX    M23   -13.5635     -10.8508  165.2 27.127  21.7016 30.4
BOX    M0    -13.5635     -10.8508   0.0 27.127  21.7016 230.0
*
*
*   Centre
PART 167 ARRAY
5  4  1  (38)*15  (40)*5
*
PART 168 OVERLAP
BOX    P167  -13.43025      -10.7442  0.0 26.8605 21.4884 230.0
BOX    M23   -13.5635     -10.8508  34.4 27.127  21.7016 30.4
BOX    M23   -13.5635     -10.8508  165.2 27.127  21.7016 30.4
BOX    M0    -13.5635     -10.8508   0.0 27.127  21.7016 230.0
*
*
*   Right centre
PART 169 ARRAY
5  4  1  (38)*10  38  (40)*4  (40)*5
*
PART 170 OVERLAP
BOX    P169  -13.43025      -10.7442  0.0 26.8605 21.4884 230.0
BOX    M23   -13.5635     -10.8508  34.4 27.127  21.7016 30.4
BOX    M23   -13.5635     -10.8508  165.2 27.127  21.7016 30.4
BOX    M0    -13.5635     -10.8508   0.0 27.127  21.7016 230.0
*
*
*   Right side
PART 171 ARRAY
3  4  1  (38)*2  40  (40)*9

```

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```

*
PART 172 OVERLAP
BOX   P171  -8.05815 -10.7442  0.0  16.1163 21.4884 230.0
BOX   M23   -8.1381  -10.8508  34.4  16.2762 21.7016 30.4
BOX   M23   -8.1381  -10.8508  165.2      16.2762 21.7016 30.4
BOX   M0    -8.1381  -10.8508  0.0  16.2762 21.7016 230.0
*
*
* combine these arrays to form the row 9 array
PART 173 ARRAY
5  1  1  164 166 168 170 172
*
*
*****
*
*       Cluster of superlattice groups in a circle of shield material
*
*****
* Cluster of superlattice groups in a circle of shield material
PART 174 CLUSTER
BOX P173  -56.9667  94.9445  -115.0  113.9334  21.7016 230.0
BOX P162  -94.9445  67.8175  -115.0  189.889   27.127 230.0
BOX P147  -116.6461 40.6905  -115.0  233.2922  27.127 230.0
BOX P128  -116.6461 13.5635  -115.0  233.2922  27.127 230.0
BOX P115  -116.6461 -13.5635  -115.0  233.2922  27.127 230.0
BOX P102  -116.6461 -40.6905  -115.0  233.2922  27.127 230.0
BOX P89   -116.6461 -67.8175  -115.0  233.2922  27.127 230.0
BOX P70   -94.9445  -94.9445  -115.0  189.889   27.127 230.0
BOX P55   -56.9667  -116.6461 -115.0  113.9334  21.7016 230.0
ZROD M24   0.0      0.0      -116.0    135.0    232.0
*
*****
* Albedo for free boundaries at side and top and reflection at bottom
*
ALBEDO 0.0  0.0  0.0
END
*
*****
*
BEGIN CONTROL DATA
STAGES -50  2400  5000  STDV 0.0002
END
*
*****
*
BEGIN SOURCE GEOMETRY
ZONEMAT
ALL / MATERIAL 1
END
*
*****
*
BEGIN ACTION TALLIES
NONORM
NO ACTION TALLIES
NOPRINT FLUXES SCEDST BNDXNG REGACT NPARAM SYSCAT
SGUIDE HOLACT
PRINT MATACT
END
*
*****

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

A2. MCNP Monte Carlo Models for MZA and MZB

The MCNP JEFF-3.1 Model of MZA

```
Zebra Assembly MZA detailed model. Superlattice & Void gaps.JEFF-3.1
c
c The experimental value of k-effective to be used with this model is
c                               1.0097 +/- 0.0016
c
c See www.zebra.webnik.org for details.
c
c ----- Elements of the assembly -----
c
c --- Core Element C11A
c
c Lower padding
111      16 3.279692E-02 -8 21 -22 23 -24 u=1 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
112      0  8 -9 21 -22 23 -24 fill=31 (0 0 30.0) u=1 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
121      0  9 -41 21 -22 23 -24 fill=21 (0 0 63.0048) u=1 imp:n=1
c
122      0 41 -42 21 -22 23 -24 fill=21 (0 0 71.7414) u=1 imp:n=1
c
123      0 42 -43 21 -22 23 -24 fill=21 (0 0 80.478) u=1 imp:n=1
c
124      0 43 -10 21 -22 23 -24 fill=21 (0 0 89.2146) u=1 imp:n=1
c
c
c
c The 12 core cells
c
151      0 10 -44 21 -22 23 -24 fill=11 (0 0 97.9512) u=1 imp:n=1
c
152      0 44 -45 21 -22 23 -24 fill=11 (0 0 105.447) u=1 imp:n=1
c
153      0 45 -46 21 -22 23 -24 fill=11 (0 0 112.9428) u=1 imp:n=1
c
154      0 46 -47 21 -22 23 -24 fill=11 (0 0 120.4386) u=1 imp:n=1
c
155      0 47 -48 21 -22 23 -24 fill=11 (0 0 127.9344) u=1 imp:n=1
c
156      0 48 -49 21 -22 23 -24 fill=11 (0 0 135.4302) u=1 imp:n=1
c
157      0 49 -50 21 -22 23 -24 fill=11 (0 0 142.926) u=1 imp:n=1
c
158      0 50 -51 21 -22 23 -24 fill=11 (0 0 150.4218) u=1 imp:n=1
c
159      0 51 -52 21 -22 23 -24 fill=11 (0 0 157.9176) u=1 imp:n=1
c
160      0 52 -53 21 -22 23 -24 fill=11 (0 0 165.4134) u=1 imp:n=1
c
161      0 53 -54 21 -22 23 -24 fill=11 (0 0 172.9092) u=1 imp:n=1
c
162      0 54 -11 21 -22 23 -24 fill=11 (0 0 180.405) u=1 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
181      0 11 -56 21 -22 23 -24 fill=21 (0 0 187.9008) u=1 imp:n=1
c
182      0 56 -57 21 -22 23 -24 fill=21 (0 0 196.6374 ) u=1 imp:n=1
c
183      0 57 -58 21 -22 23 -24 fill=21 (0 0 205.374) u=1 imp:n=1
c
184      0 58 -12 21 -22 23 -24 fill=21 (0 0 214.1106) u=1 imp:n=1
c
c Upper Plenum
c
```


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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

186      0  12 -13 21 -22 23 -24 fill=32 (0 0 222.8472) u=1 imp:n=1
c
c Upper padding
c
188      16 3.279692E-02 13 -16 21 -22 23 -24 u=1 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
c gap inside wrapper
191      0  62 -63 64 -65 (-21:22:-23:24) u=1 imp:n=1
c wrapper
192      17 8.5677E-02 66 -67 68 -69 (-62:63:-64:65) u=1 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
193      0  1 -2 3 -4 (-66:67:-68:69) u=1 imp:n=1
c
c End of Core Element C11A
c
c
c --- Core Element C11B
c
c Lower padding
211      16 3.279692E-02 -8 21 -22 23 -24 u=2 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
212      0  8 -9 21 -22 23 -24 fill=31 (0 0 30.0) u=2 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
221      0  9 -41 21 -22 23 -24 fill=22 (0 0 63.0048) u=2 imp:n=1
c
222      0  41 -42 21 -22 23 -24 fill=22 (0 0 71.7414) u=2 imp:n=1
c
223      0  42 -43 21 -22 23 -24 fill=22 (0 0 80.478) u=2 imp:n=1
c
224      0  43 -10 21 -22 23 -24 fill=22 (0 0 89.2146) u=2 imp:n=1
c
c
c
c The 12 core cells
c
251      0  10 -44 21 -22 23 -24 fill=12 (0 0 97.9512) u=2 imp:n=1
c
252      0  44 -45 21 -22 23 -24 fill=12 (0 0 105.447) u=2 imp:n=1
c
253      0  45 -46 21 -22 23 -24 fill=12 (0 0 112.9428) u=2 imp:n=1
c
254      0  46 -47 21 -22 23 -24 fill=12 (0 0 120.4386) u=2 imp:n=1
c
255      0  47 -48 21 -22 23 -24 fill=12 (0 0 127.9344) u=2 imp:n=1
c
256      0  48 -49 21 -22 23 -24 fill=12 (0 0 135.4302) u=2 imp:n=1
c
257      0  49 -50 21 -22 23 -24 fill=12 (0 0 142.926) u=2 imp:n=1
c
258      0  50 -51 21 -22 23 -24 fill=12 (0 0 150.4218) u=2 imp:n=1
c
259      0  51 -52 21 -22 23 -24 fill=12 (0 0 157.9176) u=2 imp:n=1
c
260      0  52 -53 21 -22 23 -24 fill=12 (0 0 165.4134) u=2 imp:n=1
c
261      0  53 -54 21 -22 23 -24 fill=12 (0 0 172.9092) u=2 imp:n=1
c
262      0  54 -11 21 -22 23 -24 fill=12 (0 0 180.405) u=2 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
281      0  11 -56 21 -22 23 -24 fill=22 (0 0 187.9008) u=2 imp:n=1
c
282      0  56 -57 21 -22 23 -24 fill=22 (0 0 196.6374 ) u=2 imp:n=1
c
283      0  57 -58 21 -22 23 -24 fill=22 (0 0 205.374) u=2 imp:n=1
c
284      0  58 -12 21 -22 23 -24 fill=22 (0 0 214.1106) u=2 imp:n=1

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Upper Plenum
c
286    0 12 -13 21 -22 23 -24 fill=32 (0 0 222.8472) u=2 imp:n=1
c
c Upper padding
c
288    16 3.279692E-02 13 -16 21 -22 23 -24 u=2 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
c gap inside wrapper
291    0 62 -63 64 -65 (-21:22:-23:24) u=2 imp:n=1
c wrapper
292    17 8.5677E-02 66 -67 68 -69 (-62:63:-64:65) u=2 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
293    0 1 -2 3 -4 (-66:67:-68:69) u=2 imp:n=1
c
c End of Core Element C11B
c
c
c --- Core Element C11C
c
c Lower padding
311    16 3.279692E-02 -8 21 -22 23 -24 u=3 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
312    0 8 -9 21 -22 23 -24 fill=31 (0 0 30.0) u=3 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
321    0 9 -41 21 -22 23 -24 fill=22 (0 0 63.0048) u=3 imp:n=1
c
322    0 41 -42 21 -22 23 -24 fill=22 (0 0 71.7414) u=3 imp:n=1
c
323    0 42 -43 21 -22 23 -24 fill=22 (0 0 80.478) u=3 imp:n=1
c
324    0 43 -10 21 -22 23 -24 fill=22 (0 0 89.2146) u=3 imp:n=1
c
c
c
c The 12 core cells
c
351    0 10 -44 21 -22 23 -24 fill=13 (0 0 97.9512) u=3 imp:n=1
c
352    0 44 -45 21 -22 23 -24 fill=13 (0 0 105.447) u=3 imp:n=1
c
353    0 45 -46 21 -22 23 -24 fill=13 (0 0 112.9428) u=3 imp:n=1
c
354    0 46 -47 21 -22 23 -24 fill=13 (0 0 120.4386) u=3 imp:n=1
c
355    0 47 -48 21 -22 23 -24 fill=13 (0 0 127.9344) u=3 imp:n=1
c
356    0 48 -49 21 -22 23 -24 fill=13 (0 0 135.4302) u=3 imp:n=1
c
357    0 49 -50 21 -22 23 -24 fill=13 (0 0 142.926) u=3 imp:n=1
c
358    0 50 -51 21 -22 23 -24 fill=13 (0 0 150.4218) u=3 imp:n=1
c
359    0 51 -52 21 -22 23 -24 fill=13 (0 0 157.9176) u=3 imp:n=1
c
360    0 52 -53 21 -22 23 -24 fill=13 (0 0 165.4134) u=3 imp:n=1
c
361    0 53 -54 21 -22 23 -24 fill=13 (0 0 172.9092) u=3 imp:n=1
c
362    0 54 -11 21 -22 23 -24 fill=13 (0 0 180.405) u=3 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
381    0 11 -56 21 -22 23 -24 fill=22 (0 0 187.9008) u=3 imp:n=1
c
382    0 56 -57 21 -22 23 -24 fill=22 (0 0 196.6374 ) u=3 imp:n=1
c

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

383      0  57 -58 21 -22 23 -24 fill=22 (0 0 205.374) u=3 imp:n=1
c
384      0  58 -12 21 -22 23 -24 fill=22 (0 0 214.1106) u=3 imp:n=1
c
c  Upper Plenum
c
386      0  12 -13 21 -22 23 -24 fill=32 (0 0 222.8472) u=3 imp:n=1
c
c  Upper padding
c
388      16 3.279692E-02 13 -16 21 -22 23 -24 u=3 imp:n=1 TMP=2.5301E-08
c
c
c  Wrapper region
c  gap inside wrapper
391      0  62 -63 64 -65 (-21:22:-23:24) u=3 imp:n=1
c  wrapper
392      17 8.5677E-02 66 -67 68 -69 (-62:63:-64:65) u=3 imp:n=1 &
      TMP=2.5301E-08
c  gap outside wrapper
393      0  1 -2 3 -4 (-66:67:-68:69) u=3 imp:n=1
c
c  End of Core Element C11C
c
c
c  --- Core Element C11D
c
c  Lower padding
411      16 3.279692E-02 -8 21 -22 23 -24 u=5 imp:n=1 TMP=2.5301E-08
c
c  Lower Plenum
c
412      0  8 -9 21 -22 23 -24 fill=31 (0 0 30.0) u=5 imp:n=1
c
c  Lower Axial Blanket comprising 4 cells
c
421      0  9 -41 21 -22 23 -24 fill=22 (0 0 63.0048) u=5 imp:n=1
c
422      0  41 -42 21 -22 23 -24 fill=22 (0 0 71.7414) u=5 imp:n=1
c
423      0  42 -43 21 -22 23 -24 fill=22 (0 0 80.478) u=5 imp:n=1
c
424      0  43 -10 21 -22 23 -24 fill=22 (0 0 89.2146) u=5 imp:n=1
c
c
c
c  The 12 core cells
c
451      0  10 -44 21 -22 23 -24 fill=15 (0 0 97.9512) u=5 imp:n=1
c
452      0  44 -45 21 -22 23 -24 fill=15 (0 0 105.447) u=5 imp:n=1
c
453      0  45 -46 21 -22 23 -24 fill=15 (0 0 112.9428) u=5 imp:n=1
c
454      0  46 -47 21 -22 23 -24 fill=15 (0 0 120.4386) u=5 imp:n=1
c
455      0  47 -48 21 -22 23 -24 fill=15 (0 0 127.9344) u=5 imp:n=1
c
456      0  48 -49 21 -22 23 -24 fill=15 (0 0 135.4302) u=5 imp:n=1
c
457      0  49 -50 21 -22 23 -24 fill=15 (0 0 142.926) u=5 imp:n=1
c
458      0  50 -51 21 -22 23 -24 fill=15 (0 0 150.4218) u=5 imp:n=1
c
459      0  51 -52 21 -22 23 -24 fill=15 (0 0 157.9176) u=5 imp:n=1
c
460      0  52 -53 21 -22 23 -24 fill=15 (0 0 165.4134) u=5 imp:n=1
c
461      0  53 -54 21 -22 23 -24 fill=15 (0 0 172.9092) u=5 imp:n=1
c
462      0  54 -11 21 -22 23 -24 fill=15 (0 0 180.405) u=5 imp:n=1
c
c  Upper Axial Blanket. 4 Cells
c
c
481      0  11 -56 21 -22 23 -24 fill=22 (0 0 187.9008) u=5 imp:n=1

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
482    0  56 -57 21 -22 23 -24 fill=22 (0 0 196.6374 ) u=5 imp:n=1
c
483    0  57 -58 21 -22 23 -24 fill=22 (0 0 205.374) u=5 imp:n=1
c
484    0  58 -12 21 -22 23 -24 fill=22 (0 0 214.1106) u=5 imp:n=1
c
c Upper Plenum
c
486    0  12 -13 21 -22 23 -24 fill=32 (0 0 222.8472) u=5 imp:n=1
c
c Upper padding
c
488    16 3.279692E-02 13 -16 21 -22 23 -24 u=5 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
c gap inside wrapper
491    0 62 -63 64 -65 (-21:22:-23:24) u=5 imp:n=1
c wrapper
492    17 8.5677E-02 66 -67 68 -69 (-62:63:-64:65) u=5 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
493    0  1 -2 3 -4 (-66:67:-68:69) u=5 imp:n=1
c
c
c End of Core Element C11D
c
c --- Radial Blanket Elements
c
c Lower padding
1211   like 111 but u=6 imp:n=1 TMP=2.5301E-08
c Lower Plenum
1212   like 112 but u=6 imp:n=1 TMP=2.5301E-08
c Radial blanket
c Lower Radial Blanket Section comprising 3 cells
c
1221    0  9 -803 21 -22 23 -24 fill=25 (0 0 63.0048) u=6 imp:n=1
c
1222    0 803 -804 21 -22 23 -24 fill=25 (0 0 73.155) u=6 imp:n=1
c
1223    0 804 -805 21 -22 23 -24 fill=25 (0 0 83.3052) u=6 imp:n=1
c
c
c The 20 Radial blanket Central Section Cells
c
1231    0 805 -806 21 -22 23 -24 fill=24 (0 0 93.4554) u=6 imp:n=1
c
1232    0 806 -807 21 -22 23 -24 fill=24 (0 0 98.485) u=6 imp:n=1
c
1233    0 807 -808 21 -22 23 -24 fill=24 (0 0 103.5146) u=6 imp:n=1
c
1234    0 808 -809 21 -22 23 -24 fill=24 (0 0 108.5442) u=6 imp:n=1
c
1235    0 809 -810 21 -22 23 -24 fill=24 (0 0 113.5738) u=6 imp:n=1
c
1236    0 810 -811 21 -22 23 -24 fill=24 (0 0 118.6034) u=6 imp:n=1
c
1237    0 811 -812 21 -22 23 -24 fill=24 (0 0 123.633) u=6 imp:n=1
c
1238    0 812 -813 21 -22 23 -24 fill=24 (0 0 128.6626) u=6 imp:n=1
c
1239    0 813 -814 21 -22 23 -24 fill=24 (0 0 133.6922) u=6 imp:n=1
c
1240    0 814 -815 21 -22 23 -24 fill=24 (0 0 138.7218) u=6 imp:n=1
c
1241    0 815 -816 21 -22 23 -24 fill=24 (0 0 143.7514) u=6 imp:n=1
c
1242    0 816 -817 21 -22 23 -24 fill=24 (0 0 148.781) u=6 imp:n=1
c
1243    0 817 -818 21 -22 23 -24 fill=24 (0 0 153.8106) u=6 imp:n=1
c
1244    0 818 -819 21 -22 23 -24 fill=24 (0 0 158.8402) u=6 imp:n=1
c
1245    0 819 -820 21 -22 23 -24 fill=24 (0 0 163.8698) u=6 imp:n=1
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

1246    0  820 -821 21 -22 23 -24 fill=24 (0 0 168.8994) u=6 imp:n=1
c
1247    0  821 -822 21 -22 23 -24 fill=24 (0 0 173.929) u=6 imp:n=1
c
1248    0  822 -823 21 -22 23 -24 fill=24 (0 0 178.9586) u=6 imp:n=1
c
1249    0  823 -824 21 -22 23 -24 fill=24 (0 0 183.9882) u=6 imp:n=1
c
1250    0  824 -825 21 -22 23 -24 fill=24 (0 0 189.0178) u=6 imp:n=1
c
c   Upper Radial Blanket. 4 Cells
c
1261    0  825 -826 21 -22 23 -24 fill=25 (0 0 194.0474) u=6 imp:n=1
c
1262    0  826 -827 21 -22 23 -24 fill=25 (0 0 204.1976) u=6 imp:n=1
c
1263    0  827 -828 21 -22 23 -24 fill=25 (0 0 214.3478) u=6 imp:n=1
c
c   Upper Plenum
1271    0  828 -829 21 -22 23 -24 fill=32 (0 0 224.498) u=6 imp:n=1
c
c   Upper padding
1272    16 3.279692E-02 829 -16 21 -22 23 -24 u=6 imp:n=1 TMP=2.5301E-08
c   Wrapper region
1280    like 191 but u=6 imp:n=1
1281    like 192 but u=6 imp:n=1
1282    like 193 but u=6 imp:n=1
c
c
c   --- Radial shield
c
1326    12 8.32720E-02 28 -29 30 -31 u=7 imp:n=1 TMP=2.5301E-08
c
1327    13 8.32720E-05 1 -2 3 -4 (-28:29:-30:31) u=7 imp:n=1
      TMP=2.5301E-08
c
1400    13 8.32720E-05 1 -2 3 -4 u=9 imp:n=1 TMP=2.5301E-08
c
c   --- Assembly
c
1419    0   89 -90 91 -92 u=10 lat=1
      fill=-3:3 -3:3 0:0
      201 131 132 133 134 135 201
      137 114 111 102 111 115 138
      167 111 103 129 104 111 168
      157 105 126 101 141 106 158
      147 111 107 142 108 111 148
      127 112 111 109 111 113 128
      201 121 122 123 124 125 201
      imp:n=1
c
c
c   --- Fuel Region
c
1429    0  7 -16 -17 fill=10 imp:n=1
c   --- Universe
1430    0 (-7:16:17) imp:n=0
c
c   ----- CELL CARDS -----
c
c   MZA Core Cell A.
c
c   Na plate
c   Na plate core
2101    5 2.3126E-02 202 -203 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
c   Na plate can
2102    6 7.865043E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=11 imp:n=1 TMP=2.5301E-08
c
c   UO2 plate
c   UO2 core
2103    3 6.867137E-02 205 -206 105 -106 107 -108 u=11 imp:n=1 TMP=2.5301E-08
c   UO2 plate can
2104    4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=11 imp:n=1 TMP=2.5301E-08
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c Na plate
c Na plate core
2105 5 2.3126E-02 208 -209 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
C Na plate can
2106 6 7.865043E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=11 imp:n=1 TMP=2.5301E-08
c
c Pu plate
C Plate core
2107 1 4.023746E-02 101 -102 103 -104 211 -212 u=11 imp:n=1 TMP=2.5301E-08
C Pu canning
2108 2 6.6033E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=11 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2109 7 8.607216E-02 213 -214 21 -22 23 -24 u=11 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2110 3 6.867137E-02 215 -216 105 -106 107 -108 u=11 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2111 4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=11 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2112 5 2.3126E-02 218 -219 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
C Na plate can
2113 6 7.865043E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=11 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2114 5 2.3126E-02 221 -222 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
C Na plate can
2115 6 7.865043E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=11 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2116 3 6.867137E-02 224 -225 105 -106 107 -108 u=11 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2117 4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=11 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2118 10 8.1484E-02 226 -227 21 -22 23 -24 u=11 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate
C Plate core
2119 1 4.023746E-02 228 -229 101 -102 103 -104 u=11 imp:n=1 TMP=2.5301E-08
C Pu canning
2120 2 6.6033E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=11 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2121 5 2.3126E-02 231 -232 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
C Na plate can
2122 6 7.865043E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=11 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2123 3 6.867137E-02 234 -235 105 -106 107 -108 u=11 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2124 4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=11 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2125 5 2.3126E-02 237 -238 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
C Na plate can
2126 6 7.865043E-02 236 -239 21 -22 23 -24 &

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

(-109:110:-111:112:-237:238) u=11  imp:n=1  TMP=2.5301E-08
c
c End of MZA Core Cell A
c
c
c MZA Core Cell B.
c
c Na plate
c Na plate core
2201  45 2.31908E-02 202 -203 109 -110 111 -112 u=12  imp:n=1  TMP=2.5301E-08
c Na plate can
2202  46 7.87241E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=12  imp:n=1  TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2203  3 6.867137E-02 205 -206 105 -106 107 -108 u=12  imp:n=1  TMP=2.5301E-08
c UO2 plate can
2204  4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=12  imp:n=1  TMP=2.5301E-08
c
c Na plate
c Na plate core
2205  45 2.31908E-02 208 -209 109 -110 111 -112 u=12  imp:n=1  TMP=2.5301E-08
c Na plate can
2206  46 7.87241E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=12  imp:n=1  TMP=2.5301E-08
c
c Pu plate
c Plate core
2207  31 4.04903E-02 101 -102 103 -104 211 -212 u=12  imp:n=1  TMP=2.5301E-08
c Pu canning
2208  32 6.74722E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=12  imp:n=1  TMP=2.5301E-08
c
c Steel plate
2209  7 8.607216E-02 213 -214 21 -22 23 -24 u=12  imp:n=1  TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2210  3 6.867137E-02 215 -216 105 -106 107 -108 u=12  imp:n=1  TMP=2.5301E-08
c UO2 plate can
2211  4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=12  imp:n=1  TMP=2.5301E-08
c
c Na plate
c Na plate core
2212  45 2.31908E-02 218 -219 109 -110 111 -112 u=12  imp:n=1  TMP=2.5301E-08
c Na plate can
2213  46 7.87241E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=12  imp:n=1  TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2214  45 2.31908E-02 221 -222 109 -110 111 -112 u=12  imp:n=1  TMP=2.5301E-08
c Na plate can
2215  46 7.87241E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=12  imp:n=1  TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2216  3 6.867137E-02 224 -225 105 -106 107 -108 u=12  imp:n=1  TMP=2.5301E-08
c UO2 plate can
2217  4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=12  imp:n=1  TMP=2.5301E-08
c
c Graphite plate GI8
2218  10 8.1484E-02 226 -227 21 -22 23 -24 u=12  imp:n=1  TMP=2.5301E-08
c
c
c Pu plate
c Plate core
2219  31 4.04903E-02 228 -229 101 -102 103 -104 u=12  imp:n=1  TMP=2.5301E-08
c Pu canning
2220  32 6.74722E-02 227 -230 21 -22 23 -24 &

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

(-101:102:-103:104:-228:229) u=12  imp:n=1  TMP=2.5301E-08
c
c Na plate
c Na plate core
2221  45 2.31908E-02 231 -232 109 -110 111 -112 u=12  imp:n=1  TMP=2.5301E-08
C Na plate can
2222  46 7.87241E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=12  imp:n=1  TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2223  3 6.867137E-02 234 -235 105 -106 107 -108 u=12  imp:n=1  TMP=2.5301E-08
c UO2 plate can
2224  4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=12  imp:n=1  TMP=2.5301E-08
c
c Na plate
c Na plate core
2225  45 2.31908E-02 237 -238 109 -110 111 -112 u=12  imp:n=1  TMP=2.5301E-08
C Na plate can
2226  46 7.87241E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=12  imp:n=1  TMP=2.5301E-08
c
c End of MZA Core Cell B
c
c
c MZA Core Cell C.
c
c Na plate
c Na plate core
2301  45 2.31908E-02 202 -203 109 -110 111 -112 u=13  imp:n=1  TMP=2.5301E-08
C Na plate can
2302  46 7.87241E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=13  imp:n=1  TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2303  3 6.867137E-02 205 -206 105 -106 107 -108 u=13  imp:n=1  TMP=2.5301E-08
c UO2 plate can
2304  4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=13  imp:n=1  TMP=2.5301E-08
c
c Na plate
c Na plate core
2305  45 2.31908E-02 208 -209 109 -110 111 -112 u=13  imp:n=1  TMP=2.5301E-08
C Na plate can
2306  46 7.87241E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=13  imp:n=1  TMP=2.5301E-08
c
c Pu plate
C Plate core
2307  33 3.99151E-02 101 -102 103 -104 211 -212 u=13  imp:n=1  TMP=2.5301E-08
C Pu canning
2308  34 6.72170E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=13  imp:n=1  TMP=2.5301E-08
c
c Steel plate
2309  7 8.607216E-02 213 -214 21 -22 23 -24 u=13  imp:n=1  TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2310  3 6.867137E-02 215 -216 105 -106 107 -108 u=13  imp:n=1  TMP=2.5301E-08
c UO2 plate can
2311  4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=13  imp:n=1  TMP=2.5301E-08
c
c Na plate
c Na plate core
2312  45 2.31908E-02 218 -219 109 -110 111 -112 u=13  imp:n=1  TMP=2.5301E-08
C Na plate can
2313  46 7.87241E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=13  imp:n=1  TMP=2.5301E-08
c
c
c Na plate
c Na plate core

```


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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

2314 45 2.31908E-02 221 -222 109 -110 111 -112 u=13 imp:n=1 TMP=2.5301E-08
C Na plate can
2315 46 7.87241E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=13 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2316 3 6.867137E-02 224 -225 105 -106 107 -108 u=13 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2317 4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=13 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2318 10 8.1484E-02 226 -227 21 -22 23 -24 u=13 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate
C Plate core
2319 33 3.99151E-02 228 -229 101 -102 103 -104 u=13 imp:n=1 TMP=2.5301E-08
C Pu canning
2320 34 6.72170E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=13 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2321 45 2.31908E-02 231 -232 109 -110 111 -112 u=13 imp:n=1 TMP=2.5301E-08
C Na plate can
2322 46 7.87241E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=13 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2323 3 6.867137E-02 234 -235 105 -106 107 -108 u=13 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2324 4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=13 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2325 45 2.31908E-02 237 -238 109 -110 111 -112 u=13 imp:n=1 TMP=2.5301E-08
C Na plate can
2326 46 7.87241E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=13 imp:n=1 TMP=2.5301E-08
c
c End of MZA Core Cell C
c
c
c MZA Core Cell D.
c
c Na plate
c Na plate core
2401 45 2.31908E-02 202 -203 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
C Na plate can
2402 46 7.87241E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=15 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2403 3 6.867137E-02 205 -206 105 -106 107 -108 u=15 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2404 4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=15 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2405 45 2.31908E-02 208 -209 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
C Na plate can
2406 46 7.87241E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=15 imp:n=1 TMP=2.5301E-08
c
c Pu plate
C Plate core
2407 35 4.01503E-02 101 -102 103 -104 211 -212 u=15 imp:n=1 TMP=2.5301E-08
C Pu canning
2408 36 6.71396E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=15 imp:n=1 TMP=2.5301E-08

```

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CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Steel plate
2409 7 8.607216E-02 213 -214 21 -22 23 -24 u=15 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2410 3 6.867137E-02 215 -216 105 -106 107 -108 u=15 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2411 4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=15 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2412 45 2.31908E-02 218 -219 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
c Na plate can
2413 46 7.87241E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=15 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2414 45 2.31908E-02 221 -222 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
c Na plate can
2415 46 7.87241E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=15 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2416 3 6.867137E-02 224 -225 105 -106 107 -108 u=15 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2417 4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=15 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2418 10 8.1484E-02 226 -227 21 -22 23 -24 u=15 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate
c Plate core
2419 35 4.01503E-02 228 -229 101 -102 103 -104 u=15 imp:n=1 TMP=2.5301E-08
c Pu canning
2420 36 6.71396E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=15 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2421 45 2.31908E-02 231 -232 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
c Na plate can
2422 46 7.87241E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=15 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2423 3 6.867137E-02 234 -235 105 -106 107 -108 u=15 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2424 4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=15 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2425 45 2.31908E-02 237 -238 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
c Na plate can
2426 46 7.87241E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=15 imp:n=1 TMP=2.5301E-08
c
c End of MZA Core Cell D
c
c Axial blanket cell B11
c
c Na plate
c Na plate core
2601 5 2.3126E-02 402 -403 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2602 6 7.865043E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=21 imp:n=1 TMP=2.5301E-08
c

```

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LIQUID METAL FAST REACTOR - LMFR
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```

c U8 plate
2603 8 4.7208E-02 404 -405 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2604 10 8.1484E-02 405 -406 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2605 5 2.3126E-02 407 -408 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2606 6 7.865043E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=21 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2607 7 8.607216E-02 409 -410 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2608 8 4.7208E-02 410 -411 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2609 5 2.3126E-02 412 -413 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2610 6 7.865043E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=21 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2611 10 8.1484E-02 414 -415 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2612 5 2.3126E-02 416 -417 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2613 6 7.865043E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=21 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2614 7 8.607216E-02 418 -419 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2615 8 4.7208E-02 419 -420 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2616 5 2.3126E-02 421 -422 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2617 6 7.865043E-02 420 -423 21 -22 23 -24 &
      (-109:110:-111:112:-421:422) u=21 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2618 10 8.1484E-02 423 -424 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2619 5 2.3126E-02 425 -426 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2620 6 7.865043E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=21 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2621 8 4.7208E-02 427 -428 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2622 7 8.607216E-02 428 -429 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2623 5 2.3126E-02 430 -431 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2624 6 7.865043E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=21 imp:n=1 TMP=2.5301E-08
c
c

```

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LIQUID METAL FAST REACTOR - LMFR
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```

c U8 plate
2625 8 4.7208E-02 432 -433 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8
2626 10 8.1484E-02 433 -434 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2627 5 2.3126E-02 435 -436 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2628 6 7.865043E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=21 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B11
c
c
c Axial blanket cell B11-A
c
c Na plate
c Na plate core
2701 45 2.31908E-02 402 -403 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
c Na plate can
2702 46 7.87241E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=22 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2703 8 4.7208E-02 404 -405 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2704 10 8.1484E-02 405 -406 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2705 45 2.31908E-02 407 -408 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
c Na plate can
2706 46 7.87241E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=22 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2707 7 8.607216E-02 409 -410 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2708 8 4.7208E-02 410 -411 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2709 45 2.31908E-02 412 -413 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
c Na plate can
2710 46 7.87241E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=22 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2711 10 8.1484E-02 414 -415 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2712 45 2.31908E-02 416 -417 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
c Na plate can
2713 46 7.87241E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=22 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2714 7 8.607216E-02 418 -419 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2715 8 4.7208E-02 419 -420 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2716 45 2.31908E-02 421 -422 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
c Na plate can
2717 46 7.87241E-02 420 -423 21 -22 23 -24 &
      (-109:110:-111:112:-421:422) u=22 imp:n=1 TMP=2.5301E-08

```

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LIQUID METAL FAST REACTOR - LMFR
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```
c
c Graphite plate GI8
2718 10 8.1484E-02 423 -424 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2719 45 2.31908E-02 425 -426 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
c Na plate can
2720 46 7.87241E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=22 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2721 8 4.7208E-02 427 -428 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2722 7 8.607216E-02 428 -429 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2723 45 2.31908E-02 430 -431 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
c Na plate can
2724 46 7.87241E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=22 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2725 8 4.7208E-02 432 -433 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8
2726 10 8.1484E-02 433 -434 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2727 45 2.31908E-02 435 -436 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
c Na plate can
2728 46 7.87241E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=22 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B11-A
c
c Radial Blanket Central Range
c
c Graphite plate GII8
2801 11 8.5125E-02 501 -502 21 -22 23 -24 u=24 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2802 5 2.3126E-02 503 -504 109 -110 111 -112 u=24 imp:n=1 TMP=2.5301E-08
c Na plate can
2803 6 7.865043E-02 502 -505 21 -22 23 -24 &
      (-109:110:-111:112:-503:504) u=24 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2804 11 8.5125E-02 505 -506 21 -22 23 -24 u=24 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2805 7 8.607216E-02 506 -507 21 -22 23 -24 u=24 imp:n=1 TMP=2.5301E-08
c
c U2 plate
2806 9 4.7925E-02 507 -508 21 -22 23 -24 u=24 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2807 11 8.5125E-02 508 -509 21 -22 23 -24 u=24 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2808 5 2.3126E-02 510 -511 109 -110 111 -112 u=24 imp:n=1 TMP=2.5301E-08
c Na plate can
2809 6 7.865043E-02 509 -512 21 -22 23 -24 &
      (-109:110:-111:112:-510:511) u=24 imp:n=1 TMP=2.5301E-08
c
c MST8 plate
c
2810 27 8.4980E-02 512 -513 21 -22 23 -24 u=24 imp:n=1 TMP=2.5301E-08
```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
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```

c
c Graphite plate GII8
2811  11 8.5125E-02 513 -514 21 -22 23 -24 u=24  imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2812  5 2.3126E-02  515 -516 109 -110 111 -112 u=24  imp:n=1 TMP=2.5301E-08
c Na plate can
2813  6 7.865043E-02 514 -517 21 -22 23 -24 &
      (-109:110:-111:112:-515:516) u=24  imp:n=1 TMP=2.5301E-08
c
c End of Central Section of the Radial blanket
c
c Upper and Lower Section of the radial Blanket
c
c ALG8
2851  29 2.6752E-02 601 -603 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c AL2O34
2852  30 1.106986E-01 603 -604 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c GII8
2853  11 8.5125E-02 604 -605 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c ALG8
2854  29 2.6752E-02 605 -606 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c U2 plate
2855  9 4.7925E-02 606 -607 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c ALG8
2856  29 2.6752E-02 607 -608 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c GII8
2857  11 8.5125E-02 608 -609 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c AL2O34
2858  30 1.106986E-01 609 -610 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c MST2 (MST8) plate
c
2859  27 8.4980E-02 610 -611  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2860  29 2.6752E-02 611 -612 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c GII8
2861  11 8.5125E-02 612 -613 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2862  29 2.6752E-02 613 -615 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c U2 plate
2863  9 4.7925E-02 615 -616 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c AL2O34
2864  30 1.106986E-01 616 -617 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2865  29 2.6752E-02 617 -618 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c GII8
2866  11 8.5125E-02 618 -619 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c MST8 plate
c
2867  27 8.4980E-02 619 -620  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08

```

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```

c
c
c  ALG8
2868  29 2.6752E-02 620 -621 21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c  End of upper and lower radial blanket sections
c
c c Lower Plenum Cell
c
c  ALSC3 plate
2901  28 4.7627E-02 7 -33  21 -22 23 -24 u=31 imp:n=1 TMP=2.5301E-08
c
c  MST1 plate
c
2902  27 8.4980E-02 33 -34  21 -22 23 -24 u=31 imp:n=1 TMP=2.5301E-08
c
c  ALSC3 plate
2903  28 4.7627E-02 34 -35 21 -22 23 -24 u=31 imp:n=1 TMP=2.5301E-08
c
c  MST3 plate
c
2904  27 8.4980E-02 35 -36  21 -22 23 -24 u=31 imp:n=1 TMP=2.5301E-08
c
c  ALSC3 plate
c
2905  28 4.7627E-02 36 -37 21 -22 23 -24 u=31 imp:n=1 TMP=2.5301E-08
c
c  Upper Plenum Cell
c
c  ALSC3 plate
c
2911  28 4.7627E-02 7 -33  21 -22 23 -24 u=32 imp:n=1 TMP=2.5301E-08
c
c  MST3 plate
c
2912  27 8.4980E-02 33 -38  21 -22 23 -24 u=32 imp:n=1 TMP=2.5301E-08
c
c  ALSC3 plate
2913  28 4.7627E-02 38 -39 21 -22 23 -24 u=32 imp:n=1 TMP=2.5301E-08
c
c  MST1 plate
c
2914  27 8.4980E-02 39 -36  21 -22 23 -24 u=32 imp:n=1 TMP=2.5301E-08
c
c  ALSC3 plate
2915  28 4.7627E-02 36 -37 21 -22 23 -24 u=32 imp:n=1 TMP=2.5301E-08
c
c  Cell data complete
c
c
c
c  Form the region surrounding groups of 5x5 elements, containing grids
c
c
3001  0 89 -90 91 -92 (-85:86:-87:88) -71 u=100 imp:n=1
c
3002  19 7.403935E-02 89 -90 91 -92 (-85:86:-87:88) 71 -72 u=100 imp:n=1
c
3003  0 89 -90 91 -92 (-85:86:-87:88) 72 -73 u=100 imp:n=1
c
3004  19 7.403935E-02 89 -90 91 -92 (-85:86:-87:88) 73 -74 u=100 imp:n=1
c
3005  0 89 -90 91 -92 (-85:86:-87:88) 74 u=100 imp:n=1
c
c
c
c  Form arrays of 5x5 elements
c
c
c  Central array of 5x5 core elements
c
c
3011  0  1 -2 3 -4 u=51 lat=1
      fill=-2:2 -2:2 0:0
      1 1 1 1 1
      1 1 1 1 1

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

1 1 1 1 1
1 1 1 1 1
1 1 1 1 1
imp:n=1
c
3012  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=101 imp:n=1
c
3013  0 7 -16 85 -86 87 -88 fill=51 u=101 imp:n=1
c
c
c ROW 5
c
c Top left array of 5x5 core elements in Row 5
c
3021    0   1 -2 3 -4 u=53 lat=1
      fill=-2:2 -2:2 0:0
      6 6 6 5 5
      6 6 5 5 3
      6 5 3 3 3
      5 5 3 3 2
      5 3 3 2 2
      imp:n=1
c
c
c Surround material
c
3022  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=103 imp:n=1
c
c
3023  0 7 -16 85 -86 87 -88 fill=53 u=103 imp:n=1
c
c
c ROW 5
c
c Central array of 5x5 core elements in Row 5
c
3026    0   1 -2 3 -4 u=79 lat=1
      fill=-2:2 -2:2 0:0
      5 3 3 3 5
      3 3 3 3 3
      3 2 2 2 3
      2 2 2 2 2
      1 1 1 1 1
      imp:n=1
c
c
c Surround material
c
3027  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=129 imp:n=1
c
c
3028  0 7 -16 85 -86 87 -88 fill=79 u=129 imp:n=1
c
c Top right array of 5x5 core elements in Row 5
c
3031    0   1 -2 3 -4 u=54 lat=1
      fill=-2:2 -2:2 0:0
      5 5 6 6 6
      3 5 5 6 6
      3 3 3 5 6
      2 3 3 5 5
      2 2 3 3 5
      imp:n=1
c
c
c Surround material
c
3032  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=104 imp:n=1
c
c
3033  0 7 -16 85 -86 87 -88 fill=54 u=104 imp:n=1
c
c ROW 6
c
c Top central array of 5x5 core elements in row 6
c

```


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LIQUID METAL FAST REACTOR - LMFR
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```

3041    0    1 -2 3 -4 u=52 lat=1
        fill=-2:2 -2:2 0:0
        6 6 6 6 6
        6 6 6 6 6
        6 6 6 6 6
        6 6 6 6 6
        6 5 5 5 6
        imp:n=1
c
c Surround material
c
3042    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=102 imp:n=1
c
3043    0 7 -16 85 -86 87 -88 fill=52 u=102 imp:n=1
c
c
c ROW 4
c
c Left edge array of 5x5 core elements in row 4
c
3051    0    1 -2 3 -4 u=55 lat=1
        fill=-2:2 -2:2 0:0
        6 6 6 6 6
        6 6 6 6 5
        6 6 6 6 5
        6 6 6 6 5
        6 6 6 6 6
        imp:n=1
c
c
c Surround material
c
3052    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=105 imp:n=1
c
c
3053    0 7 -16 85 -86 87 -88 fill=55 u=105 imp:n=1
c
c
c Middle Left array of 5x5 core elements in row 4
c
3054    0    1 -2 3 -4 u=76 lat=1
        fill=-2:2 -2:2 0:0
        5 3 3 2 1
        3 3 2 2 1
        3 3 2 2 1
        3 3 2 2 1
        5 3 3 2 1
        imp:n=1
c
c
c Surround material
c
3055    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=126 imp:n=1
c
c
3056    0 7 -16 85 -86 87 -88 fill=76 u=126 imp:n=1
c
c
c Middle Right array of 5x5 core elements in row 4
c
3057    0    1 -2 3 -4 u=91 lat=1
        fill=-2:2 -2:2 0:0
        1 2 3 3 5
        1 2 2 3 3
        1 2 2 3 3
        1 2 2 3 3
        1 2 3 3 5
        imp:n=1
c
c
c Surround material
c
3058    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=141 imp:n=1
c
c

```

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LIQUID METAL FAST REACTOR - LMFR
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```

3059   0 7 -16 85 -86 87 -88 fill=91 u=141 imp:n=1
c
c
c Right edge array of 5x5 core elements in row 4
c
3061     0   1 -2 3 -4 u=56 lat=1
      fill=-2:2 -2:2 0:0
      6 6 6 6 6
      5 6 6 6 6
      5 6 6 6 6
      5 6 6 6 6
      6 6 6 6 6
      imp:n=1
c
c
c Surround material
c
3062     0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=106 imp:n=1
c
c
3063     0 7 -16 85 -86 87 -88 fill=56 u=106 imp:n=1
c
c
c ROW 3
c
c Lower left array of 5x5 core elements in Row 3
c
c
3071     0   1 -2 3 -4 u=57 lat=1
      fill=-2:2 -2:2 0:0
      5 3 3 2 2
      5 5 3 3 2
      6 5 3 3 3
      6 6 5 5 3
      6 6 6 5 5
      imp:n=1
c
c Surround material
c
3072     0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=107 imp:n=1
c
3073     0 7 -16 85 -86 87 -88 fill=57 u=107 imp:n=1
c
c
c Middle array of 5x5 core elements in Row 3
c
c
3076     0   1 -2 3 -4 u=92 lat=1
      fill=-2:2 -2:2 0:0
      1 1 1 1 1
      2 2 2 2 2
      3 2 2 2 3
      3 3 3 3 3
      5 3 3 3 5
      imp:n=1
c
c Surround material
c
3077     0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=142 imp:n=1
c
3078     0 7 -16 85 -86 87 -88 fill=92 u=142 imp:n=1
c
c Lower right array of 5x5 core elements in Row 3
c
3081     0   1 -2 3 -4 u=58 lat=1
      fill=-2:2 -2:2 0:0
      2 2 3 3 5
      2 3 3 5 5
      3 3 3 5 6
      3 3 5 6 6
      5 5 6 6 6
      imp:n=1
c
c
c Surround material
c

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

3082  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=108 imp:n=1
c
c
3083  0 7 -16 85 -86 87 -88 fill=58 u=108 imp:n=1
c
c
c          ROW 2
c
c Lower central group
c
c
3091  0 1 -2 3 -4 u=59 lat=1
      fill=-2:2 -2:2 0:0
      6 5 5 5 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
      imp:n=1
c
c
c Surround material
c
c
3092  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=109 imp:n=1
c
c
3093  0 7 -16 85 -86 87 -88 fill=59 u=109 imp:n=1
c
c
c 5x5 array of blanket elements
c
c
3101  0 1 -2 3 -4 u=61 lat=1
      fill=-2:2 -2:2 0:0
      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
      imp:n=1
c
c
c Surround material
c
c
3102  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=111 imp:n=1
c
c
3103  0 7 -16 85 -86 87 -88 fill=61 u=111 imp:n=1
c
c
c Blanket-Reflector Arrays
c
c ROW 2
c
c Bottom Left
c
c
3111  0 1 -2 3 -4 u=62 lat=1
      fill=-2:2 -2:2 0:0
      7 6 6 6 6
      7 7 6 6 6
      7 7 7 6 6
      7 7 7 7 6
      9 7 7 7 7
      imp:n=1
c
c
c Surround material
c
c
3112  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=112 imp:n=1
c
c
3113  0 7 -16 85 -86 87 -88 fill=62 u=112 imp:n=1
c
c
c Row 2 Bottom Right Blanket Reflector Array
c
c
3121  0 1 -2 3 -4 u=63 lat=1
      fill=-2:2 -2:2 0:0

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

        6 6 6 6 7
        6 6 6 7 7
        6 6 7 7 7
        6 7 7 7 7
        7 7 7 7 9
        imp:n=1
c
c
c Surround material
c
3122   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=113 imp:n=1
c
3123   0 7 -16 85 -86 87 -88 fill=63 u=113 imp:n=1
c
c
c ROW 6
c
c Top Left Blanket-Reflector Array
c
c
3131   0   1 -2 3 -4 u=64 lat=1
        fill=-2:2 -2:2 0:0
        9 7 7 7 7
        7 7 7 7 6
        7 7 7 6 6
        7 7 6 6 6
        7 6 6 6 6
        imp:n=1
c
c
c Surround material
c
3132   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=114 imp:n=1
c
3133   0 7 -16 85 -86 87 -88 fill=64 u=114 imp:n=1
c
c Row 6 Top Right Blanket Reflector Array
c
c
3141   0   1 -2 3 -4 u=65 lat=1
        fill=-2:2 -2:2 0:0
        7 7 7 7 9
        6 7 7 7 7
        6 6 7 7 7
        6 6 6 7 7
        6 6 6 6 7
        imp:n=1
c
c
c Surround material
c
3142   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=115 imp:n=1
c
3143   0 7 -16 85 -86 87 -88 fill=65 u=115 imp:n=1
c
c
c Row 1 Blanket - Reflector arrays
c
c Row 1 First Left array
c
c
3151   0   1 -2 3 -4 u=71 lat=1
        fill=-2:2 -2:2 0:0
        9 9 7 7 7
        9 9 9 7 7
        9 9 9 9 9
        9 9 9 9 9
        9 9 9 9 9
        imp:n=1
c
c
c Surround material
c
3152   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=121 imp:n=1
c
3153   0 7 -16 85 -86 87 -88 fill=71 u=121 imp:n=1

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Row 1 Mid-Left
c
c
3161    0    1 -2 3 -4 u=72 lat=1
        fill=-2:2 -2:2 0:0
        7 7 6 6 6
        7 7 7 7 7
        7 7 7 7 7
        9 9 9 9 7
        9 9 9 9 9
        imp:n=1

c
c
c Surround material
c
3162    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=122 imp:n=1
c
3163    0 7 -16 85 -86 87 -88 fill=72 u=122 imp:n=1
c
c Row 1 Central Array
c
3171    0    1 -2 3 -4 u=73 lat=1
        fill=-2:2 -2:2 0:0
        6 6 6 6 6
        7 6 6 6 7
        7 7 7 7 7
        7 7 7 7 7
        7 7 7 7 7
        imp:n=1

c
c
c Surround material
c
3172    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=123 imp:n=1
c
3173    0 7 -16 85 -86 87 -88 fill=73 u=123 imp:n=1
c
c Row 1 First Right array
c
c
3181    0    1 -2 3 -4 u=74 lat=1
        fill=-2:2 -2:2 0:0
        6 6 6 7 7
        7 7 7 7 7
        7 7 7 7 7
        7 9 9 9 9
        9 9 9 9 9
        imp:n=1

c
c
c Surround material
c
3182    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=124 imp:n=1
c
3183    0 7 -16 85 -86 87 -88 fill=74 u=124 imp:n=1
c
c Row 1 Far Right
c
c
3191    0    1 -2 3 -4 u=75 lat=1
        fill=-2:2 -2:2 0:0
        7 7 7 9 9
        7 7 9 9 9
        9 9 9 9 9
        9 9 9 9 9
        9 9 9 9 9
        imp:n=1

c
c
c Surround material
c
3192    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=125 imp:n=1
c
3193    0 7 -16 85 -86 87 -88 fill=75 u=125 imp:n=1
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Row 2 Blanket reflector arrays
c
c Row 2 First Left array
c
c
3201    0    1 -2 3 -4 u=77 lat=1
        fill=-2:2 -2:2 0:0
        9 9 9 7 7
        9 9 9 7 7
        9 9 9 9 7
        9 9 9 9 9
        9 9 9 9 9
        imp:n=1

c
c
c Surround material
c
3202    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=127 imp:n=1
c
3203    0 7 -16 85 -86 87 -88 fill=77 u=127 imp:n=1
c
c Row 2 Far Right
c
c
3211    0    1 -2 3 -4 u=78 lat=1
        fill=-2:2 -2:2 0:0
        7 7 9 9 9
        7 7 9 9 9
        7 9 9 9 9
        9 9 9 9 9
        9 9 9 9 9
        imp:n=1

c
c
c Surround material
c
3212    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=128 imp:n=1
c
3213    0 7 -16 85 -86 87 -88 fill=78 u=128 imp:n=1
c
c Row 4 Blanket- Reflector arrays
c
c
c Row 4 First Left array
c
c
3221    0    1 -2 3 -4 u=93 lat=1
        fill=-2:2 -2:2 0:0
        7 7 7 7 6
        7 7 7 6 6
        7 7 7 6 6
        7 7 7 6 6
        7 7 7 7 6
        imp:n=1

c
c
c Surround material
c
3222    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=157 imp:n=1
c
3223    0 7 -16 85 -86 87 -88 fill=93 u=157 imp:n=1
c
c
c Row 4 Far Right
c
c
3231    0    1 -2 3 -4 u=94 lat=1
        fill=-2:2 -2:2 0:0
        6 7 7 7 7
        6 6 7 7 7
        6 6 7 7 7
        6 6 7 7 7
        6 7 7 7 7
        imp:n=1
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Surround material
c
3232   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=158 imp:n=1
c
3233   0 7 -16 85 -86 87 -88 fill=94 u=158 imp:n=1
c
c Row 6 Blanket- Reflector arrays
c
c
c Row 6 First Left array
c
3241     0   1 -2 3 -4 u=87 lat=1
      fill=-2:2 -2:2 0:0
      9 9 9 9 9
      9 9 9 9 9
      9 9 9 9 7
      9 9 9 7 7
      9 9 9 7 7
      imp:n=1

c
c
c Surround material
c
3242   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=137 imp:n=1
c
3243   0 7 -16 85 -86 87 -88 fill=87 u=137 imp:n=1
c
c Row 6 Far Right
c
3251     0   1 -2 3 -4 u=88 lat=1
      fill=-2:2 -2:2 0:0
      9 9 9 9 9
      9 9 9 9 9
      7 9 9 9 9
      7 7 9 9 9
      7 7 9 9 9
      imp:n=1

c
c
c Surround material
c
3252   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=138 imp:n=1
c
3253   0 7 -16 85 -86 87 -88 fill=88 u=138 imp:n=1
c
c
c Row 5 Blanket- Reflector arrays
c
c
c Row 5 First Left array
c
c
3261     0   1 -2 3 -4 u=95 lat=1
      fill=-2:2 -2:2 0:0
      9 9 7 7 7
      9 9 7 7 7
      9 9 7 7 6
      9 9 7 7 6
      9 7 7 7 6
      imp:n=1

c
c
c Surround material
c
3262   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=167 imp:n=1
c
3263   0 7 -16 85 -86 87 -88 fill=95 u=167 imp:n=1
c
c Row 4 Far Right
c
3271     0   1 -2 3 -4 u=96 lat=1
      fill=-2:2 -2:2 0:0
      7 7 7 9 9
      7 7 7 9 9
      6 7 7 9 9

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

6 7 7 9 9
6 7 7 7 9
imp:n=1
c
c
c Surround material
c
3272  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=168 imp:n=1
c
3273  0 7 -16 85 -86 87 -88 fill=96 u=168 imp:n=1
c
c
c Row 3 Blanket- Reflector arrays
c
c Row 3 First Left array
c
3281  0 1 -2 3 -4 u=97 lat=1
      fill=-2:2 -2:2 0:0
      9 7 7 7 6
      9 9 7 7 6
      9 9 7 7 6
      9 9 7 7 7
      9 9 7 7 7
      imp:n=1
c
c
c Surround material
c
3282  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=147 imp:n=1
c
3283  0 7 -16 85 -86 87 -88 fill=97 u=147 imp:n=1
c
c Row 3 Far Right
c
3291  0 1 -2 3 -4 u=98 lat=1
      fill=-2:2 -2:2 0:0
      6 7 7 7 9
      6 7 7 9 9
      6 7 7 9 9
      7 7 7 9 9
      7 7 7 9 9
      imp:n=1
c
c
c Surround material
c
3292  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=148 imp:n=1
c
3293  0 7 -16 85 -86 87 -88 fill=98 u=148 imp:n=1
c
c Row 7 Blanket - Reflector arrays
c
c Row 7 First Left array
c
c
3301  0 1 -2 3 -4 u=81 lat=1
      fill=-2:2 -2:2 0:0
      9 9 9 9 9
      9 9 9 9 9
      9 9 9 9 9
      9 9 9 7 7
      9 9 7 7 7
      imp:n=1
c
c
c Surround material
c
3302  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=131 imp:n=1
c
3303  0 7 -16 85 -86 87 -88 fill=81 u=131 imp:n=1
c
c Row 7 Mid-Left
c
3311  0 1 -2 3 -4 u=82 lat=1
      fill=-2:2 -2:2 0:0
      9 9 9 9 9

```


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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

9 9 9 9 7
7 7 7 7 7
7 7 7 7 7
7 7 6 6 6
imp:n=1
c
c
c Surround material
c
3312  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=132 imp:n=1
c
3313  0 7 -16 85 -86 87 -88 fill=82 u=132 imp:n=1
c
c Row 7 Central Array
c
3321  0 1 -2 3 -4 u=83 lat=1
      fill=-2:2 -2:2 0:0
      7 7 7 7 7
      7 7 7 7 7
      7 7 7 7 7
      7 6 6 6 7
      6 6 6 6 6
      imp:n=1
c
c
c Surround material
c
3322  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=133 imp:n=1
c
3323  0 7 -16 85 -86 87 -88 fill=83 u=133 imp:n=1
c
c Row 7 First Right array
c
3331  0 1 -2 3 -4 u=84 lat=1
      fill=-2:2 -2:2 0:0
      9 9 9 9 9
      7 9 9 9 9
      7 7 7 7 7
      7 7 7 7 7
      6 6 6 7 7
      imp:n=1
c
c
c Surround material
c
3332  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=134 imp:n=1
c
3333  0 7 -16 85 -86 87 -88 fill=84 u=134 imp:n=1
c
c Row 7 Far Right
c
3341  0 1 -2 3 -4 u=85 lat=1
      fill=-2:2 -2:2 0:0
      9 9 9 9 9
      9 9 9 9 9
      9 9 9 9 9
      7 7 9 9 9
      7 7 7 9 9
      imp:n=1
c
c
c Surround material
c
3342  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=135 imp:n=1
c
3343  0 7 -16 85 -86 87 -88 fill=85 u=135 imp:n=1
c
c Beyond the reflector 5x5 Region 9
c
3351  0 1 -2 3 -4 u=191 lat=1
      fill=-2:2 -2:2 0:0
      9 9 9 9 9
      9 9 9 9 9
      9 9 9 9 9
      9 9 9 9 9
      9 9 9 9 9

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

      imp:n=1
c
c
c Surround material
c
3352   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=201 imp:n=1
c
c
3353   0 7 -16 85 -86 87 -88 fill=191 u=201 imp:n=1
c
c -----
c

c
c ----- SURFACE CARDS -----
c
c MZA Core and MZB Outer Core Element cell surfaces
1      px -2.68605
2      px 2.68605
3      py -2.68605
4      py 2.68605
7      pz 0.0 $ Assembly lower limit
8      pz 30.0 $ End Lower Packing, Start Plenum
9      pz 63.0048 $ End Plenum, Start Lower Axial Blanket
10     pz 97.9512 $ End Lower Blanket, Start Core Fuel
11     pz 187.9008 $ End Core Fuel, Start Upper Axial Blanket
12     pz 222.8472 $ End Upper Blanket, Start Upper Plenum
13     pz 255.852 $ End Upper Plenum, Start Upper Packing
16     pz 285.0 $ Assembly upper axial limit
17     cz 94.6345 $ Assembly outer radius
21     px -2.5335 $ Nominal half-width of plates
22     px 2.5335
23     py -2.5335
24     py 2.5335
28     px -2.54 $ Radial shield half-width
29     px 2.54
30     py -2.54
31     py 2.54
c
c axial heights in the lower plenum
33     pz 7.62 $ alsc3
34     pz 10.1585 $ mst1
35     pz 17.7785 $ alsc3
36     pz 25.3848 $ mst3
37     pz 33.0048 $ alsc3
c different axial heights in the upper plenum
38     pz 15.2263 $ mst3
39     pz 22.8463 $ alsc3 / mst1
c
c cell subdivisions in the axial blanket and core cells of MZA elements
c
c 9      pz 63.0048 $ End Plenum, Start Lower Axial Blanket
41     pz 71.7414
42     pz 80.478
43     pz 89.2146
c 10     pz 97.9512 $ lower axial blanket / core
44     pz 105.447
45     pz 112.9428
46     pz 120.4386
47     pz 127.9344
48     pz 135.4302
49     pz 142.926
50     pz 150.4218
51     pz 157.9176
52     pz 165.4134
53     pz 172.9092
54     pz 180.405
c 11     pz 187.9008 $ core / upper axial blanket
56     pz 196.6374
57     pz 205.374
58     pz 214.1106
c 12     pz 222.8472 $ axial blanket / plenum
c
c
62     px -2.551 $ sheath inner half-width
63     px 2.551

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

64      py -2.551
65      py 2.551
66      px -2.6272 $ sheath outer half-width
67      px 2.6272
68      py -2.6272
69      py 2.6272
c
c
c Grid plate heights
c
71      pz 31.8
72      pz 62.2
73      pz 162.6
74      pz 193.0
c
c coordinates of the elements in 5x5 arrays
81      px -8.05815
82      px 8.05815
83      py -8.05815
84      py 8.05815
85      px -13.43025
86      px 13.43025
87      py -13.43025
88      py 13.43025
89      px -13.5635
90      px 13.5635
91      py -13.5635
92      py 13.5635
c
c plate inner core widths
c
101     px -2.3355 $ Pu metal plate core width
102     px 2.3355
103     py -2.3355
104     py 2.3355
105     px -2.4255 $ UO2 plate core width
106     px 2.4255
107     py -2.4255
108     py 2.4255
109     px -2.4815 $ Na plate core width
110     px 2.4815
111     py -2.4815
112     py 2.4815
c 113    px -2.4765 $ MOX plate PUIV4
c 114    px 2.4765
c 115    py -2.4765
c 116    py 2.4765
c
c
c MZA Core Cell Axial heights
c
201     pz 0
202     pz 0.03683
203     pz 0.57917 $ Na
204     pz 0.616
205     pz 0.65283
206     pz 1.20707 $ UO2
207     pz 1.2439
208     pz 1.28073
209     pz 1.82307 $ Na
210     pz 1.8599
211     pz 1.90562
212     pz 2.14068 $ Pu
213     pz 2.1864
214     pz 2.5036 $ SS
215     pz 2.54043
216     pz 3.09467 $ UO2
217     pz 3.1315
218     pz 3.16833
219     pz 3.71067 $ Na
220     pz 3.7475
221     pz 3.78433
222     pz 4.32667 $ Na
223     pz 4.3635
224     pz 4.40033
225     pz 4.95457 $ UO2

```

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LIQUID METAL FAST REACTOR - LMFR
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226	pz	4.9914	
227	pz	5.3094	\$ GI8
228	pz	5.35512	
229	pz	5.59018	\$ Pu
230	pz	5.6359	
231	pz	5.67273	
232	pz	6.21507	\$ Na
233	pz	6.2519	
234	pz	6.28873	
235	pz	6.84297	\$ UO2
236	pz	6.8798	
237	pz	6.91663	
238	pz	7.45897	\$ Na
239	pz	7.4958	
c			
c MZB Inner core cell axial heights			
c			
c 301	pz	0	
c 302	pz	0.03683	
c 303	pz	0.57917	\$ na
c 304	pz	0.616	
c 305	pz	0.65283	
c			
c Axial blanket cells			
c			
401	pz	0	
402	pz	0.03683	
403	pz	0.57917	\$ na
404	pz	0.616	
405	pz	0.933	\$ u8
406	pz	1.251	\$ g
407	pz	1.28783	
408	pz	1.83017	\$ na
409	pz	1.867	
410	pz	2.1842	\$ ss
411	pz	2.5012	\$ u8
412	pz	2.53803	
413	pz	3.08037	\$ na
414	pz	3.1172	
415	pz	3.4352	\$ g
416	pz	3.47203	
417	pz	4.01437	\$ na
418	pz	4.0512	
419	pz	4.3684	\$ ss
420	pz	4.6854	\$ u8
421	pz	4.72223	
422	pz	5.26457	\$ na
423	pz	5.3014	
424	pz	5.6194	\$ g
425	pz	5.65623	
426	pz	6.19857	\$ na
427	pz	6.2354	
428	pz	6.5524	\$ u8
429	pz	6.8696	\$ ss
430	pz	6.90643	
431	pz	7.44877	\$ na
432	pz	7.4856	
433	pz	7.8036	\$ g
434	pz	8.1206	\$ u8
435	pz	8.15743	
436	pz	8.69977	\$ na
437	pz	8.7366	
c			
c Inner (axially) radial blanket cells			
c			
501	pz	0	
502	pz	0.31775	\$ g
503	pz	0.35458	
504	pz	0.89692	\$ na
505	pz	0.93375	
506	pz	1.2515	\$ g
507	pz	1.5751	\$ ss
508	pz	2.8474	\$ u2
509	pz	3.16515	\$ g
510	pz	3.20198	
511	pz	3.74432	\$ na

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

512 pz 3.78115
513 pz 4.09585 $ mst
514 pz 4.4136 $ g
515 pz 4.45043
516 pz 4.99277 $ na
517 pz 5.0296
c
c Upper and lower sections of the radial blanket
c
601 pz 0
c 602 pz 0.317 $ al
603 pz 0.634 $ al
604 pz 1.2657 $ al2o3
605 pz 1.58345 $ gii
606 pz 1.90045 $ al
607 pz 3.17275 $ u2
608 pz 3.48975 $ al
609 pz 3.8075 $ gii
610 pz 4.4392 $ al2o3
611 pz 5.711 $ mst2
612 pz 6.028 $ al
613 pz 6.34575 $ gii
c 614 pz 6.66275 $ al
615 pz 6.97975 $ al
616 pz 8.25205 $ u2
617 pz 8.88375 $ al2o3
618 pz 9.20075 $ al
619 pz 9.5185 $ gii
620 pz 9.8332 $ mst8
621 pz 10.1502 $ al
c
c heights of cells in the MZB inner core elements
c
c 701 pz 97.9512 $ First core cell upper boundary
c
c Heights of cells in the radial blanket
c
801 pz 30.0 $ Packing
802 pz 63.0048 $ End Lower plenum/
803 pz 73.155
804 pz 83.3052
805 pz 93.4554 $ End Lower Blanket
806 pz 98.485
807 pz 103.5146
808 pz 108.5442
809 pz 113.5738
810 pz 118.6034
811 pz 123.633
812 pz 128.6626
813 pz 133.6922
814 pz 138.7218
815 pz 143.7514
816 pz 148.781
817 pz 153.8106
818 pz 158.8402
819 pz 163.8698
820 pz 168.8994
821 pz 173.929
822 pz 178.9586
823 pz 183.9882
824 pz 189.0178
825 pz 194.0474 $ End Middle Blanket
826 pz 204.1976
827 pz 214.3478
828 pz 224.498 $ End Upper Blanket
829 pz 257.5028 $ End Upper plenum
830 pz 285.0 $ Top of assembly
c
c
c -----
c
c
c
c ----- TALLY CARDS -----
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

c --- MATERIALS CARDS ---

c

c Region Compositions

C MATERIAL 1 Pu metal plate PUV8 core

c

m1 92238.31c 1.3318E-06
 94238.31c 2.9103E-05
 94239.31c 2.9328E-02
 94240.31c 6.7928E-03
 94241.31c 1.0119E-03
 94242.31c 1.6639E-04
 95241.31c 9.4236E-05
 1001.31c 1.7475E-04
 6000.31c 2.5027E-04
 7014.31c 1.3413E-05
 8016.31c 5.0640E-05
 13027.31c 2.1760E-05
 14028.31c 2.3831E-05
 25055.31c 1.0687E-06
 24050.31c 2.2568E-07
 24052.31c 4.3521E-06
 24053.31c 4.9349E-07
 24054.31c 1.2284E-07
 26054.31c 9.7085E-07
 26056.31c 1.5240E-05
 26057.31c 3.5197E-07
 26058.31c 4.6840E-08
 28058.31c 8.0358E-06
 28060.31c 3.0954E-06
 28061.31c 1.3455E-07
 28062.31c 4.2902E-07
 28064.31c 1.0926E-07
 31000.31c 2.2424E-03

c

 42000.66c 1.9583E-06
 42092.31c 2.9375E-07
 42094.31c 1.9583E-07
 42095.31c 2.9375E-07
 42096.31c 2.9375E-07
 42097.31c 1.9583E-07
 42098.31c 4.8958E-07
 42100.31c 1.9583E-07

c total 4.023746E-02

c MATERIAL 2 PuV8 plate canning

c

m2 1001.31c 1.3404E-05
 6000.31c 9.2801E-05
 14028.31c 4.1625E-04
 15031.31c 1.8432E-05
 16032.31c 9.3252E-06
 25055.31c 7.5220E-04
 24050.31c 4.0213E-04
 24052.31c 7.7546E-03
 24053.31c 8.7931E-04
 24054.31c 2.1888E-04
 26054.31c 2.0054E-03
 26056.31c 3.1481E-02
 26057.31c 7.2703E-04
 26058.31c 9.6754E-05
 28058.31c 3.0905E-03
 28060.31c 1.1905E-03
 28061.31c 5.1748E-05
 28062.31c 1.6500E-04
 28064.31c 4.2019E-05

c

 29063.31c 1.6626E-02
 29063.31c 1.1638E-02
 29065.31c 4.9880E-03

c total 6.6033E-02

C MATERIAL 3 UO2 plate UO24R4 core

c

m3 1001.31c 2.4503E-05
 6000.31c 3.0842E-05
 8016.31c 4.5733E-02
 13027.31c 3.3911E-06
 14028.31c 1.3190E-05
 26054.31c 3.8771E-07
 26056.31c 6.0862E-06

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

26057.31c 1.4056E-07
26058.31c 1.8706E-08
92234.31c 1.1871E-06
92235.31c 1.6462E-04
92238.31c 2.2694E-02
c total 6.867137E-02
c MATERIAL 4 UO2 plate UO24R4 canning
c
m4      1001.31c 1.7335E-05
        6000.31c 1.4546E-04
        14028.31c 6.0964E-04
        15031.31c 2.2563E-05
        16032.31c 2.1792E-05
        25055.31c 9.7951E-04
        24050.31c 5.3726E-04
        24052.31c 1.0361E-02
        24053.31c 1.1748E-03
        24054.31c 2.9243E-04
        26054.31c 2.5374E-03
        26056.31c 3.9831E-02
        26057.31c 9.1988E-04
        26058.31c 1.2242E-04
        28058.31c 4.0937E-03
        28060.31c 1.5769E-03
        28061.31c 6.8547E-05
        28062.31c 2.1856E-04
        28064.31c 5.5660E-05
        29063.31c 5.7122E-04
        29065.31c 2.4481E-04
        47107.31c 6.3840E-04
        47109.31c 5.9840E-04
c total 6.5639E-02
C MATERIAL 5 sodium plate NASTBR4 core
c
m5      1001.31c 2.1098E-06
        3006.31c 2.8720E-08
        3007.31c 3.5424E-07
        5010.31c 2.9500E-08
        5011.31c 1.1802E-07
        8016.31c 1.9937E-06
        11023.31c 2.3119E-02
        19039.31c 4.6230E-07
        20040.31c 1.7244E-06
        26054.31c 2.2256E-09
        26056.31c 3.4937E-08
        26057.31c 8.0685E-10
        26058.31c 1.0738E-10
c total 2.3126E-02
c MATERIAL 6 Sodium plate NASTBR4 canning
c
m6      1001.31c 2.1496E-05
        6000.31c 2.1646E-04
        14028.31c 6.0171E-04
        15031.31c 2.7979E-05
        16032.31c 2.7023E-05
        25055.31c 1.0806E-03
        24050.31c 6.5175E-04
        24052.31c 1.2568E-02
        24053.31c 1.4252E-03
        24054.31c 3.5475E-04
        26054.31c 3.1596E-03
        26056.31c 4.9599E-02
        26057.31c 1.1454E-03
        26058.31c 1.5244E-04
        28058.31c 4.9357E-03
        28060.31c 1.9012E-03
        28061.31c 8.2645E-05
        28062.31c 2.6351E-04
        28064.31c 6.7108E-05
        28064.31c 6.5701E-05
        41093.31c 3.0316E-04
c total 7.865043E-02
C MATERIAL 7 STSTBR8 steel plate
c
m7      1001.31c 2.3265E-05
        6000.31c 7.8091E-04

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

13027.31c 1.7381E-04
14028.31c 1.3358E-03
22048.31c 2.9384E-04
25055.31c 9.3901E-04
24050.31c 7.0932E-04
24052.31c 1.3679E-02
24053.31c 1.5510E-03
24054.31c 3.8609E-04
26054.31c 3.4063E-03
26056.31c 5.3472E-02
26057.31c 1.2349E-03
26058.31c 1.6434E-04
28058.31c 5.2766E-03
28060.31c 2.0326E-03
28061.31c 8.8354E-05
28062.31c 2.8171E-04
28064.31c 7.1743E-05
29063.31c 5.1661E-05
29065.31c 2.2140E-05
c 42000.66c 9.7764E-05
42092.31c 1.4665E-05
42094.31c 9.7764E-06
42095.31c 1.4665E-05
42096.31c 1.4665E-05
42097.31c 9.7764E-06
42098.31c 2.4441E-05
42100.31c 9.7764E-06
c total 8.607216E-02
c
C MATERIAL 8 U8 metal plate
m8 1001.31c 4.4048E-05
6000.31c 4.9283E-04
14028.31c 2.1076E-04
26054.31c 6.1951E-06
26056.31c 9.7250E-05
26057.31c 2.2459E-06
26058.31c 2.9889E-08
92235.31c 3.3369E-04
92238.31c 4.6021E-02
c total 4.7208E-02
C MATERIAL 9 U2 metal plate
m9 1001.31c 4.3899E-05
6000.31c 4.6047E-04
14028.31c 1.9692E-04
26054.31c 5.7884E-06
26056.31c 9.0866E-05
26057.31c 2.0985E-06
26058.31c 2.7927E-08
92235.31c 3.3962E-04
92238.31c 4.6785E-02
c total 4.7925E-02
c MATERIAL 10 Graphite plate GI8
m10 1001.31c 4.8551E-05
6000.31c 8.1417E-02
16032.31c 1.2207E-05
26054.31c 3.5851E-07
26056.31c 5.6278E-06
26057.31c 1.2997E-07
26058.31c 1.7297E-08
c Total 8.1484E-02
c MATERIAL 11 Graphite plate GII8
m11 1001.31c 2.0286E-05
6000.31c 8.5101E-02
16032.31c 1.2751E-06
26054.31c 1.0700E-07
26056.31c 1.6796E-06
26057.31c 3.8790E-08
26058.31c 5.1623E-09
c total 8.5125E-02
c Steel radial shield
m12 1001.31c 4.6306E-05
6000.31c 6.8972E-04
14028.31c 3.1158E-04
15031.31c 4.2944E-05
16032.31c 3.7110E-05
25055.31c 7.1275E-04

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ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

26054.31c 4.9065E-03
26056.31c 7.4517E-02
26057.31c 1.7491E-03
26058.31c 2.5903E-04
c total 8.32720E-02
c
c radial shield void surround low density
ml3 1001.31c 4.6306E-08
6000.31c 6.8972E-07
14028.31c 3.1158E-07
15031.31c 4.2944E-08
16032.31c 3.7110E-08
25055.31c 7.1275E-07
26054.31c 4.9065E-06
26056.31c 7.4517E-05
26057.31c 1.7491E-06
26058.31c 2.5903E-07
c total 8.32720E-05
c
c Axial shield
ml4 1001.31c 2.5700E-05
6000.31c 5.1066E-04
13027.31c 1.3989E-04
22048.31c 3.9416E-05
24050.31c 1.2213E-06
24052.31c 2.2823E-05
24053.31c 2.5531E-06
24054.31c 6.2449E-07
25055.31c 3.2634E-04
26054.31c 5.0496E-03
26056.31c 7.6690E-02
26057.31c 1.8001E-03
26058.31c 2.6658E-04
28058.31c 1.2564E-06
28060.31c 4.6968E-07
28061.31c 2.2000E-08
28062.31c 6.2769E-08
28064.31c 1.6774E-08
29063.31c 3.1184E-05
29065.31c 1.3364E-05
c 42000.66c 9.8355E-06
42092.31c 1.4753E-06
42094.31c 9.8355E-07
42095.31c 1.4753E-06
42096.31c 1.4753E-06
42097.31c 9.8355E-07
42098.31c 2.4589E-06
42100.31c 9.8355E-07
c total 8.4932E-02
c
c Assembly Axial Padding at bottom and top of elements
ml6 1001.31c 3.1777E-05
6000.31c 9.9996E-05
13027.31c 8.3095E-06
24050.31c 6.9087E-08
24052.31c 1.2911E-06
24053.31c 1.4442E-07
24054.31c 3.5326E-08
25055.31c 1.0785E-04
26054.31c 1.9605E-03
26056.31c 2.9775E-02
26057.31c 6.9890E-04
26058.31c 1.0350E-04
28058.31c 1.5636E-07
28060.31c 5.8452E-08
28061.31c 2.7378E-09
28062.31c 7.8115E-09
28064.31c 2.0875E-09
29063.31c 6.5270E-06
29065.31c 2.7973E-06
c Total 3.279692E-02
c
c Stainless steel wrapper material
c
ml7 1001.31c 2.3206E-05
6000.31c 7.7892E-04

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ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

13027.31c 3.4674E-04
14028.31c 9.9933E-04
22048.31c 2.9311E-04
23000.31c 9.1827E-05
25055.31c 1.1921E-03
24050.31c 6.9970E-04
24052.31c 1.3493E-02
24053.31c 1.5300E-03
24054.31c 3.8086E-04
26054.31c 3.3097E-03
26056.31c 5.1952E-02
26057.31c 1.1998E-03
26058.31c 1.5967E-04
28058.31c 6.1314E-03
28060.31c 2.3618E-03
28061.31c 1.0266E-04
28062.31c 3.2734E-04
28064.31c 8.3365E-05
29063.31c 5.1529E-05
29065.31c 2.2084E-05
c 42000.66c 1.4627E-04
42092.31c 2.1941E-05
42094.31c 1.4627E-05
42095.31c 2.1941E-05
42096.31c 2.1941E-05
42097.31c 1.4627E-05
42098.31c 3.6568E-05
42100.31c 1.4627E-05
c Total 8.5677E-02
c
c Superlattice grid plate
c
m19 1001.31c 2.4442E-04
6000.31c 2.9057E-04
14028.31c 4.3858E-05
15031.31c 1.3256E-05
16032.31c 4.3530E-05
25055.31c 2.5785E-04
26054.31c 4.2756E-03
26056.31c 6.7114E-02
26057.31c 1.5500E-03
26058.31c 2.0627E-04
c Total 19 7.403935E-02
c
C M27 Mild Steel MST3
m27 1001.31c 2.8087E-05
6000.31c 5.1066E-04
13027.31c 1.3989E-04
22048.31c 3.9416E-05
25055.31c 3.2634E-04
24050.31c 1.1828E-06
24052.31c 2.2809E-05
24053.31c 2.5864E-06
24054.31c 6.4380E-07
26054.31c 4.8985E-03
26056.31c 7.6895E-02
26057.31c 1.7758E-03
26058.31c 2.3633E-04
28058.31c 3.2836E-05
28060.31c 1.2648E-05
28061.31c 5.4982E-07
28062.31c 1.7531E-06
28064.31c 4.4645E-07
29063.31c 3.1184E-05
29065.31c 1.3364E-05
c 42000.66c 9.8355E-06
42092.31c 1.4753E-06
42094.31c 9.8355E-07
42095.31c 1.4753E-06
42096.31c 1.4753E-06
42097.31c 9.8355E-07
42098.31c 2.4589E-06
42100.31c 9.8355E-07
c Total atoms 8.4980E-02
c
c M28 Aluminium plate ALSC3

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ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

m28      13027.31c  4.7590E-02
          14028.31c  4.5790E-06
          25055.31c  9.3634E-07
          26054.31c  1.7498E-06
          26056.31c  2.7467E-05
          26057.31c  6.3434E-07
          26058.31c  8.4420E-08
          29063.31c  1.2574E-06
          29065.31c  5.4640E-07
c Total  4.7627E-02
c
c M29 Aluminium plate ALG8
m29      13027.31c  2.6704E-02
          14028.31c  1.0296E-05
          25055.31c  6.5793E-07
          26054.31c  2.1261E-06
          26056.31c  3.3375E-05
          26057.31c  7.7077E-07
          26058.31c  1.0257E-07
          29063.31c  3.1853E-07
          29065.31c  1.3652E-07
c Total  2.6752E-02
c
c MATERIAL 30 AL2O34
m30      1001.31c  5.1483E-05
          5010.31c  4.5063E-06
          5011.31c  1.6599E-05
          8016.31c  6.6386E-02
          13027.31c  4.4240E-02
c Total  1.106986E-01
c
c MATERIAL 31 Pu metal plate PUVI8 core
c
m31      92238.31c  2.4663E-07
          94238.31c  3.6995E-05
          94239.31c  2.8972E-02
          94240.31c  7.3421E-03
          94241.31c  1.1537E-03
          94242.31c  2.0132E-04
          95241.31c  8.6769E-05
          1001.31c  1.0485E-04
          6000.31c  2.2876E-04
          7014.31c  2.4312E-05
          8016.31c  3.5962E-05
          13027.31c  1.7408E-05
          25055.31c  1.0687E-06
          24050.31c  1.3737E-07
          24052.31c  2.6491E-06
          24053.31c  3.0038E-07
          24054.31c  7.4772E-08
          26054.31c  1.1307E-06
          26056.31c  1.7749E-05
          26057.31c  4.0990E-07
          26058.31c  5.4549E-08
          28058.31c  4.6308E-06
          28060.31c  1.7838E-06
          28061.31c  7.7540E-08
          28062.31c  2.4723E-07
          28064.31c  6.2963E-08
          31000.31c  2.2555E-03
c total 31 4.04903E-02
c MATERIAL 32 PuVI8 plate canning
c
m32      1001.31c  1.3955E-05
          6000.31c  1.1413E-04
          14028.31c  3.6853E-04
          15031.31c  1.3545E-05
          16032.31c  9.3252E-06
          25055.31c  8.6563E-04
          24050.31c  4.1142E-04
          24052.31c  7.9338E-03
          24053.31c  8.9963E-04
          24054.31c  2.2394E-04
          26054.31c  2.0924E-03
          26056.31c  3.2846E-02

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ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

26057.31c 7.5855E-04
26058.31c 1.0095E-04
28058.31c 2.8554E-03
28060.31c 1.0999E-03
28061.31c 4.7812E-05
28062.31c 1.5245E-04
28064.31c 3.8823E-05
29063.31c 1.1638E-02
29065.31c 4.9880E-03
c total 32 6.74722E-02
c
C MATERIAL 33 Pu metal plate PUVII8 core
c
m33      92238.31c 9.3720E-07
          94238.31c 3.1569E-05
          94239.31c 2.9028E-02
          94240.31c 6.9606E-03
          94241.31c 1.1476E-03
          94242.31c 1.8725E-04
          95241.31c 5.3467E-05
          1001.31c 1.3980E-04
          6000.31c 2.0335E-04
          7014.31c 6.7066E-06
          8016.31c 5.4310E-05
          13027.31c 1.6973E-05
          14028.31c 1.0870E-05
          25055.31c 8.5494E-07
          24050.31c 1.7662E-07
          24052.31c 3.4059E-06
          24053.31c 3.8621E-07
          24054.31c 9.6135E-08
          26054.31c 6.1449E-07
          26056.31c 9.6461E-06
          26057.31c 2.2277E-07
          26058.31c 2.9646E-08
          28058.31c 6.1291E-06
          28060.31c 2.3609E-06
          28061.31c 1.0263E-07
          28062.31c 3.2722E-07
          28064.31c 8.3333E-08
          31000.31c 2.0492E-03
c total 33 3.99151E-02
c MATERIAL 34 PuVII8 plate canning
c
m34      1001.31c 1.3771E-05
          6000.31c 1.1357E-04
          14028.31c 3.6675E-04
          15031.31c 1.3479E-05
          25055.31c 8.6145E-04
          24050.31c 4.0943E-04
          24052.31c 7.8955E-03
          24053.31c 8.9529E-04
          24054.31c 2.2286E-04
          26054.31c 2.0823E-03
          26056.31c 3.2687E-02
          26057.31c 7.5489E-04
          26058.31c 1.0046E-04
          28058.31c 2.8417E-03
          28060.31c 1.0946E-03
          28061.31c 4.7581E-05
          28062.31c 1.5171E-04
          28064.31c 3.8636E-05
          29063.31c 1.1638E-02
          29065.31c 4.9880E-03
c total 34 6.72170E-02
c
C MATERIAL 35 Pu metal plate PUVIII8 core
c
m35      92238.31c 6.9057E-07
          94238.31c 3.0583E-05
          94239.31c 2.9035E-02
          94240.31c 6.9371E-03
          94241.31c 1.1574E-03
          94242.31c 1.8773E-04
          95241.31c 4.4181E-05
          1001.31c 1.2815E-04

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ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

6000.31c  4.2429E-04
7014.31c  2.4312E-05
8016.31c  8.8804E-05
13027.31c 2.3065E-05
14028.31c  1.4215E-05
25055.31c  1.4962E-06
24050.31c  1.5700E-07
24052.31c  3.0275E-06
24053.31c  3.4330E-07
24054.31c  8.5455E-08
26054.31c  9.5858E-07
26056.31c  1.5048E-05
26057.31c  3.4751E-07
26058.31c  4.6247E-08
28058.31c  5.8567E-06
28060.31c  2.2560E-06
28061.31c  9.8066E-08
28062.31c  3.1268E-07
28064.31c  7.9630E-08
31000.31c  2.0247E-03
c total 35 4.01503E-02
c MATERIAL 36 PuVIII8 plate canning
c CR 9.4087E-03 FE 3.5570E-02 NI 4.1678E-03
m36  1001.31c  1.3771E-05
      6000.31c  1.1340E-04
      14028.31c 3.6619E-04
      15031.31c  1.3461E-05
      25055.31c  8.6013E-04
      24050.31c  4.0881E-04
      24052.31c  7.8835E-03
      24053.31c  8.9392E-04
      24054.31c  2.2252E-04
      26054.31c  2.0791E-03
      26056.31c  3.2637E-02
      26057.31c  7.5372E-04
      26058.31c  1.0031E-04
      28058.31c  2.8373E-03
      28060.31c  1.0929E-03
      28061.31c  4.7509E-05
      28062.31c  1.5148E-04
      28064.31c  3.8577E-05
      29063.31c  1.1638E-02
      29065.31c  4.9880E-03
c total 36 6.71396E-02
c
c MATERIAL 45 sodium plate NASTDL4 core
c
m45  1001.31c  1.3418E-05
      8016.31c  5.6353E-06
      11023.31c 2.3168E-02
      20040.31c 3.5994E-06
      26054.31c  9.4362E-09
      26056.31c  1.4813E-07
      26057.31c  3.4209E-09
      26058.31c  4.5526E-10
c total 45 2.31908E-02
c MATERIAL 46 Sodium plate NASTDL4 canning
c
m46  1001.31c  2.4319E-05
      6000.31c  2.8978E-04
      14028.31c  6.0218E-04
      15031.31c  3.2445E-05
      16032.31c  3.2865E-05
      25055.31c  1.3425E-03
      24050.31c  6.3446E-04
      24052.31c  1.2235E-02
      24053.31c  1.3873E-03
      24054.31c  3.4534E-04
      26054.31c  3.1836E-03
      26056.31c  4.9976E-02
      26057.31c  1.1541E-03
      26058.31c  1.5360E-04
      28058.31c  4.7807E-03
      28060.31c  1.8415E-03
      28061.31c  8.0049E-05
      28062.31c  2.5523E-04

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```
28064.31c 6.5000E-05
41093.31c 3.0815E-04
c total 46 7.87241E-02
c
c --- MODE CARDS ---
c
c
mode n
kcode 10000 1.0 100 1500
ksrc 0.0 0.0 107.5 0.0 0.0 118.5 0.0 0.0 130.0 0.0 0.0 141.0
      0.0 0.0 152.5 0.0 0.0 163.5 0.0 0.0 175.0 0.0 0.0 186.0
      27.0 0.0 107.5 27.0 0.0 118.5 27.0 0.0 130.0 27.0 0.0 141.0
      27.0 0.0 152.5 27.0 0.0 163.5 27.0 0.0 175.0 27.0 0.0 186.0
      -27.0 0.0 107.5 -27.0 0.0 118.5 -27.0 0.0 130.0 -27.0 0.0 141.0
      -27.0 0.0 152.5 -27.0 0.0 163.5 -27.0 0.0 175.0 -27.0 0.0 186.0
      0.0 27.0 107.5 0.0 27.0 118.5 0.0 27.0 130.0 0.0 27.0 141.0
      0.0 27.0 152.5 0.0 27.0 163.5 0.0 27.0 175.0 0.0 27.0 186.0
      0.0 -27.0 107.5 0.0 -27.0 118.5 0.0 -27.0 130.0 0.0 -27.0 141.0
      0.0 -27.0 152.5 0.0 -27.0 163.5 0.0 -27.0 175.0 0.0 -27.0 186.0
      27.0 27.0 107.5 27.0 27.0 118.5 27.0 27.0 130.0 27.0 27.0 141.0
      27.0 27.0 152.5 27.0 27.0 163.5 27.0 27.0 175.0 27.0 27.0 186.0
      -27.0 27.0 107.5 -27.0 27.0 118.5 -27.0 27.0 130.0 -27.0 27.0 141.0
      -27.0 27.0 152.5 -27.0 27.0 163.5 -27.0 27.0 175.0 -27.0 27.0 186.0
      27.0 -27.0 107.5 27.0 -27.0 118.5 27.0 -27.0 130.0 27.0 -27.0 141.0
      27.0 -27.0 152.5 27.0 -27.0 163.5 27.0 -27.0 175.0 27.0 -27.0 186.0
      -27.0 -27.0 107.5 -27.0 -27.0 118.5 -27.0 -27.0 130.0 -27.0 -27.0 141.0
      -27.0 -27.0 152.5 -27.0 -27.0 163.5 -27.0 -27.0 175.0 -27.0 -27.0 186.0
      8.1 8.1 107.5 8.1 8.1 118.5 8.1 8.1 130.0 8.1 8.1 141.0
      8.1 8.1 152.5 8.1 8.1 163.5 8.1 8.1 175.0 8.1 8.1 186.0
      -8.1 8.1 107.5 -8.1 8.1 118.5 -8.1 8.1 130.0 -8.1 8.1 141.0
      -8.1 8.1 152.5 -8.1 8.1 163.5 -8.1 8.1 175.0 -8.1 8.1 186.0
      8.1 -8.1 107.5 8.1 -8.1 118.5 8.1 -8.1 130.0 8.1 -8.1 141.0
      8.1 -8.1 152.5 8.1 -8.1 163.5 8.1 -8.1 175.0 8.1 -8.1 186.0
      -8.1 -8.1 107.5 -8.1 -8.1 118.5 -8.1 -8.1 130.0 -8.1 -8.1 141.0
      -8.1 -8.1 152.5 -8.1 -8.1 163.5 -8.1 -8.1 175.0 -8.1 -8.1 186.0
print
```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

MCNP JEFF-3.1 Model C of MZA

```

Zebra Assembly MZA detailed model C. Uniform lattice no Void gaps.
c JEFF-3.1
c The experimental value of k-effective to be used with this model is
c      1.0097 +/- 0.0016
c
c See www.zebra.webnik.org for details.
c
c ----- Elements of the assembly -----
c
c --- Core Element C11A
c
c Lower padding
111      16 3.279692E-02 -8 21 -22 23 -24 u=1 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
112      0  8 -9 21 -22 23 -24 fill=31 (0 0 30.0) u=1 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
121      0  9 -41 21 -22 23 -24 fill=21 (0 0 63.0048) u=1 imp:n=1
c
122      0  41 -42 21 -22 23 -24 fill=21 (0 0 71.7414) u=1 imp:n=1
c
123      0  42 -43 21 -22 23 -24 fill=21 (0 0 80.478) u=1 imp:n=1
c
124      0  43 -10 21 -22 23 -24 fill=21 (0 0 89.2146) u=1 imp:n=1
c
c
c
c The 12 core cells
c
151      0  10 -44 21 -22 23 -24 fill=11 (0 0 97.9512) u=1 imp:n=1
c
152      0  44 -45 21 -22 23 -24 fill=11 (0 0 105.447) u=1 imp:n=1
c
153      0  45 -46 21 -22 23 -24 fill=11 (0 0 112.9428) u=1 imp:n=1
c
154      0  46 -47 21 -22 23 -24 fill=11 (0 0 120.4386) u=1 imp:n=1
c
155      0  47 -48 21 -22 23 -24 fill=11 (0 0 127.9344) u=1 imp:n=1
c
156      0  48 -49 21 -22 23 -24 fill=11 (0 0 135.4302) u=1 imp:n=1
c
157      0  49 -50 21 -22 23 -24 fill=11 (0 0 142.926) u=1 imp:n=1
c
158      0  50 -51 21 -22 23 -24 fill=11 (0 0 150.4218) u=1 imp:n=1
c
159      0  51 -52 21 -22 23 -24 fill=11 (0 0 157.9176) u=1 imp:n=1
c
160      0  52 -53 21 -22 23 -24 fill=11 (0 0 165.4134) u=1 imp:n=1
c
161      0  53 -54 21 -22 23 -24 fill=11 (0 0 172.9092) u=1 imp:n=1
c
162      0  54 -11 21 -22 23 -24 fill=11 (0 0 180.405) u=1 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
181      0  11 -56 21 -22 23 -24 fill=21 (0 0 187.9008) u=1 imp:n=1
c
182      0  56 -57 21 -22 23 -24 fill=21 (0 0 196.6374 ) u=1 imp:n=1
c
183      0  57 -58 21 -22 23 -24 fill=21 (0 0 205.374) u=1 imp:n=1
c
184      0  58 -12 21 -22 23 -24 fill=21 (0 0 214.1106) u=1 imp:n=1
c
c Upper Plenum
c
186      0  12 -13 21 -22 23 -24 fill=32 (0 0 222.8472) u=1 imp:n=1
c
c Upper padding
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

188      16 3.279692E-02 13 -16 21 -22 23 -24 u=1 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
191      17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=1 imp:n=1
c
c End of Core Element C11A
c
c
c --- Core Element C11B
c
c Lower padding
211      16 3.279692E-02 -8 21 -22 23 -24 u=2 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
212      0  8 -9 21 -22 23 -24 fill=31 (0 0 30.0) u=2 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
221      0  9 -41 21 -22 23 -24 fill=22 (0 0 63.0048) u=2 imp:n=1
c
222      0 41 -42 21 -22 23 -24 fill=22 (0 0 71.7414) u=2 imp:n=1
c
223      0 42 -43 21 -22 23 -24 fill=22 (0 0 80.478) u=2 imp:n=1
c
224      0 43 -10 21 -22 23 -24 fill=22 (0 0 89.2146) u=2 imp:n=1
c
c
c
c The 12 core cells
c
251      0 10 -44 21 -22 23 -24 fill=12 (0 0 97.9512) u=2 imp:n=1
c
252      0 44 -45 21 -22 23 -24 fill=12 (0 0 105.447) u=2 imp:n=1
c
253      0 45 -46 21 -22 23 -24 fill=12 (0 0 112.9428) u=2 imp:n=1
c
254      0 46 -47 21 -22 23 -24 fill=12 (0 0 120.4386) u=2 imp:n=1
c
255      0 47 -48 21 -22 23 -24 fill=12 (0 0 127.9344) u=2 imp:n=1
c
256      0 48 -49 21 -22 23 -24 fill=12 (0 0 135.4302) u=2 imp:n=1
c
257      0 49 -50 21 -22 23 -24 fill=12 (0 0 142.926) u=2 imp:n=1
c
258      0 50 -51 21 -22 23 -24 fill=12 (0 0 150.4218) u=2 imp:n=1
c
259      0 51 -52 21 -22 23 -24 fill=12 (0 0 157.9176) u=2 imp:n=1
c
260      0 52 -53 21 -22 23 -24 fill=12 (0 0 165.4134) u=2 imp:n=1
c
261      0 53 -54 21 -22 23 -24 fill=12 (0 0 172.9092) u=2 imp:n=1
c
262      0 54 -11 21 -22 23 -24 fill=12 (0 0 180.405) u=2 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
281      0 11 -56 21 -22 23 -24 fill=22 (0 0 187.9008) u=2 imp:n=1
c
282      0 56 -57 21 -22 23 -24 fill=22 (0 0 196.6374 ) u=2 imp:n=1
c
283      0 57 -58 21 -22 23 -24 fill=22 (0 0 205.374) u=2 imp:n=1
c
284      0 58 -12 21 -22 23 -24 fill=22 (0 0 214.1106) u=2 imp:n=1
c
c Upper Plenum
c
286      0 12 -13 21 -22 23 -24 fill=32 (0 0 222.8472) u=2 imp:n=1
c
c Upper padding
c
288      16 3.279692E-02 13 -16 21 -22 23 -24 u=2 imp:n=1 TMP=2.5301E-08
c
c

```


ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c Wrapper region
291      17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=2 imp:n=1
c
c End of Core Element C11B
c
c --- Core Element C11C
c
c Lower padding
311      16 3.279692E-02 -8 21 -22 23 -24 u=3 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
312      0  8 -9 21 -22 23 -24 fill=31 (0 0 30.0) u=3 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
321      0  9 -41 21 -22 23 -24 fill=22 (0 0 63.0048) u=3 imp:n=1
c
322      0 41 -42 21 -22 23 -24 fill=22 (0 0 71.7414) u=3 imp:n=1
c
323      0 42 -43 21 -22 23 -24 fill=22 (0 0 80.478) u=3 imp:n=1
c
324      0 43 -10 21 -22 23 -24 fill=22 (0 0 89.2146) u=3 imp:n=1
c
c
c The 12 core cells
c
351      0 10 -44 21 -22 23 -24 fill=13 (0 0 97.9512) u=3 imp:n=1
c
352      0 44 -45 21 -22 23 -24 fill=13 (0 0 105.447) u=3 imp:n=1
c
353      0 45 -46 21 -22 23 -24 fill=13 (0 0 112.9428) u=3 imp:n=1
c
354      0 46 -47 21 -22 23 -24 fill=13 (0 0 120.4386) u=3 imp:n=1
c
355      0 47 -48 21 -22 23 -24 fill=13 (0 0 127.9344) u=3 imp:n=1
c
356      0 48 -49 21 -22 23 -24 fill=13 (0 0 135.4302) u=3 imp:n=1
c
357      0 49 -50 21 -22 23 -24 fill=13 (0 0 142.926) u=3 imp:n=1
c
358      0 50 -51 21 -22 23 -24 fill=13 (0 0 150.4218) u=3 imp:n=1
c
359      0 51 -52 21 -22 23 -24 fill=13 (0 0 157.9176) u=3 imp:n=1
c
360      0 52 -53 21 -22 23 -24 fill=13 (0 0 165.4134) u=3 imp:n=1
c
361      0 53 -54 21 -22 23 -24 fill=13 (0 0 172.9092) u=3 imp:n=1
c
362      0 54 -11 21 -22 23 -24 fill=13 (0 0 180.405) u=3 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
381      0 11 -56 21 -22 23 -24 fill=22 (0 0 187.9008) u=3 imp:n=1
c
382      0 56 -57 21 -22 23 -24 fill=22 (0 0 196.6374 ) u=3 imp:n=1
c
383      0 57 -58 21 -22 23 -24 fill=22 (0 0 205.374) u=3 imp:n=1
c
384      0 58 -12 21 -22 23 -24 fill=22 (0 0 214.1106) u=3 imp:n=1
c
c Upper Plenum
c
386      0 12 -13 21 -22 23 -24 fill=32 (0 0 222.8472) u=3 imp:n=1
c
c Upper padding
c
388      16 3.279692E-02 13 -16 21 -22 23 -24 u=3 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
391      17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=3 imp:n=1
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c End of Core Element C11C
c
c
c --- Core Element C11D
c
c Lower padding
411      16 3.279692E-02 -8 21 -22 23 -24 u=5 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
412      0  8 -9 21 -22 23 -24 fill=31 (0 0 30.0) u=5 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
421      0  9 -41 21 -22 23 -24 fill=22 (0 0 63.0048) u=5 imp:n=1
c
422      0 41 -42 21 -22 23 -24 fill=22 (0 0 71.7414) u=5 imp:n=1
c
423      0 42 -43 21 -22 23 -24 fill=22 (0 0 80.478) u=5 imp:n=1
c
424      0 43 -10 21 -22 23 -24 fill=22 (0 0 89.2146) u=5 imp:n=1
c
c
c
c The 12 core cells
c
451      0 10 -44 21 -22 23 -24 fill=15 (0 0 97.9512) u=5 imp:n=1
c
452      0 44 -45 21 -22 23 -24 fill=15 (0 0 105.447) u=5 imp:n=1
c
453      0 45 -46 21 -22 23 -24 fill=15 (0 0 112.9428) u=5 imp:n=1
c
454      0 46 -47 21 -22 23 -24 fill=15 (0 0 120.4386) u=5 imp:n=1
c
455      0 47 -48 21 -22 23 -24 fill=15 (0 0 127.9344) u=5 imp:n=1
c
456      0 48 -49 21 -22 23 -24 fill=15 (0 0 135.4302) u=5 imp:n=1
c
457      0 49 -50 21 -22 23 -24 fill=15 (0 0 142.926) u=5 imp:n=1
c
458      0 50 -51 21 -22 23 -24 fill=15 (0 0 150.4218) u=5 imp:n=1
c
459      0 51 -52 21 -22 23 -24 fill=15 (0 0 157.9176) u=5 imp:n=1
c
460      0 52 -53 21 -22 23 -24 fill=15 (0 0 165.4134) u=5 imp:n=1
c
461      0 53 -54 21 -22 23 -24 fill=15 (0 0 172.9092) u=5 imp:n=1
c
462      0 54 -11 21 -22 23 -24 fill=15 (0 0 180.405) u=5 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
481      0 11 -56 21 -22 23 -24 fill=22 (0 0 187.9008) u=5 imp:n=1
c
482      0 56 -57 21 -22 23 -24 fill=22 (0 0 196.6374 ) u=5 imp:n=1
c
483      0 57 -58 21 -22 23 -24 fill=22 (0 0 205.374) u=5 imp:n=1
c
484      0 58 -12 21 -22 23 -24 fill=22 (0 0 214.1106) u=5 imp:n=1
c
c Upper Plenum
c
486      0 12 -13 21 -22 23 -24 fill=32 (0 0 222.8472) u=5 imp:n=1
c
c Upper padding
c
488      16 3.279692E-02 13 -16 21 -22 23 -24 u=5 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
491      17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=5 imp:n=1
c
c
c End of Core Element C11D
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c --- Radial Blanket Elements
c
c Lower padding
1211    like 111 but u=6 imp:n=1 TMP=2.5301E-08
c Lower Plenum
1212    like 112 but u=6 imp:n=1 TMP=2.5301E-08
c Radial blanket
c Lower Radial Blanket Section comprising 3 cells
c
1221      0  9 -803 21 -22 23 -24 fill=25 (0 0 63.0048) u=6 imp:n=1
c
1222      0  803 -804 21 -22 23 -24 fill=25 (0 0 73.155) u=6 imp:n=1
c
1223      0  804 -805 21 -22 23 -24 fill=25 (0 0 83.3052) u=6 imp:n=1
c
c
c The 20 Radial blanket Central Section Cells
c
1231      0  805 -806 21 -22 23 -24 fill=24 (0 0 93.4554) u=6 imp:n=1
c
1232      0  806 -807 21 -22 23 -24 fill=24 (0 0 98.485) u=6 imp:n=1
c
1233      0  807 -808 21 -22 23 -24 fill=24 (0 0 103.5146) u=6 imp:n=1
c
1234      0  808 -809 21 -22 23 -24 fill=24 (0 0 108.5442) u=6 imp:n=1
c
1235      0  809 -810 21 -22 23 -24 fill=24 (0 0 113.5738) u=6 imp:n=1
c
1236      0  810 -811 21 -22 23 -24 fill=24 (0 0 118.6034) u=6 imp:n=1
c
1237      0  811 -812 21 -22 23 -24 fill=24 (0 0 123.633) u=6 imp:n=1
c
1238      0  812 -813 21 -22 23 -24 fill=24 (0 0 128.6626) u=6 imp:n=1
c
1239      0  813 -814 21 -22 23 -24 fill=24 (0 0 133.6922) u=6 imp:n=1
c
1240      0  814 -815 21 -22 23 -24 fill=24 (0 0 138.7218) u=6 imp:n=1
c
1241      0  815 -816 21 -22 23 -24 fill=24 (0 0 143.7514) u=6 imp:n=1
c
1242      0  816 -817 21 -22 23 -24 fill=24 (0 0 148.781) u=6 imp:n=1
c
1243      0  817 -818 21 -22 23 -24 fill=24 (0 0 153.8106) u=6 imp:n=1
c
1244      0  818 -819 21 -22 23 -24 fill=24 (0 0 158.8402) u=6 imp:n=1
c
1245      0  819 -820 21 -22 23 -24 fill=24 (0 0 163.8698) u=6 imp:n=1
c
1246      0  820 -821 21 -22 23 -24 fill=24 (0 0 168.8994) u=6 imp:n=1
c
1247      0  821 -822 21 -22 23 -24 fill=24 (0 0 173.929) u=6 imp:n=1
c
1248      0  822 -823 21 -22 23 -24 fill=24 (0 0 178.9586) u=6 imp:n=1
c
1249      0  823 -824 21 -22 23 -24 fill=24 (0 0 183.9882) u=6 imp:n=1
c
1250      0  824 -825 21 -22 23 -24 fill=24 (0 0 189.0178) u=6 imp:n=1
c
c Upper Radial Blanket. 4 Cells
c
1261      0  825 -826 21 -22 23 -24 fill=25 (0 0 194.0474) u=6 imp:n=1
c
1262      0  826 -827 21 -22 23 -24 fill=25 (0 0 204.1976) u=6 imp:n=1
c
1263      0  827 -828 21 -22 23 -24 fill=25 (0 0 214.3478) u=6 imp:n=1
c
c Upper Plenum
1271      0  828 -829 21 -22 23 -24 fill=32 (0 0 224.498) u=6 imp:n=1
c
c Upper padding
1272      16 3.279692E-02 829 -16 21 -22 23 -24 u=6 imp:n=1 TMP=2.5301E-08
c Wrapper region
c
1275      17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=6 imp:n=1
c
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c --- Radial shield
c
1326    12 8.32720E-02 28 -29 30 -31 u=7 imp:n=1 TMP=2.5301E-08
c
1327    13 8.32720E-05 1 -2 3 -4 (-28:29:-30:31) u=7 imp:n=1
      TMP=2.5301E-08
c
1400    13 8.32720E-05 1 -2 3 -4 u=9 imp:n=1 TMP=2.5301E-08
c
c --- Assembly
c
1419    0   1 -2 3 -4 u=10 lat=1
      fill=-18:18 -18:18 0:0
      9 36r
      9 15r 7 4r 9 15r
      9 14r 7 6r 9 14r
      9 10r 7 14r 9 10r
      9 8r 7 7r 6 2r 7 7r 9 8r
      9 7r 7 4r 6 10r 7 4r 9 7r
      9 6r 7 3r 6 14r 7 3r 9 6r
      9 5r 7 3r 6 16r 7 3r 9 5r
      9 4r 7 3r 6 18r 7 3r 9 4r
      9 3r 7 3r 6 20r 7 3r 9 3r
      9 3r 7 2r 6 9r 5 2r 6 9r 7 2r 9 3r
      9 2r 7 2r 6 7r 5 2r 3 2r 5 2r 6 7r 7 2r 9 2r
      9 2r 7 2r 6 6r 5 5 3 6r 5 5 6 6r 7 2r 9 2r
      9 2r 7 1r 6 6r 5 3 3r 2 2r 3 3r 5 6 6r 7 1r 9 2r
      9 2r 7 1r 6 5r 5 5 3 3 2 6r 3 3 5 6 5r 7 1r 9 2r
      9 1r 7 2r 6 5r 5 3 3 2 2 1 4r 2 2 3 3 5 6 5r 7 2r 9 1r
      9 7 3r 6 5r 5 3 3 2 1 6r 2 3 3 5 6 5r 7 3r 9
      9 7 2r 6 5r 5 3 3 2 2 1 6r 2 2 3 3 5 6 5r 7 2r 9
      9 7 2r 6 5r 5 3 3 2 2 1 6r 2 2 3 3 5 6 5r 7 2r 9
      9 7 2r 6 5r 5 3 3 2 2 1 6r 2 2 3 3 5 6 5r 7 2r 9
      9 7 3r 6 5r 5 3 3 2 1 6r 2 3 3 5 6 5r 7 3r 9
      9 1r 7 2r 6 5r 5 3 3 2 2 1 4r 2 2 3 3 5 6 5r 7 2r 9 1r
      9 2r 7 1r 6 5r 5 5 3 3 2 6r 3 3 5 6 5r 7 1r 9 2r
      9 2r 7 1r 6 6r 5 3 3r 2 2r 3 3r 5 6 6r 7 1r 9 2r
      9 2r 7 2r 6 6r 5 5 3 6r 5 5 6 6r 7 2r 9 2r
      9 2r 7 2r 6 7r 5 2r 3 2r 5 2r 6 7r 7 2r 9 2r
      9 3r 7 2r 6 9r 5 2r 6 9r 7 2r 9 3r
      9 3r 7 3r 6 20r 7 3r 9 3r
      9 4r 7 3r 6 18r 7 3r 9 4r
      9 5r 7 3r 6 16r 7 3r 9 5r
      9 6r 7 3r 6 14r 7 3r 9 6r
      9 7r 7 4r 6 10r 7 4r 9 7r
      9 8r 7 7r 6 2r 7 7r 9 8r
      9 10r 7 14r 9 10r
      9 14r 7 6r 9 14r
      9 15r 7 4r 9 15r
      9 36r
      imp:n=1
c
c
c --- Fuel Region
c
1429    0 7 -16 -17 fill=10 imp:n=1
c --- Universe
1430    0 (-7:16:17) imp:n=0
c
c ----- CELL CARDS -----
c
c MZA Core Cell A.
c
c Na plate
c Na plate core
2101    5 2.3126E-02 202 -203 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
c Na plate can
2102    6 7.865043E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=11 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2103    3 6.867137E-02 205 -206 105 -106 107 -108 u=11 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2104    4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=11 imp:n=1 TMP=2.5301E-08

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Na plate
c Na plate core
2105 5 2.3126E-02 208 -209 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
C Na plate can
2106 6 7.865043E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=11 imp:n=1 TMP=2.5301E-08
c
c Pu plate
C Plate core
2107 1 4.023746E-02 101 -102 103 -104 211 -212 u=11 imp:n=1 TMP=2.5301E-08
C Pu canning
2108 2 6.6033E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=11 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2109 7 8.607216E-02 213 -214 21 -22 23 -24 u=11 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2110 3 6.867137E-02 215 -216 105 -106 107 -108 u=11 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2111 4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=11 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2112 5 2.3126E-02 218 -219 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
C Na plate can
2113 6 7.865043E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=11 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2114 5 2.3126E-02 221 -222 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
C Na plate can
2115 6 7.865043E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=11 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2116 3 6.867137E-02 224 -225 105 -106 107 -108 u=11 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2117 4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=11 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2118 10 8.1484E-02 226 -227 21 -22 23 -24 u=11 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate
C Plate core
2119 1 4.023746E-02 228 -229 101 -102 103 -104 u=11 imp:n=1 TMP=2.5301E-08
C Pu canning
2120 2 6.6033E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=11 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2121 5 2.3126E-02 231 -232 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
C Na plate can
2122 6 7.865043E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=11 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2123 3 6.867137E-02 234 -235 105 -106 107 -108 u=11 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2124 4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=11 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2125 5 2.3126E-02 237 -238 109 -110 111 -112 u=11 imp:n=1 TMP=2.5301E-08
C Na plate can

```

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LIQUID METAL FAST REACTOR - LMFR
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```

2126   6 7.865043E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=11  imp:n=1 TMP=2.5301E-08
c
c End of MZA Core Cell A
c
c
c MZA Core Cell B.
c
c Na plate
c Na plate core
2201   45 2.31908E-02 202 -203 109 -110 111 -112 u=12  imp:n=1 TMP=2.5301E-08
C Na plate can
2202   46 7.87241E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=12  imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2203   3 6.867137E-02 205 -206 105 -106 107 -108 u=12  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2204   4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=12  imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2205   45 2.31908E-02 208 -209 109 -110 111 -112 u=12  imp:n=1 TMP=2.5301E-08
C Na plate can
2206   46 7.87241E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=12  imp:n=1 TMP=2.5301E-08
c
c Pu plate
C Plate core
2207   31 4.04903E-02 101 -102 103 -104 211 -212 u=12  imp:n=1 TMP=2.5301E-08
C Pu canning
2208   32 6.74722E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=12  imp:n=1 TMP=2.5301E-08
c
c Steel plate
2209   7 8.607216E-02 213 -214 21 -22 23 -24 u=12  imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2210   3 6.867137E-02 215 -216 105 -106 107 -108 u=12  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2211   4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=12  imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2212   45 2.31908E-02 218 -219 109 -110 111 -112 u=12  imp:n=1 TMP=2.5301E-08
C Na plate can
2213   46 7.87241E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=12  imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2214   45 2.31908E-02 221 -222 109 -110 111 -112 u=12  imp:n=1 TMP=2.5301E-08
C Na plate can
2215   46 7.87241E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=12  imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2216   3 6.867137E-02 224 -225 105 -106 107 -108 u=12  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2217   4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=12  imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2218   10 8.1484E-02 226 -227 21 -22 23 -24 u=12  imp:n=1 TMP=2.5301E-08
c
c
c Pu plate
C Plate core
2219   31 4.04903E-02 228 -229 101 -102 103 -104 u=12  imp:n=1 TMP=2.5301E-08
C Pu canning

```

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```

2220 32 6.74722E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=12 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2221 45 2.31908E-02 231 -232 109 -110 111 -112 u=12 imp:n=1 TMP=2.5301E-08
c Na plate can
2222 46 7.87241E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=12 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2223 3 6.867137E-02 234 -235 105 -106 107 -108 u=12 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2224 4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=12 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2225 45 2.31908E-02 237 -238 109 -110 111 -112 u=12 imp:n=1 TMP=2.5301E-08
c Na plate can
2226 46 7.87241E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=12 imp:n=1 TMP=2.5301E-08
c
c End of MZA Core Cell B
c
c
c MZA Core Cell C.
c
c Na plate
c Na plate core
2301 45 2.31908E-02 202 -203 109 -110 111 -112 u=13 imp:n=1 TMP=2.5301E-08
c Na plate can
2302 46 7.87241E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=13 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2303 3 6.867137E-02 205 -206 105 -106 107 -108 u=13 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2304 4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=13 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2305 45 2.31908E-02 208 -209 109 -110 111 -112 u=13 imp:n=1 TMP=2.5301E-08
c Na plate can
2306 46 7.87241E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=13 imp:n=1 TMP=2.5301E-08
c
c Pu plate
c Plate core
2307 33 3.99151E-02 101 -102 103 -104 211 -212 u=13 imp:n=1 TMP=2.5301E-08
c Pu canning
2308 34 6.72170E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=13 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2309 7 8.607216E-02 213 -214 21 -22 23 -24 u=13 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2310 3 6.867137E-02 215 -216 105 -106 107 -108 u=13 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2311 4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=13 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2312 45 2.31908E-02 218 -219 109 -110 111 -112 u=13 imp:n=1 TMP=2.5301E-08
c Na plate can
2313 46 7.87241E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=13 imp:n=1 TMP=2.5301E-08
c
c
c Na plate

```

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```

c Na plate core
2314 45 2.31908E-02 221 -222 109 -110 111 -112 u=13 imp:n=1 TMP=2.5301E-08
C Na plate can
2315 46 7.87241E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=13 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2316 3 6.867137E-02 224 -225 105 -106 107 -108 u=13 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2317 4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=13 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2318 10 8.1484E-02 226 -227 21 -22 23 -24 u=13 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate
C Plate core
2319 33 3.99151E-02 228 -229 101 -102 103 -104 u=13 imp:n=1 TMP=2.5301E-08
C Pu canning
2320 34 6.72170E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=13 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2321 45 2.31908E-02 231 -232 109 -110 111 -112 u=13 imp:n=1 TMP=2.5301E-08
C Na plate can
2322 46 7.87241E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=13 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2323 3 6.867137E-02 234 -235 105 -106 107 -108 u=13 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2324 4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=13 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2325 45 2.31908E-02 237 -238 109 -110 111 -112 u=13 imp:n=1 TMP=2.5301E-08
C Na plate can
2326 46 7.87241E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=13 imp:n=1 TMP=2.5301E-08
c
c End of MZA Core Cell C
c
c
c MZA Core Cell D.
c
c Na plate
c Na plate core
2401 45 2.31908E-02 202 -203 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
C Na plate can
2402 46 7.87241E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=15 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2403 3 6.867137E-02 205 -206 105 -106 107 -108 u=15 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2404 4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=15 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2405 45 2.31908E-02 208 -209 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
C Na plate can
2406 46 7.87241E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=15 imp:n=1 TMP=2.5301E-08
c
c Pu plate
C Plate core
2407 35 4.01503E-02 101 -102 103 -104 211 -212 u=15 imp:n=1 TMP=2.5301E-08
C Pu canning
2408 36 6.71396E-02 210 -213 21 -22 23 -24 &

```


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LIQUID METAL FAST REACTOR - LMFR
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```

(-101:102:-103:104:-211:212) u=15 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2409 7 8.607216E-02 213 -214 21 -22 23 -24 u=15 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2410 3 6.867137E-02 215 -216 105 -106 107 -108 u=15 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2411 4 6.5639E-02 214 -217 21 -22 23 -24 &
(-105:106:-107:108:-215:216) u=15 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2412 45 2.31908E-02 218 -219 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
C Na plate can
2413 46 7.87241E-02 217 -220 21 -22 23 -24 &
(-109:110:-111:112:-218:219) u=15 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2414 45 2.31908E-02 221 -222 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
C Na plate can
2415 46 7.87241E-02 220 -223 21 -22 23 -24 &
(-109:110:-111:112:-221:222) u=15 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2416 3 6.867137E-02 224 -225 105 -106 107 -108 u=15 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2417 4 6.5639E-02 223 -226 21 -22 23 -24 &
(-105:106:-107:108:-224:225) u=15 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2418 10 8.1484E-02 226 -227 21 -22 23 -24 u=15 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate
C Plate core
2419 35 4.01503E-02 228 -229 101 -102 103 -104 u=15 imp:n=1 TMP=2.5301E-08
C Pu canning
2420 36 6.71396E-02 227 -230 21 -22 23 -24 &
(-101:102:-103:104:-228:229) u=15 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2421 45 2.31908E-02 231 -232 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
C Na plate can
2422 46 7.87241E-02 230 -233 21 -22 23 -24 &
(-109:110:-111:112:-231:232) u=15 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2423 3 6.867137E-02 234 -235 105 -106 107 -108 u=15 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2424 4 6.5639E-02 233 -236 21 -22 23 -24 &
(-105:106:-107:108:-234:235) u=15 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2425 45 2.31908E-02 237 -238 109 -110 111 -112 u=15 imp:n=1 TMP=2.5301E-08
C Na plate can
2426 46 7.87241E-02 236 -239 21 -22 23 -24 &
(-109:110:-111:112:-237:238) u=15 imp:n=1 TMP=2.5301E-08
c
c End of MZA Core Cell D
c
c Axial blanket cell B11
c
c Na plate
c Na plate core
2601 5 2.3126E-02 402 -403 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2602 6 7.865043E-02 401 -404 21 -22 23 -24 &
(-109:110:-111:112:-402:403) u=21 imp:n=1 TMP=2.5301E-08

```

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```

c
c U8 plate
2603 8 4.7208E-02 404 -405 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2604 10 8.1484E-02 405 -406 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2605 5 2.3126E-02 407 -408 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2606 6 7.865043E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=21 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2607 7 8.607216E-02 409 -410 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2608 8 4.7208E-02 410 -411 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2609 5 2.3126E-02 412 -413 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2610 6 7.865043E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=21 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2611 10 8.1484E-02 414 -415 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2612 5 2.3126E-02 416 -417 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2613 6 7.865043E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=21 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2614 7 8.607216E-02 418 -419 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2615 8 4.7208E-02 419 -420 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2616 5 2.3126E-02 421 -422 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2617 6 7.865043E-02 420 -423 21 -22 23 -24 &
      (-109:110:-111:112:-421:422) u=21 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2618 10 8.1484E-02 423 -424 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2619 5 2.3126E-02 425 -426 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2620 6 7.865043E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=21 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2621 8 4.7208E-02 427 -428 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2622 7 8.607216E-02 428 -429 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2623 5 2.3126E-02 430 -431 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2624 6 7.865043E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=21 imp:n=1 TMP=2.5301E-08
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```
c
c U8 plate
2625 8 4.7208E-02 432 -433 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8
2626 10 8.1484E-02 433 -434 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2627 5 2.3126E-02 435 -436 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2628 6 7.865043E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=21 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B11
c
c
c Axial blanket cell B11-A
c
c Na plate
c Na plate core
2701 45 2.31908E-02 402 -403 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2702 46 7.87241E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=22 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2703 8 4.7208E-02 404 -405 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2704 10 8.1484E-02 405 -406 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2705 45 2.31908E-02 407 -408 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2706 46 7.87241E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=22 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2707 7 8.607216E-02 409 -410 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2708 8 4.7208E-02 410 -411 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2709 45 2.31908E-02 412 -413 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2710 46 7.87241E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=22 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2711 10 8.1484E-02 414 -415 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2712 45 2.31908E-02 416 -417 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2713 46 7.87241E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=22 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2714 7 8.607216E-02 418 -419 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2715 8 4.7208E-02 419 -420 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2716 45 2.31908E-02 421 -422 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2717 46 7.87241E-02 420 -423 21 -22 23 -24 &
```

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LIQUID METAL FAST REACTOR - LMFR
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```

(-109:110:-111:112:-421:422) u=22  imp:n=1  TMP=2.5301E-08
c
c Graphite plate GI8
2718  10 8.1484E-02 423 -424 21 -22 23 -24 u=22  imp:n=1  TMP=2.5301E-08
c
c Na plate
c Na plate core
2719  45 2.31908E-02 425 -426 109 -110 111 -112 u=22  imp:n=1  TMP=2.5301E-08
C Na plate can
2720  46 7.87241E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=22  imp:n=1  TMP=2.5301E-08
c
c U8 plate
2721  8 4.7208E-02 427 -428 21 -22 23 -24 u=22  imp:n=1  TMP=2.5301E-08
c
c
c Steel plate
2722  7 8.607216E-02 428 -429 21 -22 23 -24 u=22  imp:n=1  TMP=2.5301E-08
c
c Na plate
c Na plate core
2723  45 2.31908E-02 430 -431 109 -110 111 -112 u=22  imp:n=1  TMP=2.5301E-08
C Na plate can
2724  46 7.87241E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=22  imp:n=1  TMP=2.5301E-08
c
c
c U8 plate
2725  8 4.7208E-02 432 -433 21 -22 23 -24 u=22  imp:n=1  TMP=2.5301E-08
c
c
c Graphite plate GI8
2726  10 8.1484E-02 433 -434 21 -22 23 -24 u=22  imp:n=1  TMP=2.5301E-08
c
c Na plate
c Na plate core
2727  45 2.31908E-02 435 -436 109 -110 111 -112 u=22  imp:n=1  TMP=2.5301E-08
C Na plate can
2728  46 7.87241E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=22  imp:n=1  TMP=2.5301E-08
c
c End of Axial Blanket Cell B11-A
c
c Radial Blanket Central Range
c
c Graphite plate GII8
2801  11 8.5125E-02 501 -502 21 -22 23 -24 u=24  imp:n=1  TMP=2.5301E-08
c
c Na plate
c Na plate core
2802  5 2.3126E-02 503 -504 109 -110 111 -112 u=24  imp:n=1  TMP=2.5301E-08
C Na plate can
2803  6 7.865043E-02 502 -505 21 -22 23 -24 &
      (-109:110:-111:112:-503:504) u=24  imp:n=1  TMP=2.5301E-08
c
c Graphite plate GII8
2804  11 8.5125E-02 505 -506 21 -22 23 -24 u=24  imp:n=1  TMP=2.5301E-08
c
c Steel plate
2805  7 8.607216E-02 506 -507 21 -22 23 -24 u=24  imp:n=1  TMP=2.5301E-08
c
c U2 plate
2806  9 4.7925E-02 507 -508 21 -22 23 -24 u=24  imp:n=1  TMP=2.5301E-08
c
c Graphite plate GII8
2807  11 8.5125E-02 508 -509 21 -22 23 -24 u=24  imp:n=1  TMP=2.5301E-08
c
c Na plate
c Na plate core
2808  5 2.3126E-02 510 -511 109 -110 111 -112 u=24  imp:n=1  TMP=2.5301E-08
C Na plate can
2809  6 7.865043E-02 509 -512 21 -22 23 -24 &
      (-109:110:-111:112:-510:511) u=24  imp:n=1  TMP=2.5301E-08
c
c MST8 plate
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
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```

2810  27 8.4980E-02 512 -513  21 -22 23 -24 u=24  imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2811  11 8.5125E-02 513 -514  21 -22 23 -24 u=24  imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2812   5 2.3126E-02  515 -516 109 -110 111 -112 u=24  imp:n=1 TMP=2.5301E-08
c Na plate can
2813   6 7.865043E-02 514 -517  21 -22 23 -24 &
      (-109:110:-111:112:-515:516) u=24  imp:n=1 TMP=2.5301E-08
c
c End of Central Section of the Radial blanket
c
c Upper and Lower Section of the radial Blanket
c
c ALG8
2851  29 2.6752E-02 601 -603  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c AL2O34
2852  30 1.106986E-01 603 -604  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c GII8
2853  11 8.5125E-02 604 -605  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c ALG8
2854  29 2.6752E-02 605 -606  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c U2 plate
2855   9 4.7925E-02 606 -607  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c ALG8
2856  29 2.6752E-02 607 -608  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c GII8
2857  11 8.5125E-02 608 -609  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c AL2O34
2858  30 1.106986E-01 609 -610  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c MST2 (MST8) plate
c
2859  27 8.4980E-02 610 -611  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2860  29 2.6752E-02 611 -612  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c GII8
2861  11 8.5125E-02 612 -613  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2862  29 2.6752E-02 613 -615  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c U2 plate
2863   9 4.7925E-02 615 -616  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c AL2O34
2864  30 1.106986E-01 616 -617  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2865  29 2.6752E-02 617 -618  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c GII8
2866  11 8.5125E-02 618 -619  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c MST8 plate
c

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

2867   27 8.4980E-02 619 -620  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c  ALG8
2868   29 2.6752E-02 620 -621  21 -22 23 -24 u=25  imp:n=1 TMP=2.5301E-08
c
c
c  End of upper and lower radial blanket sections
c
c  c Lower Plenum Cell
c
c  ALSC3 plate
2901   28 4.7627E-02  7 -33  21 -22 23 -24 u=31  imp:n=1 TMP=2.5301E-08
c
c  MST1 plate
c
2902   27 8.4980E-02 33 -34  21 -22 23 -24 u=31  imp:n=1 TMP=2.5301E-08
c
c  ALSC3 plate
2903   28 4.7627E-02 34 -35  21 -22 23 -24 u=31  imp:n=1 TMP=2.5301E-08
c
c  MST3 plate
c
2904   27 8.4980E-02 35 -36  21 -22 23 -24 u=31  imp:n=1 TMP=2.5301E-08
c
c  ALSC3 plate
c
2905   28 4.7627E-02 36 -37  21 -22 23 -24 u=31  imp:n=1 TMP=2.5301E-08
c
c  Upper Plenum Cell
c
c  ALSC3 plate
c
2911   28 4.7627E-02  7 -33  21 -22 23 -24 u=32  imp:n=1 TMP=2.5301E-08
c
c  MST3 plate
c
2912   27 8.4980E-02 33 -38  21 -22 23 -24 u=32  imp:n=1 TMP=2.5301E-08
c
c  ALSC3 plate
2913   28 4.7627E-02 38 -39  21 -22 23 -24 u=32  imp:n=1 TMP=2.5301E-08
c
c  MST1 plate
c
2914   27 8.4980E-02 39 -36  21 -22 23 -24 u=32  imp:n=1 TMP=2.5301E-08
c
c  ALSC3 plate
2915   28 4.7627E-02 36 -37  21 -22 23 -24 u=32  imp:n=1 TMP=2.5301E-08
c
c  Cell data complete
c
c  -----
c
c
c  ----- SURFACE CARDS -----
c
c  MZA Core and MZB Outer Core Element cell surfaces
1      px -2.7127
2      px  2.7127
3      py -2.7127
4      py  2.7127
7      pz 0.0 $ Assembly lower limit
8      pz 30.0 $ End Lower Packing, Start Plenum
9      pz 63.0048 $ End Plenum, Start Lower Axial Blanket
10     pz 97.9512 $ End Lower Blanket, Start Core Fuel
11     pz 187.9008 $ End Core Fuel, Start Upper Axial Blanket
12     pz 222.8472 $ End Upper Blanket, Start Upper Plenum
13     pz 255.852 $ End Upper Plenum, Start Upper Packing
16     pz 285.0 $ Assembly upper axial limit
17     cz 94.6345 $ Assembly outer radius
21     px -2.5335 $ Nominal half-width of plates
22     px  2.5335
23     py -2.5335
24     py  2.5335

```

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CRIT-BUCK-SPEC-REAC-RRATE

```

28      px -2.54 $ Radial shield half-width
29      px 2.54
30      py -2.54
31      py 2.54
c
c axial heights in the lower plenum
33      pz 7.62 $ alsc3
34      pz 10.1585 $ mst1
35      pz 17.7785 $ alsc3
36      pz 25.3848 $ mst3
37      pz 33.0048 $ alsc3
c different axial heights in the upper plenum
38      pz 15.2263 $ mst3
39      pz 22.8463 $ alsc3 / mst1
c
c cell subdivisions in the axial blanket and core cells of MZA elements
c
c 9      pz 63.0048 $ End Plenum, Start Lower Axial Blanket
41      pz 71.7414
42      pz 80.478
43      pz 89.2146
c 10 pz 97.9512 $ lower axial blanket / core
44      pz 105.447
45      pz 112.9428
46      pz 120.4386
47      pz 127.9344
48      pz 135.4302
49      pz 142.926
50      pz 150.4218
51      pz 157.9176
52      pz 165.4134
53      pz 172.9092
54      pz 180.405
c 11      pz 187.9008 $ core / upper axial blanket
56      pz 196.6374
57      pz 205.374
58      pz 214.1106
c 12      pz 222.8472 $ axial blanket / plenum
c
c
62      px -2.551 $ sheath inner half-width
63      px 2.551
64      py -2.551
65      py 2.551
66      px -2.6272 $ sheath outer half-width
67      px 2.6272
68      py -2.6272
69      py 2.6272
c
c
c Grid plate heights
c
71      pz 31.8
72      pz 62.2
73      pz 162.6
74      pz 193.0
c
c coordinates of the elements in 5x5 arrays
81      px -8.05815
82      px 8.05815
83      py -8.05815
84      py 8.05815
85      px -13.43025
86      px 13.43025
87      py -13.43025
88      py 13.43025
89      px -13.5635
90      px 13.5635
91      py -13.5635
92      py 13.5635
c
c plate inner core widths
c
101     px -2.3355 $ Pu metal plate core width
102     px 2.3355
103     py -2.3355

```

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LIQUID METAL FAST REACTOR - LMFR
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104 py 2.3355
105 px -2.4255 \$ UO2 plate core width
106 px 2.4255
107 py -2.4255
108 py 2.4255
109 px -2.4815 \$ Na plate core width
110 px 2.4815
111 py -2.4815
112 py 2.4815
c 113 px -2.4765 \$ MOX plate PUIV4
c 114 px 2.4765
c 115 py -2.4765
c 116 py 2.4765

c

c

c MZA Core Cell Axial heights

c

201 pz 0
202 pz 0.03683
203 pz 0.57917 \$ Na
204 pz 0.616
205 pz 0.65283
206 pz 1.20707 \$ UO2
207 pz 1.2439
208 pz 1.28073
209 pz 1.82307 \$ Na
210 pz 1.8599
211 pz 1.90562
212 pz 2.14068 \$ Pu
213 pz 2.1864
214 pz 2.5036 \$ SS
215 pz 2.54043
216 pz 3.09467 \$ UO2
217 pz 3.1315
218 pz 3.16833
219 pz 3.71067 \$ Na
220 pz 3.7475
221 pz 3.78433
222 pz 4.32667 \$ Na
223 pz 4.3635
224 pz 4.40033
225 pz 4.95457 \$ UO2
226 pz 4.9914
227 pz 5.3094 \$ GI8
228 pz 5.35512
229 pz 5.59018 \$ Pu
230 pz 5.6359
231 pz 5.67273
232 pz 6.21507 \$ Na
233 pz 6.2519
234 pz 6.28873
235 pz 6.84297 \$ UO2
236 pz 6.8798
237 pz 6.91663
238 pz 7.45897 \$ Na
239 pz 7.4958

c

c MZB Inner core cell axial heights

c

c 301 pz 0
c 302 pz 0.03683
c 303 pz 0.57917 \$ na
c 304 pz 0.616
c 305 pz 0.65283

c

c Axial blanket cells

c

401 pz 0
402 pz 0.03683
403 pz 0.57917 \$ na
404 pz 0.616
405 pz 0.933 \$ u8
406 pz 1.251 \$ g
407 pz 1.28783
408 pz 1.83017 \$ na
409 pz 1.867

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410	pz	2.1842	\$ ss
411	pz	2.5012	\$ u8
412	pz	2.53803	
413	pz	3.08037	\$ na
414	pz	3.1172	
415	pz	3.4352	\$ g
416	pz	3.47203	
417	pz	4.01437	\$ na
418	pz	4.0512	
419	pz	4.3684	\$ ss
420	pz	4.6854	\$ u8
421	pz	4.72223	
422	pz	5.26457	\$ na
423	pz	5.3014	
424	pz	5.6194	\$ g
425	pz	5.65623	
426	pz	6.19857	\$ na
427	pz	6.2354	
428	pz	6.5524	\$ u8
429	pz	6.8696	\$ ss
430	pz	6.90643	
431	pz	7.44877	\$ na
432	pz	7.4856	
433	pz	7.8036	\$ g
434	pz	8.1206	\$ u8
435	pz	8.15743	
436	pz	8.69977	\$ na
437	pz	8.7366	
c			
c Inner (axially) radial blanket cells			
c			
501	pz	0	
502	pz	0.31775	\$ g
503	pz	0.35458	
504	pz	0.89692	\$ na
505	pz	0.93375	
506	pz	1.2515	\$ g
507	pz	1.5751	\$ ss
508	pz	2.8474	\$ u2
509	pz	3.16515	\$ g
510	pz	3.20198	
511	pz	3.74432	\$ na
512	pz	3.78115	
513	pz	4.09585	\$ mst
514	pz	4.4136	\$ g
515	pz	4.45043	
516	pz	4.99277	\$ na
517	pz	5.0296	
c			
c Upper and lower sections of the radial blanket			
c			
601	pz	0	
c 602	pz	0.317	\$ al
603	pz	0.634	\$ al
604	pz	1.2657	\$ al2o3
605	pz	1.58345	\$ gii
606	pz	1.90045	\$ al
607	pz	3.17275	\$ u2
608	pz	3.48975	\$ al
609	pz	3.8075	\$ gii
610	pz	4.4392	\$ al2o3
611	pz	5.711	\$ mst2
612	pz	6.028	\$ al
613	pz	6.34575	\$ gii
c 614	pz	6.66275	\$ al
615	pz	6.97975	\$ al
616	pz	8.25205	\$ u2
617	pz	8.88375	\$ al2o3
618	pz	9.20075	\$ al
619	pz	9.5185	\$ gii
620	pz	9.8332	\$ mst8
621	pz	10.1502	\$ al
c			
c heights of cells in the MZB inner core elements			
c			
c 701	pz	97.9512	\$ First core cell upper boundary

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```

c
c Heights of cells in the radial blanket
c
801 pz 30.0 $ Packing
802 pz 63.0048 $ End Lower plenum/
803 pz 73.155
804 pz 83.3052
805 pz 93.4554 $ End Lower Blanket
806 pz 98.485
807 pz 103.5146
808 pz 108.5442
809 pz 113.5738
810 pz 118.6034
811 pz 123.633
812 pz 128.6626
813 pz 133.6922
814 pz 138.7218
815 pz 143.7514
816 pz 148.781
817 pz 153.8106
818 pz 158.8402
819 pz 163.8698
820 pz 168.8994
821 pz 173.929
822 pz 178.9586
823 pz 183.9882
824 pz 189.0178
825 pz 194.0474 $ End Middle Blanket
826 pz 204.1976
827 pz 214.3478
828 pz 224.498 $ End Upper Blanket
829 pz 257.5028 $ End Upper plenum
830 pz 285.0 $ Top of assembly

```

```

c
c
c -----
c

```

```

c
c
c ----- TALLY CARDS -----
c
c --- MATERIALS CARDS ---
c

```

```

c Region Compositions
C MATERIAL 1 Pu metal plate PUV8 core

```

```

c
ml 92238.31c 1.3318E-06
    94238.31c 2.9103E-05
    94239.31c 2.9328E-02
    94240.31c 6.7928E-03
    94241.31c 1.0119E-03
    94242.31c 1.6639E-04
    95241.31c 9.4236E-05
    1001.31c 1.7475E-04
    6000.31c 2.5027E-04
    7014.31c 1.3413E-05
    8016.31c 5.0640E-05
    13027.31c 2.1760E-05
    14028.31c 2.3831E-05
    25055.31c 1.0687E-06
    24050.31c 2.2568E-07
    24052.31c 4.3521E-06
    24053.31c 4.9349E-07
    24054.31c 1.2284E-07
    26054.31c 9.7085E-07
    26056.31c 1.5240E-05
    26057.31c 3.5197E-07
    26058.31c 4.6840E-08
    28058.31c 8.0358E-06
    28060.31c 3.0954E-06
    28061.31c 1.3455E-07
    28062.31c 4.2902E-07
    28064.31c 1.0926E-07
    31000.31c 2.2424E-03

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

42092.31c 2.9375E-07
42094.31c 1.9583E-07
42095.31c 2.9375E-07
42096.31c 2.9375E-07
42097.31c 1.9583E-07
42098.31c 4.8958E-07
42100.31c 1.9583E-07
c total 4.023746E-02
c MATERIAL 2 PuV8 plate canning
c
m2    1001.31c 1.3404E-05
      6000.31c 9.2801E-05
      14028.31c 4.1625E-04
      15031.31c 1.8432E-05
      16032.31c 9.3252E-06
      25055.31c 7.5220E-04
      24050.31c 4.0213E-04
      24052.31c 7.7546E-03
      24053.31c 8.7931E-04
      24054.31c 2.1888E-04
      26054.31c 2.0054E-03
      26056.31c 3.1481E-02
      26057.31c 7.2703E-04
      26058.31c 9.6754E-05
      28058.31c 3.0905E-03
      28060.31c 1.1905E-03
      28061.31c 5.1748E-05
      28062.31c 1.6500E-04
      28064.31c 4.2019E-05
c      29063.31c 1.6626E-02
      29063.31c 1.1638E-02
      29065.31c 4.9880E-03
c total 6.6033E-02
C MATERIAL 3 UO2 plate UO24R4 core
c
m3    1001.31c 2.4503E-05
      6000.31c 3.0842E-05
      8016.31c 4.5733E-02
      13027.31c 3.3911E-06
      14028.31c 1.3190E-05
      26054.31c 3.8771E-07
      26056.31c 6.0862E-06
      26057.31c 1.4056E-07
      26058.31c 1.8706E-08
      92234.31c 1.1871E-06
      92235.31c 1.6462E-04
      92238.31c 2.2694E-02
c total 6.867137E-02
c MATERIAL 4 UO2 plate UO24R4 canning
c
m4    1001.31c 1.7335E-05
      6000.31c 1.4546E-04
      14028.31c 6.0964E-04
      15031.31c 2.2563E-05
      16032.31c 2.1792E-05
      25055.31c 9.7951E-04
      24050.31c 5.3726E-04
      24052.31c 1.0361E-02
      24053.31c 1.1748E-03
      24054.31c 2.9243E-04
      26054.31c 2.5374E-03
      26056.31c 3.9831E-02
      26057.31c 9.1988E-04
      26058.31c 1.2242E-04
      28058.31c 4.0937E-03
      28060.31c 1.5769E-03
      28061.31c 6.8547E-05
      28062.31c 2.1856E-04
      28064.31c 5.5660E-05
      29063.31c 5.7122E-04
      29065.31c 2.4481E-04
      47107.31c 6.3840E-04
      47109.31c 5.9840E-04
c total 6.5639E-02
C MATERIAL 5 sodium plate NASTBR4 core
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```
m5      1001.31c  2.1098E-06
        3006.31c  2.8720E-08
        3007.31c  3.5424E-07
        5010.31c  2.9500E-08
        5011.31c  1.1802E-07
        8016.31c  1.9937E-06
        11023.31c 2.3119E-02
        19039.31c 4.6230E-07
        20040.31c 1.7244E-06
        26054.31c 2.2256E-09
        26056.31c 3.4937E-08
        26057.31c 8.0685E-10
        26058.31c 1.0738E-10
```

c total 2.3126E-02

c MATERIAL 6 Sodium plate NASTBR4 canning

c

```
m6      1001.31c  2.1496E-05
        6000.31c  2.1646E-04
        14028.31c 6.0171E-04
        15031.31c  2.7979E-05
        16032.31c  2.7023E-05
        25055.31c  1.0806E-03
        24050.31c  6.5175E-04
        24052.31c  1.2568E-02
        24053.31c  1.4252E-03
        24054.31c  3.5475E-04
        26054.31c  3.1596E-03
        26056.31c  4.9599E-02
        26057.31c  1.1454E-03
        26058.31c  1.5244E-04
        28058.31c  4.9357E-03
        28060.31c  1.9012E-03
        28061.31c  8.2645E-05
        28062.31c  2.6351E-04
        28064.31c  6.7108E-05
        28064.31c  6.5701E-05
        41093.31c  3.0316E-04
```

c total 7.865043E-02

C MATERIAL 7 STSTBR8 steel plate

c

```
m7      1001.31c  2.3265E-05
        6000.31c  7.8091E-04
        13027.31c  1.7381E-04
        14028.31c  1.3358E-03
        22048.31c  2.9384E-04
        25055.31c  9.3901E-04
        24050.31c  7.0932E-04
        24052.31c  1.3679E-02
        24053.31c  1.5510E-03
        24054.31c  3.8609E-04
        26054.31c  3.4063E-03
        26056.31c  5.3472E-02
        26057.31c  1.2349E-03
        26058.31c  1.6434E-04
        28058.31c  5.2766E-03
        28060.31c  2.0326E-03
        28061.31c  8.8354E-05
        28062.31c  2.8171E-04
        28064.31c  7.1743E-05
        29063.31c  5.1661E-05
        29065.31c  2.2140E-05
        42092.31c  1.4665E-05
        42094.31c  9.7764E-06
        42095.31c  1.4665E-05
        42096.31c  1.4665E-05
        42097.31c  9.7764E-06
        42098.31c  2.4441E-05
        42100.31c  9.7764E-06
```

c total 8.607216E-02

c

C MATERIAL 8 U8 metal plate

```
m8      1001.31c  4.4048E-05
        6000.31c  4.9283E-04
        14028.31c  2.1076E-04
        26054.31c  6.1951E-06
        26056.31c  9.7250E-05
```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

26057.31c  2.2459E-06
26058.31c  2.9889E-08
92235.31c  3.3369E-04
92238.31c  4.6021E-02
c total 4.7208E-02
C MATERIAL 9 U2 metal plate
m9  1001.31c  4.3899E-05
    6000.31c  4.6047E-04
    14028.31c 1.9692E-04
    26054.31c  5.7884E-06
    26056.31c  9.0866E-05
    26057.31c  2.0985E-06
    26058.31c  2.7927E-08
    92235.31c  3.3962E-04
    92238.31c  4.6785E-02
c total 4.7925E-02
c MATERIAL 10 Graphite plate GI8
m10 1001.31c  4.8551E-05
    6000.31c  8.1417E-02
    16032.31c 1.2207E-05
    26054.31c  3.5851E-07
    26056.31c  5.6278E-06
    26057.31c  1.2997E-07
    26058.31c  1.7297E-08
c Total 8.1484E-02
c MATERIAL 11 Graphite plate GII8
m11 1001.31c  2.0286E-05
    6000.31c  8.5101E-02
    16032.31c 1.2751E-06
    26054.31c  1.0700E-07
    26056.31c  1.6796E-06
    26057.31c  3.8790E-08
    26058.31c  5.1623E-09
c total 8.5125E-02
c Steel radial shield
m12 1001.31c  4.6306E-05
    6000.31c  6.8972E-04
    14028.31c 3.1158E-04
    15031.31c 4.2944E-05
    16032.31c 3.7110E-05
    25055.31c 7.1275E-04
    26054.31c 4.9065E-03
    26056.31c 7.4517E-02
    26057.31c 1.7491E-03
    26058.31c 2.5903E-04
c total 8.32720E-02
c
c radial shield void surround low density
m13 1001.31c  4.6306E-08
    6000.31c  6.8972E-07
    14028.31c 3.1158E-07
    15031.31c 4.2944E-08
    16032.31c 3.7110E-08
    25055.31c 7.1275E-07
    26054.31c 4.9065E-06
    26056.31c 7.4517E-05
    26057.31c 1.7491E-06
    26058.31c 2.5903E-07
c total 8.32720E-05
c
c Axial shield
m14 1001.31c  2.5700E-05
    6000.31c  5.1066E-04
    13027.31c 1.3989E-04
    22048.31c 3.9416E-05
    24050.31c 1.2213E-06
    24052.31c 2.2823E-05
    24053.31c 2.5531E-06
    24054.31c 6.2449E-07
    25055.31c 3.2634E-04
    26054.31c 5.0496E-03
    26056.31c 7.6690E-02
    26057.31c 1.8001E-03
    26058.31c 2.6658E-04
    28058.31c 1.2564E-06
    28060.31c 4.6968E-07

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

28061.31c 2.2000E-08
28062.31c 6.2769E-08
28064.31c 1.6774E-08
29063.31c 3.1184E-05
29065.31c 1.3364E-05
  42092.31c 1.4753E-06
  42094.31c 9.8355E-07
  42095.31c 1.4753E-06
  42096.31c 1.4753E-06
  42097.31c 9.8355E-07
  42098.31c 2.4589E-06
  42100.31c 9.8355E-07
c total 8.4932E-02
c
c Assembly Axial Padding at bottom and top of elements
ml6   1001.31c 3.1777E-05
      6000.31c 9.9996E-05
      13027.31c 8.3095E-06
      24050.31c 6.9087E-08
      24052.31c 1.2911E-06
      24053.31c 1.4442E-07
      24054.31c 3.5326E-08
      25055.31c 1.0785E-04
      26054.31c 1.9605E-03
      26056.31c 2.9775E-02
      26057.31c 6.9890E-04
      26058.31c 1.0350E-04
      28058.31c 1.5636E-07
      28060.31c 5.8452E-08
      28061.31c 2.7378E-09
      28062.31c 7.8115E-09
      28064.31c 2.0875E-09
      29063.31c 6.5270E-06
      29065.31c 2.7973E-06
c Total 3.279692E-02
c
c Smeared stainless steel wrapper material
c
ml7   1001.31c 9.7398E-06
      6000.31c 3.2692E-04
      13027.31c 1.4553E-04
      14028.31c 4.1943E-04
      22048.31c 1.2302E-04
      23000.31c 3.8541E-05
      25055.31c 5.0032E-04
      24050.31c 2.9367E-04
      24052.31c 5.6632E-03
      24053.31c 6.4216E-04
      24054.31c 1.5985E-04
      26054.31c 1.3891E-03
      26056.31c 2.1805E-02
      26057.31c 5.0358E-04
      26058.31c 6.7017E-05
      28058.31c 2.5734E-03
      28060.31c 9.9126E-04
      28061.31c 4.3089E-05
      28062.31c 1.3739E-04
      28064.31c 3.4989E-05
      29063.31c 3.1184E-05
      29065.31c 1.3364E-05
      42092.31c 1.4753E-06
      42094.31c 9.8355E-07
      42095.31c 1.4753E-06
      42096.31c 1.4753E-06
      42097.31c 9.8355E-07
      42098.31c 2.4589E-06
      42100.31c 9.8355E-07
c Total 3.595949E-02
c
c
c M27 Mild Steel MST3
m27   1001.31c 2.8087E-05
      6000.31c 5.1066E-04
      13027.31c 1.3989E-04
      22048.31c 3.9416E-05
      25055.31c 3.2634E-04

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

24050.31c 1.1828E-06
24052.31c 2.2809E-05
24053.31c 2.5864E-06
24054.31c 6.4380E-07
26054.31c 4.8985E-03
26056.31c 7.6895E-02
26057.31c 1.7758E-03
26058.31c 2.3633E-04
28058.31c 3.2836E-05
28060.31c 1.2648E-05
28061.31c 5.4982E-07
28062.31c 1.7531E-06
28064.31c 4.4645E-07
29063.31c 3.1184E-05
29065.31c 1.3364E-05
42092.31c 1.4753E-06
42094.31c 9.8355E-07
42095.31c 1.4753E-06
42096.31c 1.4753E-06
42097.31c 9.8355E-07
42098.31c 2.4589E-06
42100.31c 9.8355E-07
c Total atoms 8.4980E-02
c
c M28 Aluminium plate ALSC3
m28
    13027.31c 4.7590E-02
    14028.31c 4.5790E-06
    25055.31c 9.3634E-07
    26054.31c 1.7498E-06
    26056.31c 2.7467E-05
    26057.31c 6.3434E-07
    26058.31c 8.4420E-08
    29063.31c 1.2574E-06
    29065.31c 5.4640E-07
c Total 4.7627E-02
c
c M29 Aluminium plate ALG8
m29 13027.31c 2.6704E-02
    14028.31c 1.0296E-05
    25055.31c 6.5793E-07
    26054.31c 2.1261E-06
    26056.31c 3.3375E-05
    26057.31c 7.7077E-07
    26058.31c 1.0257E-07
    29063.31c 3.1853E-07
    29065.31c 1.3652E-07
c Total 2.6752E-02
c
c MATERIAL 30 AL2O34
m30 1001.31c 5.1483E-05
    5010.31c 4.5063E-06
    5011.31c 1.6599E-05
    8016.31c 6.6386E-02
    13027.31c 4.4240E-02
c Total 1.106986E-01
c
C MATERIAL 31 Pu metal plate PUVI8 core
c
m31 92238.31c 2.4663E-07
    94238.31c 3.6995E-05
    94239.31c 2.8972E-02
    94240.31c 7.3421E-03
    94241.31c 1.1537E-03
    94242.31c 2.0132E-04
    95241.31c 8.6769E-05
    1001.31c 1.0485E-04
    6000.31c 2.2876E-04
    7014.31c 2.4312E-05
    8016.31c 3.5962E-05
    13027.31c 1.7408E-05
    25055.31c 1.0687E-06
    24050.31c 1.3737E-07
    24052.31c 2.6491E-06
    24053.31c 3.0038E-07
    24054.31c 7.4772E-08

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ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

26054.31c 1.1307E-06
26056.31c 1.7749E-05
26057.31c 4.0990E-07
26058.31c 5.4549E-08
28058.31c 4.6308E-06
28060.31c 1.7838E-06
28061.31c 7.7540E-08
28062.31c 2.4723E-07
28064.31c 6.2963E-08
31000.31c 2.2555E-03
c total 31 4.04903E-02
c MATERIAL 32 PuVI8 plate canning
c
m32 1001.31c 1.3955E-05
      6000.31c 1.1413E-04
      14028.31c 3.6853E-04
      15031.31c 1.3545E-05
      16032.31c 9.3252E-06
      25055.31c 8.6563E-04
      24050.31c 4.1142E-04
      24052.31c 7.9338E-03
      24053.31c 8.9963E-04
      24054.31c 2.2394E-04
      26054.31c 2.0924E-03
      26056.31c 3.2846E-02
      26057.31c 7.5855E-04
      26058.31c 1.0095E-04
      28058.31c 2.8554E-03
      28060.31c 1.0999E-03
      28061.31c 4.7812E-05
      28062.31c 1.5245E-04
      28064.31c 3.8823E-05
      29063.31c 1.1638E-02
      29065.31c 4.9880E-03
c total 32 6.74722E-02
c
C MATERIAL 33 Pu metal plate PUVII8 core
c
m33 92238.31c 9.3720E-07
      94238.31c 3.1569E-05
      94239.31c 2.9028E-02
      94240.31c 6.9606E-03
      94241.31c 1.1476E-03
      94242.31c 1.8725E-04
      95241.31c 5.3467E-05
      1001.31c 1.3980E-04
      6000.31c 2.0335E-04
      7014.31c 6.7066E-06
      8016.31c 5.4310E-05
      13027.31c 1.6973E-05
      14028.31c 1.0870E-05
      25055.31c 8.5494E-07
      24050.31c 1.7662E-07
      24052.31c 3.4059E-06
      24053.31c 3.8621E-07
      24054.31c 9.6135E-08
      26054.31c 6.1449E-07
      26056.31c 9.6461E-06
      26057.31c 2.2277E-07
      26058.31c 2.9646E-08
      28058.31c 6.1291E-06
      28060.31c 2.3609E-06
      28061.31c 1.0263E-07
      28062.31c 3.2722E-07
      28064.31c 8.3333E-08
      31000.31c 2.0492E-03
c total 33 3.99151E-02
c MATERIAL 34 PuVII8 plate canning
c
m34 1001.31c 1.3771E-05
      6000.31c 1.1357E-04
      14028.31c 3.6675E-04
      15031.31c 1.3479E-05
      25055.31c 8.6145E-04
      24050.31c 4.0943E-04
      24052.31c 7.8955E-03

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ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

24053.31c 8.9529E-04
24054.31c 2.2286E-04
26054.31c 2.0823E-03
26056.31c 3.2687E-02
26057.31c 7.5489E-04
26058.31c 1.0046E-04
28058.31c 2.8417E-03
28060.31c 1.0946E-03
28061.31c 4.7581E-05
28062.31c 1.5171E-04
28064.31c 3.8636E-05
29063.31c 1.1638E-02
29065.31c 4.9880E-03
c total 34 6.72170E-02
c
C MATERIAL 35 Pu metal plate PUVIII8 core
c
m35 92238.31c 6.9057E-07
94238.31c 3.0583E-05
94239.31c 2.9035E-02
94240.31c 6.9371E-03
94241.31c 1.1574E-03
94242.31c 1.8773E-04
95241.31c 4.4181E-05
1001.31c 1.2815E-04
6000.31c 4.2429E-04
7014.31c 2.4312E-05
8016.31c 8.8804E-05
13027.31c 2.3065E-05
14028.31c 1.4215E-05
25055.31c 1.4962E-06
24050.31c 1.5700E-07
24052.31c 3.0275E-06
24053.31c 3.4330E-07
24054.31c 8.5455E-08
26054.31c 9.5858E-07
26056.31c 1.5048E-05
26057.31c 3.4751E-07
26058.31c 4.6247E-08
28058.31c 5.8567E-06
28060.31c 2.2560E-06
28061.31c 9.8066E-08
28062.31c 3.1268E-07
28064.31c 7.9630E-08
31000.31c 2.0247E-03
c total 35 4.01503E-02
c MATERIAL 36 PuVIII8 plate canning
c CR 9.4087E-03 FE 3.5570E-02 NI 4.1678E-03
m36 1001.31c 1.3771E-05
6000.31c 1.1340E-04
14028.31c 3.6619E-04
15031.31c 1.3461E-05
25055.31c 8.6013E-04
24050.31c 4.0881E-04
24052.31c 7.8835E-03
24053.31c 8.9392E-04
24054.31c 2.2252E-04
26054.31c 2.0791E-03
26056.31c 3.2637E-02
26057.31c 7.5372E-04
26058.31c 1.0031E-04
28058.31c 2.8373E-03
28060.31c 1.0929E-03
28061.31c 4.7509E-05
28062.31c 1.5148E-04
28064.31c 3.8577E-05
29063.31c 1.1638E-02
29065.31c 4.9880E-03
c total 36 6.71396E-02
c
C MATERIAL 45 sodium plate NASTDL4 core
c
m45 1001.31c 1.3418E-05
8016.31c 5.6353E-06
11023.31c 2.3168E-02
20040.31c 3.5994E-06

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ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

26054.31c 9.4362E-09
26056.31c 1.4813E-07
26057.31c 3.4209E-09
26058.31c 4.5526E-10
c total 45 2.31908E-02
c MATERIAL 46 Sodium plate NASTDL4 canning
c
m46      1001.31c 2.4319E-05
        6000.31c 2.8978E-04
        14028.31c 6.0218E-04
        15031.31c 3.2445E-05
        16032.31c 3.2865E-05
        25055.31c 1.3425E-03
        24050.31c 6.3446E-04
        24052.31c 1.2235E-02
        24053.31c 1.3873E-03
        24054.31c 3.4534E-04
        26054.31c 3.1836E-03
        26056.31c 4.9976E-02
        26057.31c 1.1541E-03
        26058.31c 1.5360E-04
        28058.31c 4.7807E-03
        28060.31c 1.8415E-03
        28061.31c 8.0049E-05
        28062.31c 2.5523E-04
        28064.31c 6.5000E-05
        41093.31c 3.0815E-04
c total 46 7.87241E-02
c
c --- MODE CARDS ---
c
c
mode n
kcode 10000 1.0 100 1500
ksrc 0.0 0.0 107.5 0.0 0.0 118.5 0.0 0.0 130.0 0.0 0.0 141.0
      0.0 0.0 152.5 0.0 0.0 163.5 0.0 0.0 175.0 0.0 0.0 186.0
      27.0 0.0 107.5 27.0 0.0 118.5 27.0 0.0 130.0 27.0 0.0 141.0
      27.0 0.0 152.5 27.0 0.0 163.5 27.0 0.0 175.0 27.0 0.0 186.0
      -27.0 0.0 107.5 -27.0 0.0 118.5 -27.0 0.0 130.0 -27.0 0.0 141.0
      -27.0 0.0 152.5 -27.0 0.0 163.5 -27.0 0.0 175.0 -27.0 0.0 186.0
      0.0 27.0 107.5 0.0 27.0 118.5 0.0 27.0 130.0 0.0 27.0 141.0
      0.0 27.0 152.5 0.0 27.0 163.5 0.0 27.0 175.0 0.0 27.0 186.0
      0.0 -27.0 107.5 0.0 -27.0 118.5 0.0 -27.0 130.0 0.0 -27.0 141.0
      0.0 -27.0 152.5 0.0 -27.0 163.5 0.0 -27.0 175.0 0.0 -27.0 186.0
      27.0 27.0 107.5 27.0 27.0 118.5 27.0 27.0 130.0 27.0 27.0 141.0
      27.0 27.0 152.5 27.0 27.0 163.5 27.0 27.0 175.0 27.0 27.0 186.0
      -27.0 27.0 107.5 -27.0 27.0 118.5 -27.0 27.0 130.0 -27.0 27.0 141.0
      -27.0 27.0 152.5 -27.0 27.0 163.5 -27.0 27.0 175.0 -27.0 27.0 186.0
      27.0 -27.0 107.5 27.0 -27.0 118.5 27.0 -27.0 130.0 27.0 -27.0 141.0
      27.0 -27.0 152.5 27.0 -27.0 163.5 27.0 -27.0 175.0 27.0 -27.0 186.0
      -27.0 -27.0 107.5 -27.0 -27.0 118.5 -27.0 -27.0 130.0 -27.0 -27.0 141.0
      -27.0 -27.0 152.5 -27.0 -27.0 163.5 -27.0 -27.0 175.0 -27.0 -27.0 186.0
      8.1 8.1 107.5 8.1 8.1 118.5 8.1 8.1 130.0 8.1 8.1 141.0
      8.1 8.1 152.5 8.1 8.1 163.5 8.1 8.1 175.0 8.1 8.1 186.0
      -8.1 8.1 107.5 -8.1 8.1 118.5 -8.1 8.1 130.0 -8.1 8.1 141.0
      -8.1 8.1 152.5 -8.1 8.1 163.5 -8.1 8.1 175.0 -8.1 8.1 186.0
      8.1 -8.1 107.5 8.1 -8.1 118.5 8.1 -8.1 130.0 8.1 -8.1 141.0
      8.1 -8.1 152.5 8.1 -8.1 163.5 8.1 -8.1 175.0 8.1 -8.1 186.0
      -8.1 -8.1 107.5 -8.1 -8.1 118.5 -8.1 -8.1 130.0 -8.1 -8.1 141.0
      -8.1 -8.1 152.5 -8.1 -8.1 163.5 -8.1 -8.1 175.0 -8.1 -8.1 186.0
print

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

The MCNP JEFF-3.1 Detailed Model A of MZB

```

Zebra Assembly MZB detailed model. Grid regions and Void gaps. JEFF3.1
c
c The experimental value of k-effective to be used with this model is
c 1.0044 +/- 0.0012
c See www.zebra.webnik.org for details.
c
c ----- Elements of the assembly -----
c
c --- MZB Inner Core Element A (C12-30A)
c
c Lower padding
c
111      16 3.279692E-02 -8 21 -22 23 -24 u=1 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
112      0  8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=1 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
121      0  9 -41 21 -22 23 -24 fill=41 (0 0 63.0048) u=1 imp:n=1
c
122      0  41 -42 21 -22 23 -24 fill=41 (0 0 71.7414) u=1 imp:n=1
c
123      0  42 -43 21 -22 23 -24 fill=41 (0 0 80.478) u=1 imp:n=1
c
124      0  43 -10 21 -22 23 -24 fill=41 (0 0 89.2146) u=1 imp:n=1
c
c
c The 11 MZB Inner Core Cells
c
151      0  10 -702 21 -22 23 -24 fill=21 (0 0 97.9512) u=1 imp:n=1
c
152      0  702 -703 21 -22 23 -24 fill=21 (0 0 106.0599) u=1 imp:n=1
c
153      0  703 -704 21 -22 23 -24 fill=21 (0 0 114.1686) u=1 imp:n=1
c
154      0  704 -705 21 -22 23 -24 fill=21 (0 0 122.2773) u=1 imp:n=1
c
155      0  705 -706 21 -22 23 -24 fill=21 (0 0 130.386) u=1 imp:n=1
c
156      0  706 -707 21 -22 23 -24 fill=21 (0 0 138.4947) u=1 imp:n=1
c
157      0  707 -708 21 -22 23 -24 fill=21 (0 0 146.6034) u=1 imp:n=1
c
158      0  708 -709 21 -22 23 -24 fill=21 (0 0 154.7121) u=1 imp:n=1
c
159      0  709 -710 21 -22 23 -24 fill=21 (0 0 162.8208) u=1 imp:n=1
c
160      0  710 -711 21 -22 23 -24 fill=21 (0 0 170.9295) u=1 imp:n=1
c
161      0  711 -712 21 -22 23 -24 fill=21 (0 0 179.0382) u=1 imp:n=1
c
c 712      pz      $ Core upper boundary
c
c Upper Axial Blanket. 4 Cells
c
181      0  712 -713 21 -22 23 -24 fill=41 (0 0 187.1469) u=1 imp:n=1
c
182      0  713 -714 21 -22 23 -24 fill=41 (0 0 195.8835 ) u=1 imp:n=1
c
183      0  714 -715 21 -22 23 -24 fill=41 (0 0 204.6201) u=1 imp:n=1
c
184      0  715 -716 21 -22 23 -24 fill=41 (0 0 213.3567) u=1 imp:n=1
c
c Upper Plenum
c
186      0  716 -717 21 -22 23 -24 fill=72 (0 0 222.0933) u=1 imp:n=1
c
c Upper padding
c

```

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```

188      16 3.279692E-02 717 -16 21 -22 23 -24 u=1 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
191      0 62 -63 64 -65 (-21:22:-23:24) u=1 imp:n=1
c wrapper
192      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=1 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
193      0 1 -2 3 -4 (-66:67:-68:69) u=1 imp:n=1
c
c End of Inner Core Element A
c
c --- MZB Inner Core Element B (C12-30B)
c
c Lower padding
c
211      16 3.279692E-02 -8 21 -22 23 -24 u=2 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
212      0 8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=2 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
221      0 9 -41 21 -22 23 -24 fill=41 (0 0 63.0048) u=2 imp:n=1
c
222      0 41 -42 21 -22 23 -24 fill=41 (0 0 71.7414) u=2 imp:n=1
c
223      0 42 -43 21 -22 23 -24 fill=41 (0 0 80.478) u=2 imp:n=1
c
224      0 43 -10 21 -22 23 -24 fill=41 (0 0 89.2146) u=2 imp:n=1
c
c
c The 11 MZB Inner Core Cells
c
251      0 10 -702 21 -22 23 -24 fill=22 (0 0 97.9512) u=2 imp:n=1
c
252      0 702 -703 21 -22 23 -24 fill=22 (0 0 106.0599) u=2 imp:n=1
c
253      0 703 -704 21 -22 23 -24 fill=22 (0 0 114.1686) u=2 imp:n=1
c
254      0 704 -705 21 -22 23 -24 fill=22 (0 0 122.2773) u=2 imp:n=1
c
255      0 705 -706 21 -22 23 -24 fill=22 (0 0 130.386) u=2 imp:n=1
c
256      0 706 -707 21 -22 23 -24 fill=22 (0 0 138.4947) u=2 imp:n=1
c
257      0 707 -708 21 -22 23 -24 fill=22 (0 0 146.6034) u=2 imp:n=1
c
258      0 708 -709 21 -22 23 -24 fill=22 (0 0 154.7121) u=2 imp:n=1
c
259      0 709 -710 21 -22 23 -24 fill=22 (0 0 162.8208) u=2 imp:n=1
c
260      0 710 -711 21 -22 23 -24 fill=22 (0 0 170.9295) u=2 imp:n=1
c
261      0 711 -712 21 -22 23 -24 fill=22 (0 0 179.0382) u=2 imp:n=1
c
c 712 pz $ Core upper boundary
c
c Upper Axial Blanket. 4 Cells
c
281      0 712 -713 21 -22 23 -24 fill=41 (0 0 187.1469) u=2 imp:n=1
c
282      0 713 -714 21 -22 23 -24 fill=41 (0 0 195.8835 ) u=2 imp:n=1
c
283      0 714 -715 21 -22 23 -24 fill=41 (0 0 204.6201) u=2 imp:n=1
c
284      0 715 -716 21 -22 23 -24 fill=41 (0 0 213.3567) u=2 imp:n=1
c
c Upper Plenum
c
286      0 716 -717 21 -22 23 -24 fill=72 (0 0 222.0933) u=2 imp:n=1
c
c Upper padding
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

288      16 3.279692E-02 717 -16 21 -22 23 -24 u=2 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
291      0 62 -63 64 -65 (-21:22:-23:24) u=2 imp:n=1
c wrapper
292      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=2 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
293      0 1 -2 3 -4 (-66:67:-68:69) u=2 imp:n=1
c
c End of Inner Core Element B
c
c --- MZB Inner Core Element BG
c
c Lower padding
c
311      16 3.279692E-02 -8 21 -22 23 -24 u=3 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
312      0 8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=3 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
321      0 9 -41 21 -22 23 -24 fill=42 (0 0 63.0048) u=3 imp:n=1
c
322      0 41 -42 21 -22 23 -24 fill=42 (0 0 71.7414) u=3 imp:n=1
c
323      0 42 -43 21 -22 23 -24 fill=42 (0 0 80.478) u=3 imp:n=1
c
324      0 43 -10 21 -22 23 -24 fill=42 (0 0 89.2146) u=3 imp:n=1
c
c
c The 11 MZB Inner Core Cells
c
351      0 10 -702 21 -22 23 -24 fill=23 (0 0 97.9512) u=3 imp:n=1
c
352      0 702 -703 21 -22 23 -24 fill=23 (0 0 106.0599) u=3 imp:n=1
c
353      0 703 -704 21 -22 23 -24 fill=23 (0 0 114.1686) u=3 imp:n=1
c
354      0 704 -705 21 -22 23 -24 fill=23 (0 0 122.2773) u=3 imp:n=1
c
355      0 705 -706 21 -22 23 -24 fill=23 (0 0 130.386) u=3 imp:n=1
c
356      0 706 -707 21 -22 23 -24 fill=23 (0 0 138.4947) u=3 imp:n=1
c
357      0 707 -708 21 -22 23 -24 fill=23 (0 0 146.6034) u=3 imp:n=1
c
358      0 708 -709 21 -22 23 -24 fill=23 (0 0 154.7121) u=3 imp:n=1
c
359      0 709 -710 21 -22 23 -24 fill=23 (0 0 162.8208) u=3 imp:n=1
c
360      0 710 -711 21 -22 23 -24 fill=23 (0 0 170.9295) u=3 imp:n=1
c
361      0 711 -712 21 -22 23 -24 fill=23 (0 0 179.0382) u=3 imp:n=1
c
c 712 pz $ Core upper boundary
c
c Upper Axial Blanket. 4 Cells
c
381      0 712 -713 21 -22 23 -24 fill=42 (0 0 187.1469) u=3 imp:n=1
c
382      0 713 -714 21 -22 23 -24 fill=42 (0 0 195.8835 ) u=3 imp:n=1
c
383      0 714 -715 21 -22 23 -24 fill=42 (0 0 204.6201) u=3 imp:n=1
c
384      0 715 -716 21 -22 23 -24 fill=42 (0 0 213.3567) u=3 imp:n=1
c
c Upper Plenum
c
386      0 716 -717 21 -22 23 -24 fill=72 (0 0 222.0933) u=3 imp:n=1
c
c Upper padding
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

388      16 3.279692E-02 717 -16 21 -22 23 -24 u=3 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
391      0 62 -63 64 -65 (-21:22:-23:24) u=3 imp:n=1
c wrapper
392      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=3 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
393      0 1 -2 3 -4 (-66:67:-68:69) u=3 imp:n=1
c
c End of Inner Core Element BG
c
c --- MZB Inner Core Element D (C12-30D)
c
c Lower padding
c
411      16 3.279692E-02 -8 21 -22 23 -24 u=4 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
412      0 8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=4 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
421      0 9 -41 21 -22 23 -24 fill=42 (0 0 63.0048) u=4 imp:n=1
c
422      0 41 -42 21 -22 23 -24 fill=42 (0 0 71.7414) u=4 imp:n=1
c
423      0 42 -43 21 -22 23 -24 fill=42 (0 0 80.478) u=4 imp:n=1
c
424      0 43 -10 21 -22 23 -24 fill=42 (0 0 89.2146) u=4 imp:n=1
c
c
c The 11 MZB Inner Core Cells
c
451      0 10 -702 21 -22 23 -24 fill=24 (0 0 97.9512) u=4 imp:n=1
c
452      0 702 -703 21 -22 23 -24 fill=24 (0 0 106.0599) u=4 imp:n=1
c
453      0 703 -704 21 -22 23 -24 fill=24 (0 0 114.1686) u=4 imp:n=1
c
454      0 704 -705 21 -22 23 -24 fill=24 (0 0 122.2773) u=4 imp:n=1
c
455      0 705 -706 21 -22 23 -24 fill=24 (0 0 130.386) u=4 imp:n=1
c
456      0 706 -707 21 -22 23 -24 fill=24 (0 0 138.4947) u=4 imp:n=1
c
457      0 707 -708 21 -22 23 -24 fill=24 (0 0 146.6034) u=4 imp:n=1
c
458      0 708 -709 21 -22 23 -24 fill=24 (0 0 154.7121) u=4 imp:n=1
c
459      0 709 -710 21 -22 23 -24 fill=24 (0 0 162.8208) u=4 imp:n=1
c
460      0 710 -711 21 -22 23 -24 fill=24 (0 0 170.9295) u=4 imp:n=1
c
461      0 711 -712 21 -22 23 -24 fill=24 (0 0 179.0382) u=4 imp:n=1
c
c 712 pz $ Core upper boundary
c
c Upper Axial Blanket. 4 Cells
c
481      0 712 -713 21 -22 23 -24 fill=42 (0 0 187.1469) u=4 imp:n=1
c
482      0 713 -714 21 -22 23 -24 fill=42 (0 0 195.8835 ) u=4 imp:n=1
c
483      0 714 -715 21 -22 23 -24 fill=42 (0 0 204.6201) u=4 imp:n=1
c
484      0 715 -716 21 -22 23 -24 fill=42 (0 0 213.3567) u=4 imp:n=1
c
c Upper Plenum
c
486      0 716 -717 21 -22 23 -24 fill=72 (0 0 222.0933) u=4 imp:n=1
c
c Upper padding
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

488      16 3.279692E-02 717 -16 21 -22 23 -24 u=4 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
491      0 62 -63 64 -65 (-21:22:-23:24) u=4 imp:n=1
c wrapper
492      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=4 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
493      0 1 -2 3 -4 (-66:67:-68:69) u=4 imp:n=1
c
c End of Inner Core Element D
c
c --- MZB Outer Core Element A
c
c Lower padding
511      like 111 but u=5 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
512      0 8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=5 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
521      0 9 -41 21 -22 23 -24 fill=44 (0 0 63.0048) u=5 imp:n=1
c
522      0 41 -42 21 -22 23 -24 fill=44 (0 0 71.7414) u=5 imp:n=1
c
523      0 42 -43 21 -22 23 -24 fill=44 (0 0 80.478) u=5 imp:n=1
c
524      0 43 -10 21 -22 23 -24 fill=44 (0 0 89.2146) u=5 imp:n=1
c
c
c
c The 12 core cells
c
551      0 10 -44 21 -22 23 -24 fill=25 (0 0 97.9512) u=5 imp:n=1
c
552      0 44 -45 21 -22 23 -24 fill=25 (0 0 105.447) u=5 imp:n=1
c
553      0 45 -46 21 -22 23 -24 fill=25 (0 0 112.9428) u=5 imp:n=1
c
554      0 46 -47 21 -22 23 -24 fill=25 (0 0 120.4386) u=5 imp:n=1
c
555      0 47 -48 21 -22 23 -24 fill=25 (0 0 127.9344) u=5 imp:n=1
c
556      0 48 -49 21 -22 23 -24 fill=25 (0 0 135.4302) u=5 imp:n=1
c
557      0 49 -50 21 -22 23 -24 fill=25 (0 0 142.926) u=5 imp:n=1
c
558      0 50 -51 21 -22 23 -24 fill=25 (0 0 150.4218) u=5 imp:n=1
c
559      0 51 -52 21 -22 23 -24 fill=25 (0 0 157.9176) u=5 imp:n=1
c
560      0 52 -53 21 -22 23 -24 fill=25 (0 0 165.4134) u=5 imp:n=1
c
561      0 53 -54 21 -22 23 -24 fill=25 (0 0 172.9092) u=5 imp:n=1
c
562      0 54 -11 21 -22 23 -24 fill=25 (0 0 180.405) u=5 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
581      0 11 -56 21 -22 23 -24 fill=44 (0 0 187.9008) u=5 imp:n=1
c
582      0 56 -57 21 -22 23 -24 fill=44 (0 0 196.6374 ) u=5 imp:n=1
c
583      0 57 -58 21 -22 23 -24 fill=44 (0 0 205.374) u=5 imp:n=1
c
584      0 58 -12 21 -22 23 -24 fill=44 (0 0 214.1106) u=5 imp:n=1
c
c Upper Plenum
c
586      0 12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=5 imp:n=1
c
c Upper padding

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
588      16 3.279692E-02 13 -16 21 -22 23 -24 u=5 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
591      0 62 -63 64 -65 (-21:22:-23:24) u=5 imp:n=1
c wrapper
592      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=5 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
593      0 1 -2 3 -4 (-66:67:-68:69) u=5 imp:n=1
c
c End of Outer Core Element A
c
c
c --- MZB Outer Core Element B
c
c Lower padding
611      like 111 but u=6 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
612      0 8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=6 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
621      0 9 -41 21 -22 23 -24 fill=45 (0 0 63.0048) u=6 imp:n=1
c
622      0 41 -42 21 -22 23 -24 fill=45 (0 0 71.7414) u=6 imp:n=1
c
623      0 42 -43 21 -22 23 -24 fill=45 (0 0 80.478) u=6 imp:n=1
c
624      0 43 -10 21 -22 23 -24 fill=45 (0 0 89.2146) u=6 imp:n=1
c
c
c
c The 12 core cells
c
651      0 10 -44 21 -22 23 -24 fill=26 (0 0 97.9512) u=6 imp:n=1
c
652      0 44 -45 21 -22 23 -24 fill=26 (0 0 105.447) u=6 imp:n=1
c
653      0 45 -46 21 -22 23 -24 fill=26 (0 0 112.9428) u=6 imp:n=1
c
654      0 46 -47 21 -22 23 -24 fill=26 (0 0 120.4386) u=6 imp:n=1
c
655      0 47 -48 21 -22 23 -24 fill=26 (0 0 127.9344) u=6 imp:n=1
c
656      0 48 -49 21 -22 23 -24 fill=26 (0 0 135.4302) u=6 imp:n=1
c
657      0 49 -50 21 -22 23 -24 fill=26 (0 0 142.926) u=6 imp:n=1
c
658      0 50 -51 21 -22 23 -24 fill=26 (0 0 150.4218) u=6 imp:n=1
c
659      0 51 -52 21 -22 23 -24 fill=26 (0 0 157.9176) u=6 imp:n=1
c
660      0 52 -53 21 -22 23 -24 fill=26 (0 0 165.4134) u=6 imp:n=1
c
661      0 53 -54 21 -22 23 -24 fill=26 (0 0 172.9092) u=6 imp:n=1
c
662      0 54 -11 21 -22 23 -24 fill=26 (0 0 180.405) u=6 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
681      0 11 -56 21 -22 23 -24 fill=45 (0 0 187.9008) u=6 imp:n=1
c
682      0 56 -57 21 -22 23 -24 fill=45 (0 0 196.6374 ) u=6 imp:n=1
c
683      0 57 -58 21 -22 23 -24 fill=45 (0 0 205.374) u=6 imp:n=1
c
684      0 58 -12 21 -22 23 -24 fill=45 (0 0 214.1106) u=6 imp:n=1
c
c Upper Plenum
c
686      0 12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=6 imp:n=1

```


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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Upper padding
c
688      16 3.279692E-02 13 -16 21 -22 23 -24 u=6 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
691      0 62 -63 64 -65 (-21:22:-23:24) u=6 imp:n=1
c wrapper
692      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=6 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
693      0 1 -2 3 -4 (-66:67:-68:69) u=6 imp:n=1
c
c End of Outer Core Element B
c
c
c --- MZB Outer Core Element C
c
c Lower padding
711      like 111 but u=7 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
712      0 8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=7 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
721      0 9 -41 21 -22 23 -24 fill=45 (0 0 63.0048) u=7 imp:n=1
c
722      0 41 -42 21 -22 23 -24 fill=45 (0 0 71.7414) u=7 imp:n=1
c
723      0 42 -43 21 -22 23 -24 fill=45 (0 0 80.478) u=7 imp:n=1
c
724      0 43 -10 21 -22 23 -24 fill=45 (0 0 89.2146) u=7 imp:n=1
c
c
c
c The 12 core cells
c
751      0 10 -44 21 -22 23 -24 fill=27 (0 0 97.9512) u=7 imp:n=1
c
752      0 44 -45 21 -22 23 -24 fill=27 (0 0 105.447) u=7 imp:n=1
c
753      0 45 -46 21 -22 23 -24 fill=27 (0 0 112.9428) u=7 imp:n=1
c
754      0 46 -47 21 -22 23 -24 fill=27 (0 0 120.4386) u=7 imp:n=1
c
755      0 47 -48 21 -22 23 -24 fill=27 (0 0 127.9344) u=7 imp:n=1
c
756      0 48 -49 21 -22 23 -24 fill=27 (0 0 135.4302) u=7 imp:n=1
c
757      0 49 -50 21 -22 23 -24 fill=27 (0 0 142.926) u=7 imp:n=1
c
758      0 50 -51 21 -22 23 -24 fill=27 (0 0 150.4218) u=7 imp:n=1
c
759      0 51 -52 21 -22 23 -24 fill=27 (0 0 157.9176) u=7 imp:n=1
c
760      0 52 -53 21 -22 23 -24 fill=27 (0 0 165.4134) u=7 imp:n=1
c
761      0 53 -54 21 -22 23 -24 fill=27 (0 0 172.9092) u=7 imp:n=1
c
762      0 54 -11 21 -22 23 -24 fill=27 (0 0 180.405) u=7 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
781      0 11 -56 21 -22 23 -24 fill=45 (0 0 187.9008) u=7 imp:n=1
c
782      0 56 -57 21 -22 23 -24 fill=45 (0 0 196.6374 ) u=7 imp:n=1
c
783      0 57 -58 21 -22 23 -24 fill=45 (0 0 205.374) u=7 imp:n=1
c
784      0 58 -12 21 -22 23 -24 fill=45 (0 0 214.1106) u=7 imp:n=1
c
c Upper Plenum

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
786    0  12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=7 imp:n=1
c
c Upper padding
c
788    16 3.279692E-02 13 -16 21 -22 23 -24 u=7 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
791    0 62 -63 64 -65 (-21:22:-23:24) u=7 imp:n=1
c wrapper
792    17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=7 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
793    0  1 -2 3 -4 (-66:67:-68:69) u=7 imp:n=1
c
c End of Outer Core Element C
c
c
c --- MZB Outer Core Element D
c
c Lower padding
811    like 111 but u=8 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
812    0  8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=8 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
821    0  9 -41 21 -22 23 -24 fill=45 (0 0 63.0048) u=8 imp:n=1
c
822    0  41 -42 21 -22 23 -24 fill=45 (0 0 71.7414) u=8 imp:n=1
c
823    0  42 -43 21 -22 23 -24 fill=45 (0 0 80.478) u=8 imp:n=1
c
824    0  43 -10 21 -22 23 -24 fill=45 (0 0 89.2146) u=8 imp:n=1
c
c
c
c The 12 core cells
c
851    0  10 -44 21 -22 23 -24 fill=28 (0 0 97.9512) u=8 imp:n=1
c
852    0  44 -45 21 -22 23 -24 fill=28 (0 0 105.447) u=8 imp:n=1
c
853    0  45 -46 21 -22 23 -24 fill=28 (0 0 112.9428) u=8 imp:n=1
c
854    0  46 -47 21 -22 23 -24 fill=28 (0 0 120.4386) u=8 imp:n=1
c
855    0  47 -48 21 -22 23 -24 fill=28 (0 0 127.9344) u=8 imp:n=1
c
856    0  48 -49 21 -22 23 -24 fill=28 (0 0 135.4302) u=8 imp:n=1
c
857    0  49 -50 21 -22 23 -24 fill=28 (0 0 142.926) u=8 imp:n=1
c
858    0  50 -51 21 -22 23 -24 fill=28 (0 0 150.4218) u=8 imp:n=1
c
859    0  51 -52 21 -22 23 -24 fill=28 (0 0 157.9176) u=8 imp:n=1
c
860    0  52 -53 21 -22 23 -24 fill=28 (0 0 165.4134) u=8 imp:n=1
c
861    0  53 -54 21 -22 23 -24 fill=28 (0 0 172.9092) u=8 imp:n=1
c
862    0  54 -11 21 -22 23 -24 fill=28 (0 0 180.405) u=8 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
881    0  11 -56 21 -22 23 -24 fill=45 (0 0 187.9008) u=8 imp:n=1
c
882    0  56 -57 21 -22 23 -24 fill=45 (0 0 196.6374 ) u=8 imp:n=1
c
883    0  57 -58 21 -22 23 -24 fill=45 (0 0 205.374) u=8 imp:n=1
c
884    0  58 -12 21 -22 23 -24 fill=45 (0 0 214.1106) u=8 imp:n=1

```

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LIQUID METAL FAST REACTOR - LMFR
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```

c
c Upper Plenum
c
886    0 12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=8 imp:n=1
c
c Upper padding
c
888    16 3.279692E-02 13 -16 21 -22 23 -24 u=8 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
891    0 62 -63 64 -65 (-21:22:-23:24) u=8 imp:n=1
c wrapper
892    17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=8 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
893    0 1 -2 3 -4 (-66:67:-68:69) u=8 imp:n=1
c
c End of Outer Core Element D
c
c
c --- MZB Outer Core Element G
c
c Lower padding
911    like 111 but u=9 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
912    0 8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=9 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
921    0 9 -41 21 -22 23 -24 fill=46 (0 0 63.0048) u=9 imp:n=1
c
922    0 41 -42 21 -22 23 -24 fill=46 (0 0 71.7414) u=9 imp:n=1
c
923    0 42 -43 21 -22 23 -24 fill=46 (0 0 80.478) u=9 imp:n=1
c
924    0 43 -10 21 -22 23 -24 fill=46 (0 0 89.2146) u=9 imp:n=1
c
c
c
c The 12 core cells
c
951    0 10 -44 21 -22 23 -24 fill=29 (0 0 97.9512) u=9 imp:n=1
c
952    0 44 -45 21 -22 23 -24 fill=29 (0 0 105.447) u=9 imp:n=1
c
953    0 45 -46 21 -22 23 -24 fill=29 (0 0 112.9428) u=9 imp:n=1
c
954    0 46 -47 21 -22 23 -24 fill=29 (0 0 120.4386) u=9 imp:n=1
c
955    0 47 -48 21 -22 23 -24 fill=29 (0 0 127.9344) u=9 imp:n=1
c
956    0 48 -49 21 -22 23 -24 fill=29 (0 0 135.4302) u=9 imp:n=1
c
957    0 49 -50 21 -22 23 -24 fill=29 (0 0 142.926) u=9 imp:n=1
c
958    0 50 -51 21 -22 23 -24 fill=29 (0 0 150.4218) u=9 imp:n=1
c
959    0 51 -52 21 -22 23 -24 fill=29 (0 0 157.9176) u=9 imp:n=1
c
960    0 52 -53 21 -22 23 -24 fill=29 (0 0 165.4134) u=9 imp:n=1
c
961    0 53 -54 21 -22 23 -24 fill=29 (0 0 172.9092) u=9 imp:n=1
c
962    0 54 -11 21 -22 23 -24 fill=29 (0 0 180.405) u=9 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
981    0 11 -56 21 -22 23 -24 fill=46 (0 0 187.9008) u=9 imp:n=1
c
982    0 56 -57 21 -22 23 -24 fill=46 (0 0 196.6374 ) u=9 imp:n=1
c
983    0 57 -58 21 -22 23 -24 fill=46 (0 0 205.374) u=9 imp:n=1

```

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LIQUID METAL FAST REACTOR - LMFR
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```

c
984    0  58 -12 21 -22 23 -24 fill=46  (0 0 214.1106) u=9 imp:n=1
c
c  Upper Plenum
c
986    0  12 -13 21 -22 23 -24 fill=72  (0 0 222.8472) u=9 imp:n=1
c
c  Upper padding
c
988    16 3.279692E-02 13 -16 21 -22 23 -24 u=9 imp:n=1 TMP=2.5301E-08
c
c
c  Wrapper region
991    0 62 -63 64 -65 (-21:22:-23:24) u=9 imp:n=1
c  wrapper
992    17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=9 imp:n=1 &
      TMP=2.5301E-08
c  gap outside wrapper
993    0  1 -2 3 -4 (-66:67:-68:69) u=9 imp:n=1
c
c  End of Outer Core Element G
c
c
c  --- MZB Outer Core Element E=BG
c
c  Lower padding
1011    like 111 but u=10 imp:n=1 TMP=2.5301E-08
c
c  Lower Plenum
c
1012    0  8 -9 21 -22 23 -24 fill=71  (0 0 30.0) u=10 imp:n=1
c
c  Lower Axial Blanket comprising 4 cells
c
1021    0  9 -41 21 -22 23 -24 fill=46  (0 0 63.0048) u=10 imp:n=1
c
1022    0  41 -42 21 -22 23 -24 fill=46  (0 0 71.7414) u=10 imp:n=1
c
1023    0  42 -43 21 -22 23 -24 fill=46  (0 0 80.478) u=10 imp:n=1
c
1024    0  43 -10 21 -22 23 -24 fill=46  (0 0 89.2146) u=10 imp:n=1
c
c
c
c  The 12 core cells
c
1051    0  10 -44 21 -22 23 -24 fill=30  (0 0 97.9512) u=10 imp:n=1
c
1052    0  44 -45 21 -22 23 -24 fill=30  (0 0 105.447) u=10 imp:n=1
c
1053    0  45 -46 21 -22 23 -24 fill=30  (0 0 112.9428) u=10 imp:n=1
c
1054    0  46 -47 21 -22 23 -24 fill=30  (0 0 120.4386) u=10 imp:n=1
c
1055    0  47 -48 21 -22 23 -24 fill=30  (0 0 127.9344) u=10 imp:n=1
c
1056    0  48 -49 21 -22 23 -24 fill=30  (0 0 135.4302) u=10 imp:n=1
c
1057    0  49 -50 21 -22 23 -24 fill=30  (0 0 142.926) u=10 imp:n=1
c
1058    0  50 -51 21 -22 23 -24 fill=30  (0 0 150.4218) u=10 imp:n=1
c
1059    0  51 -52 21 -22 23 -24 fill=30  (0 0 157.9176) u=10 imp:n=1
c
1060    0  52 -53 21 -22 23 -24 fill=30  (0 0 165.4134) u=10 imp:n=1
c
1061    0  53 -54 21 -22 23 -24 fill=30  (0 0 172.9092) u=10 imp:n=1
c
1062    0  54 -11 21 -22 23 -24 fill=30  (0 0 180.405) u=10 imp:n=1
c
c  Upper Axial Blanket. 4 Cells
c
c
1081    0  11 -56 21 -22 23 -24 fill=46  (0 0 187.9008) u=10 imp:n=1
c
1082    0  56 -57 21 -22 23 -24 fill=46  (0 0 196.6374 ) u=10 imp:n=1

```

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LIQUID METAL FAST REACTOR - LMFR
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```

c
1083    0  57 -58 21 -22 23 -24 fill=46  (0 0 205.374) u=10 imp:n=1
c
1084    0  58 -12 21 -22 23 -24 fill=46  (0 0 214.1106) u=10 imp:n=1
c
c   Upper Plenum
c
1086    0  12 -13 21 -22 23 -24 fill=72  (0 0 222.8472) u=10 imp:n=1
c
c   Upper padding
c
1088    16 3.279692E-02 13 -16 21 -22 23 -24 u=10 imp:n=1 TMP=2.5301E-08
c
c
c   Wrapper region
1091    0  62 -63 64 -65 (-21:22:-23:24) u=10 imp:n=1
c   wrapper
1092    17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=10 imp:n=1 &
      TMP=2.5301E-08
c   gap outside wrapper
1093    0   1 -2 3 -4 (-66:67:-68:69) u=10 imp:n=1
c
c   End of Outer Core Element E=BG
c
c
c   --- MZB Outer Core Element F=DG
c
c   Lower padding
1111    like 111 but u=11 imp:n=1 TMP=2.5301E-08
c
c   Lower Plenum
c
1112    0   8 -9 21 -22 23 -24 fill=71  (0 0 30.0) u=11 imp:n=1
c
c   Lower Axial Blanket comprising 4 cells
c
1121    0   9 -41 21 -22 23 -24 fill=46  (0 0 63.0048) u=11 imp:n=1
c
1122    0  41 -42 21 -22 23 -24 fill=46  (0 0 71.7414) u=11 imp:n=1
c
1123    0  42 -43 21 -22 23 -24 fill=46  (0 0 80.478) u=11 imp:n=1
c
1124    0  43 -10 21 -22 23 -24 fill=46  (0 0 89.2146) u=11 imp:n=1
c
c
c
c   The 12 core cells
c
1151    0  10 -44 21 -22 23 -24 fill=31  (0 0 97.9512) u=11 imp:n=1
c
1152    0  44 -45 21 -22 23 -24 fill=31  (0 0 105.447) u=11 imp:n=1
c
1153    0  45 -46 21 -22 23 -24 fill=31  (0 0 112.9428) u=11 imp:n=1
c
1154    0  46 -47 21 -22 23 -24 fill=31  (0 0 120.4386) u=11 imp:n=1
c
1155    0  47 -48 21 -22 23 -24 fill=31  (0 0 127.9344) u=11 imp:n=1
c
1156    0  48 -49 21 -22 23 -24 fill=31  (0 0 135.4302) u=11 imp:n=1
c
1157    0  49 -50 21 -22 23 -24 fill=31  (0 0 142.926) u=11 imp:n=1
c
1158    0  50 -51 21 -22 23 -24 fill=31  (0 0 150.4218) u=11 imp:n=1
c
1159    0  51 -52 21 -22 23 -24 fill=31  (0 0 157.9176) u=11 imp:n=1
c
1160    0  52 -53 21 -22 23 -24 fill=31  (0 0 165.4134) u=11 imp:n=1
c
1161    0  53 -54 21 -22 23 -24 fill=31  (0 0 172.9092) u=11 imp:n=1
c
1162    0  54 -11 21 -22 23 -24 fill=31  (0 0 180.405) u=11 imp:n=1
c
c   Upper Axial Blanket. 4 Cells
c
c
1181    0  11 -56 21 -22 23 -24 fill=46  (0 0 187.9008) u=11 imp:n=1

```

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LIQUID METAL FAST REACTOR - LMFR
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```

c
1182    0  56 -57 21 -22 23 -24 fill=46 (0 0 196.6374 ) u=11 imp:n=1
c
1183    0  57 -58 21 -22 23 -24 fill=46 (0 0 205.374) u=11 imp:n=1
c
1184    0  58 -12 21 -22 23 -24 fill=46 (0 0 214.1106) u=11 imp:n=1
c
c Upper Plenum
c
1186    0  12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=11 imp:n=1
c
c Upper padding
c
1188    16 3.279692E-02 13 -16 21 -22 23 -24 u=11 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
1191    0  62 -63 64 -65 (-21:22:-23:24) u=11 imp:n=1
c wrapper
1192    17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=11 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
1193    0   1 -2 3 -4 (-66:67:-68:69) u=11 imp:n=1
c
c End of Outer Core Element F=DG
c
c
c --- Radial Blanket Elements
c
c Element B11-1
c
c Lower padding
1211    like 111 but u=16 imp:n=1 TMP=2.5301E-08
c Lower Plenum
1212    like 112 but u=16 imp:n=1 TMP=2.5301E-08
c Radial blanket
c Lower Radial Blanket Section comprising 3 cells
c
1221    0   9 -803 21 -22 23 -24 fill=55 (0 0 63.0048) u=16 imp:n=1
c
1222    0  803 -804 21 -22 23 -24 fill=55 (0 0 73.155) u=16 imp:n=1
c
1223    0  804 -805 21 -22 23 -24 fill=55 (0 0 83.3052) u=16 imp:n=1
c
c
c The 20 Radial blanket Central Section Cells
c
1231    0  805 -806 21 -22 23 -24 fill=51 (0 0 93.4554) u=16 imp:n=1
c
1232    0  806 -807 21 -22 23 -24 fill=51 (0 0 98.485) u=16 imp:n=1
c
1233    0  807 -808 21 -22 23 -24 fill=51 (0 0 103.5146) u=16 imp:n=1
c
1234    0  808 -809 21 -22 23 -24 fill=51 (0 0 108.5442) u=16 imp:n=1
c
1235    0  809 -810 21 -22 23 -24 fill=51 (0 0 113.5738) u=16 imp:n=1
c
1236    0  810 -811 21 -22 23 -24 fill=51 (0 0 118.6034) u=16 imp:n=1
c
1237    0  811 -812 21 -22 23 -24 fill=51 (0 0 123.633) u=16 imp:n=1
c
1238    0  812 -813 21 -22 23 -24 fill=51 (0 0 128.6626) u=16 imp:n=1
c
1239    0  813 -814 21 -22 23 -24 fill=51 (0 0 133.6922) u=16 imp:n=1
c
1240    0  814 -815 21 -22 23 -24 fill=51 (0 0 138.7218) u=16 imp:n=1
c
1241    0  815 -816 21 -22 23 -24 fill=51 (0 0 143.7514) u=16 imp:n=1
c
1242    0  816 -817 21 -22 23 -24 fill=51 (0 0 148.781) u=16 imp:n=1
c
1243    0  817 -818 21 -22 23 -24 fill=51 (0 0 153.8106) u=16 imp:n=1
c
1244    0  818 -819 21 -22 23 -24 fill=51 (0 0 158.8402) u=16 imp:n=1
c
1245    0  819 -820 21 -22 23 -24 fill=51 (0 0 163.8698) u=16 imp:n=1

```

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LIQUID METAL FAST REACTOR - LMFR
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```

c
1246    0  820 -821 21 -22 23 -24 fill=51 (0 0 168.8994) u=16 imp:n=1
c
1247    0  821 -822 21 -22 23 -24 fill=51 (0 0 173.929) u=16 imp:n=1
c
1248    0  822 -823 21 -22 23 -24 fill=51 (0 0 178.9586) u=16 imp:n=1
c
1249    0  823 -824 21 -22 23 -24 fill=51 (0 0 183.9882) u=16 imp:n=1
c
1250    0  824 -825 21 -22 23 -24 fill=51 (0 0 189.0178) u=16 imp:n=1
c
c  Upper Axial Blanket. 4 Cells
c
1261    0  825 -826 21 -22 23 -24 fill=55 (0 0 194.0474) u=16 imp:n=1
c
1262    0  826 -827 21 -22 23 -24 fill=55 (0 0 204.1976) u=16 imp:n=1
c
1263    0  827 -828 21 -22 23 -24 fill=55 (0 0 214.3478) u=16 imp:n=1
c
c  Upper Plenum
1271    0  828 -829 21 -22 23 -24 fill=72 (0 0 224.498) u=16 imp:n=1
c
c  Upper padding
1272    16 3.279692E-02 829 -16 21 -22 23 -24 u=16 imp:n=1 TMP=2.5301E-08
c
c  Wrapper region
1280    0  62 -63 64 -65 (-21:22:-23:24) u=16 imp:n=1
c  wrapper
1281    17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=16 imp:n=1 &
      TMP=2.5301E-08
c  gap outside wrapper
1282    0  1 -2 3 -4 (-66:67:-68:69) u=16 imp:n=1
c
c  End of Radial Blanket Element  B11-1
c
c
c  Element B11-1B
c
c  Lower padding
1311    like 111 but u=17 imp:n=1 TMP=2.5301E-08
c  Lower Plenum
1312    like 112 but u=17 imp:n=1 TMP=2.5301E-08
c  Radial blanket
c  Lower Radial Blanket Section comprising 3 cells
c
1321    0  9 -803 21 -22 23 -24 fill=55 (0 0 63.0048) u=17 imp:n=1
c
1322    0  803 -804 21 -22 23 -24 fill=55 (0 0 73.155) u=17 imp:n=1
c
1323    0  804 -805 21 -22 23 -24 fill=55 (0 0 83.3052) u=17 imp:n=1
c
c
c  The 20 Radial blanket Central Section Cells
c
1331    0  805 -806 21 -22 23 -24 fill=52 (0 0 93.4554) u=17 imp:n=1
c
1332    0  806 -807 21 -22 23 -24 fill=52 (0 0 98.485) u=17 imp:n=1
c
1333    0  807 -808 21 -22 23 -24 fill=52 (0 0 103.5146) u=17 imp:n=1
c
1334    0  808 -809 21 -22 23 -24 fill=52 (0 0 108.5442) u=17 imp:n=1
c
1335    0  809 -810 21 -22 23 -24 fill=52 (0 0 113.5738) u=17 imp:n=1
c
1336    0  810 -811 21 -22 23 -24 fill=52 (0 0 118.6034) u=17 imp:n=1
c
1337    0  811 -812 21 -22 23 -24 fill=52 (0 0 123.633) u=17 imp:n=1
c
1338    0  812 -813 21 -22 23 -24 fill=52 (0 0 128.6626) u=17 imp:n=1
c
1339    0  813 -814 21 -22 23 -24 fill=52 (0 0 133.6922) u=17 imp:n=1
c
1340    0  814 -815 21 -22 23 -24 fill=52 (0 0 138.7218) u=17 imp:n=1
c
1341    0  815 -816 21 -22 23 -24 fill=52 (0 0 143.7514) u=17 imp:n=1
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

1342    0  816 -817 21 -22 23 -24 fill=52 (0 0 148.781) u=17 imp:n=1
c
1343    0  817 -818 21 -22 23 -24 fill=52 (0 0 153.8106) u=17 imp:n=1
c
1344    0  818 -819 21 -22 23 -24 fill=52 (0 0 158.8402) u=17 imp:n=1
c
1345    0  819 -820 21 -22 23 -24 fill=52 (0 0 163.8698) u=17 imp:n=1
c
1346    0  820 -821 21 -22 23 -24 fill=52 (0 0 168.8994) u=17 imp:n=1
c
1347    0  821 -822 21 -22 23 -24 fill=52 (0 0 173.929) u=17 imp:n=1
c
1348    0  822 -823 21 -22 23 -24 fill=52 (0 0 178.9586) u=17 imp:n=1
c
1349    0  823 -824 21 -22 23 -24 fill=52 (0 0 183.9882) u=17 imp:n=1
c
1350    0  824 -825 21 -22 23 -24 fill=52 (0 0 189.0178) u=17 imp:n=1
c
c   Upper Axial Blanket. 4 Cells
c
1361    0  825 -826 21 -22 23 -24 fill=55 (0 0 194.0474) u=17 imp:n=1
c
1362    0  826 -827 21 -22 23 -24 fill=55 (0 0 204.1976) u=17 imp:n=1
c
1363    0  827 -828 21 -22 23 -24 fill=55 (0 0 214.3478) u=17 imp:n=1
c
c   Upper Plenum
1371    0  828 -829 21 -22 23 -24 fill=72 (0 0 224.498) u=17 imp:n=1
c
c   Upper padding
1372    16 3.279692E-02 829 -16 21 -22 23 -24 u=17 imp:n=1 TMP=2.5301E-08
c
c   Wrapper region
1380    0  62 -63 64 -65 (-21:22:-23:24) u=17 imp:n=1
c wrapper
1381    17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=17 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
1382    0  1 -2 3 -4 (-66:67:-68:69) u=17 imp:n=1
c
c   End of Radial Blanket Element B11-1B
c
c
c   radial Blanket Element B11-1G
c
c   Lower padding
1411    like 111 but u=18 imp:n=1 TMP=2.5301E-08
c   Lower Plenum
1412    like 112 but u=18 imp:n=1 TMP=2.5301E-08
c   Radial blanket
c   Lower Radial Blanket Section comprising 3 cells
c
1421    0  9 -803 21 -22 23 -24 fill=55 (0 0 63.0048) u=18 imp:n=1
c
1422    0  803 -804 21 -22 23 -24 fill=55 (0 0 73.155) u=18 imp:n=1
c
1423    0  804 -805 21 -22 23 -24 fill=55 (0 0 83.3052) u=18 imp:n=1
c
c
c   The 20 Radial blanket Central Section Cells
c
1431    0  805 -806 21 -22 23 -24 fill=53 (0 0 93.4554) u=18 imp:n=1
c
1432    0  806 -807 21 -22 23 -24 fill=53 (0 0 98.485) u=18 imp:n=1
c
1433    0  807 -808 21 -22 23 -24 fill=53 (0 0 103.5146) u=18 imp:n=1
c
1434    0  808 -809 21 -22 23 -24 fill=53 (0 0 108.5442) u=18 imp:n=1
c
1435    0  809 -810 21 -22 23 -24 fill=53 (0 0 113.5738) u=18 imp:n=1
c
1436    0  810 -811 21 -22 23 -24 fill=53 (0 0 118.6034) u=18 imp:n=1
c
1437    0  811 -812 21 -22 23 -24 fill=53 (0 0 123.633) u=18 imp:n=1
c
1438    0  812 -813 21 -22 23 -24 fill=53 (0 0 128.6626) u=18 imp:n=1

```


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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
1439 0 813 -814 21 -22 23 -24 fill=53 (0 0 133.6922) u=18 imp:n=1
c
1440 0 814 -815 21 -22 23 -24 fill=53 (0 0 138.7218) u=18 imp:n=1
c
1441 0 815 -816 21 -22 23 -24 fill=53 (0 0 143.7514) u=18 imp:n=1
c
1442 0 816 -817 21 -22 23 -24 fill=53 (0 0 148.781) u=18 imp:n=1
c
1443 0 817 -818 21 -22 23 -24 fill=53 (0 0 153.8106) u=18 imp:n=1
c
1444 0 818 -819 21 -22 23 -24 fill=53 (0 0 158.8402) u=18 imp:n=1
c
1445 0 819 -820 21 -22 23 -24 fill=53 (0 0 163.8698) u=18 imp:n=1
c
1446 0 820 -821 21 -22 23 -24 fill=53 (0 0 168.8994) u=18 imp:n=1
c
1447 0 821 -822 21 -22 23 -24 fill=53 (0 0 173.929) u=18 imp:n=1
c
1448 0 822 -823 21 -22 23 -24 fill=53 (0 0 178.9586) u=18 imp:n=1
c
1449 0 823 -824 21 -22 23 -24 fill=53 (0 0 183.9882) u=18 imp:n=1
c
1450 0 824 -825 21 -22 23 -24 fill=53 (0 0 189.0178) u=18 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
1461 0 825 -826 21 -22 23 -24 fill=55 (0 0 194.0474) u=18 imp:n=1
c
1462 0 826 -827 21 -22 23 -24 fill=55 (0 0 204.1976) u=18 imp:n=1
c
1463 0 827 -828 21 -22 23 -24 fill=55 (0 0 214.3478) u=18 imp:n=1
c
c Upper Plenum
1471 0 828 -829 21 -22 23 -24 fill=72 (0 0 224.498) u=18 imp:n=1
c
c Upper padding
1472 16 3.279692E-02 829 -16 21 -22 23 -24 u=18 imp:n=1 TMP=2.5301E-08
c
c Wrapper region
1480 0 62 -63 64 -65 (-21:22:-23:24) u=18 imp:n=1
c wrapper
1481 17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=18 imp:n=1 &
TMP=2.5301E-08
c gap outside wrapper
1482 0 1 -2 3 -4 (-66:67:-68:69) u=18 imp:n=1
c
c End of Radial Blanket Element B11-1G
c
c --- Radial shield
c
1526 12 8.32720E-02 28 -29 30 -31 u=19 imp:n=1 TMP=2.5301E-08
c
1527 13 8.32720E-05 1 -2 3 -4 (-28:29:-30:31) u=19 imp:n=1
TMP=2.5301E-08
c
1600 13 8.32720E-05 1 -2 3 -4 u=20 imp:n=1 TMP=2.5301E-08
c
c graphite reflector element
1610 45 8.6775E-02 21 -22 23 -24 u=91 imp:n=1 TMP=2.5301E-08
c
c Wrapper region
1611 0 62 -63 64 -65 (-21:22:-23:24) u=91 imp:n=1
c wrapper
1612 17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=91 imp:n=1 &
TMP=2.5301E-08
c gap outside wrapper
1613 0 1 -2 3 -4 (-66:67:-68:69) u=91 imp:n=1
c
c --- Assembly
c
1619 0 89 -90 91 -92 u=81 lat=1
fill=-5:5 -5:5 0:0
178 178 178 178 196 195 197 178 178 178 178
178 178 168 184 182 181 183 185 169 178 178
178 168 166 164 162 161 163 165 167 169 178

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

178 148 146 144 142 141 143 145 147 149 178
130 128 126 124 122 121 123 125 127 129 178
110 108 106 104 102 101 103 105 107 109 110
120 118 116 114 112 111 113 115 117 119 110
178 138 136 134 132 131 133 135 137 139 178
178 158 156 154 152 151 153 155 157 159 178
178 178 176 174 172 171 173 175 177 178 178
178 178 194 194 192 191 193 194 194 178 178
imp:n=1
c
c --- Assembly
c
1629      0 7 -16 901 -902 903 -904 fill=81 imp:n=1
c --- Universe
1630      0 (-7:16:-901:902:-903:904) imp:n=0
c
c ----- CELL CARDS -----
c
c MZB Inner Core Cell A
c
c Sodium Plate NASTDL4
c Na plate core
2001      25 2.3191E-02 302 -303 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2002      26 7.872422E-02 301 -304 21 -22 23 -24 &
          (-109:110:-111:112:-302:303) u=21 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2003      23 6.951414E-02 305 -306 105 -106 107 -108 u=21 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2004      24 7.067127E-02 304 -307 21 -22 23 -24 &
          (-105:106:-107:108:-305:306) u=21 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2005      25 2.3191E-02 308 -309 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2006      26 7.872422E-02 307 -310 21 -22 23 -24 &
          (-109:110:-111:112:-308:309) u=21 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUIX8
C Plate core
2007      21 4.0082E-02 311 -312 101 -102 103 -104 u=21 imp:n=1 TMP=2.5301E-08
C Pu canning
2008      22 6.7015E-02 310 -313 21 -22 23 -24 &
          (-101:102:-103:104:-311:312) u=21 imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDL4
c Na plate core
2009      25 2.3191E-02 314 -315 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2010      26 7.872422E-02 313 -316 21 -22 23 -24 &
          (-109:110:-111:112:-314:315) u=21 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2011      23 6.951414E-02 317 -318 105 -106 107 -108 u=21 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2012      24 7.067127E-02 316 -319 21 -22 23 -24 &
          (-105:106:-107:108:-317:318) u=21 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2013      25 2.3191E-02 320 -321 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
C Na plate can
2014      26 7.872422E-02 319 -322 21 -22 23 -24 &
          (-109:110:-111:112:-320:321) u=21 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2015      7 8.607216E-02 322 -323 21 -22 23 -24 u=21 imp:n=1 TMP=2.5301E-08
c
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c UO2 plate
c UO2 core
2016 23 6.951414E-02 324 -325 105 -106 107 -108 u=21 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2017 24 7.067127E-02 323 -326 21 -22 23 -24 &
      (-105:106:-107:108:-324:325) u=21 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2018 25 2.3191E-02 327 -328 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2019 26 7.872422E-02 326 -329 21 -22 23 -24 &
      (-109:110:-111:112:-327:328) u=21 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUIV4
c Plate core
2020 31 6.4446E-02 330 -331 113 -114 115 -116 u=21 imp:n=1 TMP=2.5301E-08
c Pu canning
2021 32 7.3500E-02 329 -332 21 -22 23 -24 &
      (-113:114:-115:116:-330:331) u=21 imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDL4
c Na plate core
2022 25 2.3191E-02 333 -334 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2023 26 7.872422E-02 332 -335 21 -22 23 -24 &
      (-109:110:-111:112:-333:334) u=21 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2024 23 6.951414E-02 336 -337 105 -106 107 -108 u=21 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2025 24 7.067127E-02 335 -338 21 -22 23 -24 &
      (-105:106:-107:108:-336:337) u=21 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2026 25 2.3191E-02 339 -340 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2027 26 7.872422E-02 338 -341 21 -22 23 -24 &
      (-109:110:-111:112:-339:340) u=21 imp:n=1 TMP=2.5301E-08
c
c End of Inner Core Cell A
c
c
c MZB Inner Core Axial Blanket Cell B12-30
c
c
c Na plate
c Na plate core
2031 25 2.3191E-02 402 -403 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
c Na plate can
2032 26 7.872422E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=41 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2033 8 4.7208E-02 404 -405 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2034 10 8.1484E-02 405 -406 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2035 25 2.3191E-02 407 -408 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
c Na plate can
2036 26 7.872422E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=41 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2037 7 8.607216E-02 409 -410 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2038 8 4.7208E-02 410 -411 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c Na plate
c Na plate core
2039 25 2.3191E-02 412 -413 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2040 26 7.872422E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=41 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2041 10 8.1484E-02 414 -415 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2042 25 2.3191E-02 416 -417 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2043 26 7.872422E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=41 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2044 7 8.607216E-02 418 -419 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2045 8 4.7208E-02 419 -420 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2046 25 2.3191E-02 421 -422 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2047 26 7.872422E-02 420 -423 21 -22 23 -24 &
      (-109:110:-111:112:-421:422) u=41 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2048 10 8.1484E-02 423 -424 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2049 25 2.3191E-02 425 -426 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2050 26 7.872422E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=41 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2051 8 4.7208E-02 427 -428 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2052 7 8.607216E-02 428 -429 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2053 25 2.3191E-02 430 -431 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2054 26 7.872422E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=41 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2055 8 4.7208E-02 432 -433 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8
2056 10 8.1484E-02 433 -434 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2057 25 2.3191E-02 435 -436 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2058 26 7.872422E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=41 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B12-30
c
c
c MZB Inner Core Cell B
c

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c Sodium Plate NASTDL4
c Na plate core
2101 25 2.3191E-02 302 -303 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2102 26 7.872422E-02 301 -304 21 -22 23 -24 &
      (-109:110:-111:112:-302:303) u=22 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2103 23 6.951414E-02 305 -306 105 -106 107 -108 u=22 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2104 24 7.067127E-02 304 -307 21 -22 23 -24 &
      (-105:106:-107:108:-305:306) u=22 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2105 25 2.3191E-02 308 -309 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2106 26 7.872422E-02 307 -310 21 -22 23 -24 &
      (-109:110:-111:112:-308:309) u=22 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUX8
C Plate core
2107 39 4.01805E-02 311 -312 101 -102 103 -104 u=22 imp:n=1 TMP=2.5301E-08
C Pu canning
2108 40 6.70733E-02 310 -313 21 -22 23 -24 &
      (-101:102:-103:104:-311:312) u=22 imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDL4
c Na plate core
2109 25 2.3191E-02 314 -315 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2110 26 7.872422E-02 313 -316 21 -22 23 -24 &
      (-109:110:-111:112:-314:315) u=22 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2111 23 6.951414E-02 317 -318 105 -106 107 -108 u=22 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2112 24 7.067127E-02 316 -319 21 -22 23 -24 &
      (-105:106:-107:108:-317:318) u=22 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2113 25 2.3191E-02 320 -321 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2114 26 7.872422E-02 319 -322 21 -22 23 -24 &
      (-109:110:-111:112:-320:321) u=22 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2115 7 8.607216E-02 322 -323 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c
c UO2 plate
c UO2 core
2116 23 6.951414E-02 324 -325 105 -106 107 -108 u=22 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2117 24 7.067127E-02 323 -326 21 -22 23 -24 &
      (-105:106:-107:108:-324:325) u=22 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2118 25 2.3191E-02 327 -328 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2119 26 7.872422E-02 326 -329 21 -22 23 -24 &
      (-109:110:-111:112:-327:328) u=22 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUIV4
C Plate core
2120 31 6.44446E-02 330 -331 113 -114 115 -116 u=22 imp:n=1 TMP=2.5301E-08
C Pu canning
2121 32 7.3500E-02 329 -332 21 -22 23 -24 &

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

(-113:114:-115:116:-330:331) u=22 imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDL4
c Na plate core
2122 25 2.3191E-02 333 -334 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
c Na plate can
2123 26 7.872422E-02 332 -335 21 -22 23 -24 &
(-109:110:-111:112:-333:334) u=22 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2124 23 6.951414E-02 336 -337 105 -106 107 -108 u=22 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2125 24 7.067127E-02 335 -338 21 -22 23 -24 &
(-105:106:-107:108:-336:337) u=22 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2126 25 2.3191E-02 339 -340 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
c Na plate can
2127 26 7.872422E-02 338 -341 21 -22 23 -24 &
(-109:110:-111:112:-339:340) u=22 imp:n=1 TMP=2.5301E-08
c
c End of Inner Core Cell B
c
c
c MZB Inner Core Cell BG
c
c Sodium Plate NASTDM4
c Na plate core
2201 25 2.3191E-02 302 -303 109 -110 111 -112 u=23 imp:n=1 TMP=2.5301E-08
c Na plate can
2202 20 7.87808E-02 301 -304 21 -22 23 -24 &
(-109:110:-111:112:-302:303) u=23 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2203 23 6.951414E-02 305 -306 105 -106 107 -108 u=23 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2204 24 7.067127E-02 304 -307 21 -22 23 -24 &
(-105:106:-107:108:-305:306) u=23 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2205 25 2.3191E-02 308 -309 109 -110 111 -112 u=23 imp:n=1 TMP=2.5301E-08
c Na plate can
2206 20 7.87808E-02 307 -310 21 -22 23 -24 &
(-109:110:-111:112:-308:309) u=23 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUX8
c Plate core
2207 39 4.01805E-02 311 -312 101 -102 103 -104 u=23 imp:n=1 TMP=2.5301E-08
c Pu canning
2208 40 6.70733E-02 310 -313 21 -22 23 -24 &
(-101:102:-103:104:-311:312) u=23 imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDM4
c Na plate core
2209 25 2.3191E-02 314 -315 109 -110 111 -112 u=23 imp:n=1 TMP=2.5301E-08
c Na plate can
2210 20 7.87808E-02 313 -316 21 -22 23 -24 &
(-109:110:-111:112:-314:315) u=23 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2211 23 6.951414E-02 317 -318 105 -106 107 -108 u=23 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2212 24 7.067127E-02 316 -319 21 -22 23 -24 &
(-105:106:-107:108:-317:318) u=23 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2213 25 2.3191E-02 320 -321 109 -110 111 -112 u=23 imp:n=1 TMP=2.5301E-08

```

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```

C Na plate can
2214  20 7.87808E-02 319 -322 21 -22 23 -24 &
      (-109:110:-111:112:-320:321) u=23  imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2215  7 8.607216E-02 322 -323 21 -22 23 -24 u=23  imp:n=1 TMP=2.5301E-08
c
c
c UO2 plate
c UO2 core
2216  23 6.951414E-02 324 -325 105 -106 107 -108 u=23  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2217  24 7.067127E-02 323 -326 21 -22 23 -24 &
      (-105:106:-107:108:-324:325) u=23  imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2218  25 2.3191E-02 327 -328 109 -110 111 -112 u=23  imp:n=1 TMP=2.5301E-08
C Na plate can
2219  20 7.87808E-02 326 -329 21 -22 23 -24 &
      (-109:110:-111:112:-327:328) u=23  imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUIV4
C Plate core
2220  31 6.4446E-02 330 -331 113 -114 115 -116 u=23  imp:n=1 TMP=2.5301E-08
C Pu canning
2221  32 7.3500E-02 329 -332 21 -22 23 -24 &
      (-113:114:-115:116:-330:331) u=23  imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDM4
c Na plate core
2222  25 2.3191E-02 333 -334 109 -110 111 -112 u=23  imp:n=1 TMP=2.5301E-08
C Na plate can
2223  20 7.87808E-02 332 -335 21 -22 23 -24 &
      (-109:110:-111:112:-333:334) u=23  imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2224  23 6.951414E-02 336 -337 105 -106 107 -108 u=23  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2225  24 7.067127E-02 335 -338 21 -22 23 -24 &
      (-105:106:-107:108:-336:337) u=23  imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2226  25 2.3191E-02 339 -340 109 -110 111 -112 u=23  imp:n=1 TMP=2.5301E-08
C Na plate can
2227  20 7.87808E-02 338 -341 21 -22 23 -24 &
      (-109:110:-111:112:-339:340) u=23  imp:n=1 TMP=2.5301E-08
c
c End of Inner Core Cell BG
c
c
c
c MZB Inner Core Axial Blanket Cell B12-30G
c
c
c Na plate DM
c Na plate core
2231  25 2.3191E-02 402 -403 109 -110 111 -112 u=42  imp:n=1 TMP=2.5301E-08
C Na plate can
2232  20 7.87808E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=42  imp:n=1 TMP=2.5301E-08
c
c U8 plate
2233  8 4.7208E-02 404 -405 21 -22 23 -24 u=42  imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2234  10 8.1484E-02 405 -406 21 -22 23 -24 u=42  imp:n=1 TMP=2.5301E-08
c
c Na plate DM
c Na plate core
2235  25 2.3191E-02 407 -408 109 -110 111 -112 u=42  imp:n=1 TMP=2.5301E-08

```

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C Na plate can
2236 20 7.87808E-02 406 -409 21 -22 23 -24 &
(-109:110:-111:112:-407:408) u=42 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2237 7 8.607216E-02 409 -410 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2238 8 4.7208E-02 410 -411 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate DM
c Na plate core
2239 25 2.3191E-02 412 -413 109 -110 111 -112 u=42 imp:n=1 TMP=2.5301E-08
C Na plate can
2240 20 7.87808E-02 411 -414 21 -22 23 -24 &
(-109:110:-111:112:-412:413) u=42 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2241 10 8.1484E-02 414 -415 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate DM
c Na plate core
2242 25 2.3191E-02 416 -417 109 -110 111 -112 u=42 imp:n=1 TMP=2.5301E-08
C Na plate can
2243 20 7.87808E-02 415 -418 21 -22 23 -24 &
(-109:110:-111:112:-416:417) u=42 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2244 7 8.607216E-02 418 -419 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2245 8 4.7208E-02 419 -420 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate DM
c Na plate core
2246 25 2.3191E-02 421 -422 109 -110 111 -112 u=42 imp:n=1 TMP=2.5301E-08
C Na plate can
2247 20 7.87808E-02 420 -423 21 -22 23 -24 &
(-109:110:-111:112:-421:422) u=42 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2248 10 8.1484E-02 423 -424 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2249 25 2.3191E-02 425 -426 109 -110 111 -112 u=42 imp:n=1 TMP=2.5301E-08
C Na plate can
2250 20 7.87808E-02 424 -427 21 -22 23 -24 &
(-109:110:-111:112:-425:426) u=42 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2251 8 4.7208E-02 427 -428 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2252 7 8.607216E-02 428 -429 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate DM
c Na plate core
2253 25 2.3191E-02 430 -431 109 -110 111 -112 u=42 imp:n=1 TMP=2.5301E-08
C Na plate can
2254 20 7.87808E-02 429 -432 21 -22 23 -24 &
(-109:110:-111:112:-430:431) u=42 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2255 8 4.7208E-02 432 -433 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8
2256 10 8.1484E-02 433 -434 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate DM
c Na plate core

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```

2257  25 2.3191E-02 435 -436 109 -110 111 -112 u=42  imp:n=1 TMP=2.5301E-08
C Na plate can
2258  20 7.87808E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=42  imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B12-30G
c
c
c MZB Inner Core Cell D
c
c Sodium Plate NASTDM4
c Na plate core
2301  25 2.3191E-02 302 -303 109 -110 111 -112 u=24  imp:n=1 TMP=2.5301E-08
C Na plate can
2302  20 7.87808E-02 301 -304 21 -22 23 -24 &
      (-109:110:-111:112:-302:303) u=24  imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2303  23 6.951414E-02 305 -306 105 -106 107 -108 u=24  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2304  24 7.067127E-02 304 -307 21 -22 23 -24 &
      (-105:106:-107:108:-305:306) u=24  imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2305  25 2.3191E-02 308 -309 109 -110 111 -112 u=24  imp:n=1 TMP=2.5301E-08
C Na plate can
2306  20 7.87808E-02 307 -310 21 -22 23 -24 &
      (-109:110:-111:112:-308:309) u=24  imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUXI8
C Plate core
2307  41 4.01596E-02 311 -312 101 -102 103 -104 u=24  imp:n=1 TMP=2.5301E-08
C Pu canning
2308  42 6.61403E-02 310 -313 21 -22 23 -24 &
      (-101:102:-103:104:-311:312) u=24  imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDM4
c Na plate core
2309  25 2.3191E-02 314 -315 109 -110 111 -112 u=24  imp:n=1 TMP=2.5301E-08
C Na plate can
2310  20 7.87808E-02 313 -316 21 -22 23 -24 &
      (-109:110:-111:112:-314:315) u=24  imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2311  23 6.951414E-02 317 -318 105 -106 107 -108 u=24  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2312  24 7.067127E-02 316 -319 21 -22 23 -24 &
      (-105:106:-107:108:-317:318) u=24  imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2313  25 2.3191E-02 320 -321 109 -110 111 -112 u=24  imp:n=1 TMP=2.5301E-08
C Na plate can
2314  20 7.87808E-02 319 -322 21 -22 23 -24 &
      (-109:110:-111:112:-320:321) u=24  imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2315  7 8.607216E-02 322 -323 21 -22 23 -24 u=24  imp:n=1 TMP=2.5301E-08
c
c
c UO2 plate
c UO2 core
2316  23 6.951414E-02 324 -325 105 -106 107 -108 u=24  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2317  24 7.067127E-02 323 -326 21 -22 23 -24 &
      (-105:106:-107:108:-324:325) u=24  imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2318  25 2.3191E-02 327 -328 109 -110 111 -112 u=24  imp:n=1 TMP=2.5301E-08

```

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```

C Na plate can
2319  20 7.87808E-02 326 -329 21 -22 23 -24 &
      (-109:110:-111:112:-327:328) u=24  imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUIV4
C Plate core
2320  31 6.4446E-02 330 -331 113 -114 115 -116 u=24  imp:n=1 TMP=2.5301E-08
C Pu canning
2321  32 7.3500E-02 329 -332 21 -22 23 -24 &
      (-113:114:-115:116:-330:331) u=24  imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDM4
c Na plate core
2322  25 2.3191E-02 333 -334 109 -110 111 -112 u=24  imp:n=1 TMP=2.5301E-08
C Na plate can
2323  20 7.87808E-02 332 -335 21 -22 23 -24 &
      (-109:110:-111:112:-333:334) u=24  imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2324  23 6.951414E-02 336 -337 105 -106 107 -108 u=24  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2325  24 7.067127E-02 335 -338 21 -22 23 -24 &
      (-105:106:-107:108:-336:337) u=24  imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2326  25 2.3191E-02 339 -340 109 -110 111 -112 u=24  imp:n=1 TMP=2.5301E-08
C Na plate can
2327  20 7.87808E-02 338 -341 21 -22 23 -24 &
      (-109:110:-111:112:-339:340) u=24  imp:n=1 TMP=2.5301E-08
c
c End of Inner Core Cell D
c
c                               End of Inner Core Cells
c
c MZB Outer Core Cell A.
c
c Na plate
c Na plate core
2401  5 2.3126E-02 202 -203 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2402  6 7.865043E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=25 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2403  3 6.867137E-02 205 -206 105 -106 107 -108 u=25 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2404  4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=25 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2405  5 2.3126E-02 208 -209 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2406  6 7.865043E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=25 imp:n=1 TMP=2.5301E-08
c
c Pu plate
C Plate core
2407  1 4.023746E-02 101 -102 103 -104 211 -212 u=25 imp:n=1 TMP=2.5301E-08
C Pu canning
2408  2 6.6033E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=25 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2409  7 8.607216E-02 213 -214 21 -22 23 -24 u=25 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2410  3 6.867137E-02 215 -216 105 -106 107 -108 u=25 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2411  4 6.5639E-02 214 -217 21 -22 23 -24 &

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```

(-105:106:-107:108:-215:216) u=25 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2412 5 2.3126E-02 218 -219 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2413 6 7.865043E-02 217 -220 21 -22 23 -24 &
(-109:110:-111:112:-218:219) u=25 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2414 5 2.3126E-02 221 -222 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2415 6 7.865043E-02 220 -223 21 -22 23 -24 &
(-109:110:-111:112:-221:222) u=25 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2416 3 6.867137E-02 224 -225 105 -106 107 -108 u=25 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2417 4 6.5639E-02 223 -226 21 -22 23 -24 &
(-105:106:-107:108:-224:225) u=25 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2418 10 8.1484E-02 226 -227 21 -22 23 -24 u=25 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate V
C Plate core
2419 1 4.023746E-02 228 -229 101 -102 103 -104 u=25 imp:n=1 TMP=2.5301E-08
C Pu canning
2420 2 6.6033E-02 227 -230 21 -22 23 -24 &
(-101:102:-103:104:-228:229) u=25 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2421 5 2.3126E-02 231 -232 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2422 6 7.865043E-02 230 -233 21 -22 23 -24 &
(-109:110:-111:112:-231:232) u=25 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2423 3 6.867137E-02 234 -235 105 -106 107 -108 u=25 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2424 4 6.5639E-02 233 -236 21 -22 23 -24 &
(-105:106:-107:108:-234:235) u=25 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2425 5 2.3126E-02 237 -238 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2426 6 7.865043E-02 236 -239 21 -22 23 -24 &
(-109:110:-111:112:-237:238) u=25 imp:n=1 TMP=2.5301E-08
c
c End of MZB Outer Core Cell A
c
c
c MZB Outer Core Cell B.
c
c Na plate
c Na plate core
2451 25 2.3191E-02 202 -203 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2452 26 7.872422E-02 201 -204 21 -22 23 -24 &
(-109:110:-111:112:-202:203) u=26 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2453 3 6.867137E-02 205 -206 105 -106 107 -108 u=26 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2454 4 6.5639E-02 204 -207 21 -22 23 -24 &
(-105:106:-107:108:-205:206) u=26 imp:n=1 TMP=2.5301E-08
c
c Na plate

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```
c Na plate core
2455  25 2.3191E-02 208 -209 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2456  26 7.872422E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=26 imp:n=1 TMP=2.5301E-08
c
c Pu plate VI
C Plate core
2457  33 4.04903E-02 101 -102 103 -104 211 -212 u=26 imp:n=1 TMP=2.5301E-08
C Pu canning
2458  34 6.74722E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=26 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2459  7 8.607216E-02 213 -214 21 -22 23 -24 u=26 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2460  3 6.867137E-02 215 -216 105 -106 107 -108 u=26 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2461  4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=26 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2462  25 2.3191E-02 218 -219 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2463  26 7.872422E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=26 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2464  25 2.3191E-02 221 -222 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2465  26 7.872422E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=26 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2466  3 6.867137E-02 224 -225 105 -106 107 -108 u=26 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2467  4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=26 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2468  10 8.1484E-02 226 -227 21 -22 23 -24 u=26 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate VI
C Plate core
2469  33 4.04903E-02 228 -229 101 -102 103 -104 u=26 imp:n=1 TMP=2.5301E-08
C Pu canning
2470  34 6.74722E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=26 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2471  25 2.3191E-02 231 -232 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2472  26 7.872422E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=26 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2473  3 6.867137E-02 234 -235 105 -106 107 -108 u=26 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2474  4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=26 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2475  25 2.3191E-02 237 -238 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2476  26 7.872422E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=26 imp:n=1 TMP=2.5301E-08
```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c End of MZB Outer Core Cell B
c
c
c MZB Outer Core Cell C.
c
c Na plate
c Na plate core
2501 25 2.3191E-02 202 -203 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
c Na plate can
2502 26 7.872422E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=27 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2503 3 6.867137E-02 205 -206 105 -106 107 -108 u=27 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2504 4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=27 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2505 25 2.3191E-02 208 -209 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
c Na plate can
2506 26 7.872422E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=27 imp:n=1 TMP=2.5301E-08
c
c Pu plate VII
c Plate core
2507 35 3.99151E-02 101 -102 103 -104 211 -212 u=27 imp:n=1 TMP=2.5301E-08
c Pu canning
2508 36 6.72170E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=27 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2509 7 8.607216E-02 213 -214 21 -22 23 -24 u=27 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2510 3 6.867137E-02 215 -216 105 -106 107 -108 u=27 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2511 4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=27 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2512 25 2.3191E-02 218 -219 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
c Na plate can
2513 26 7.872422E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=27 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2514 25 2.3191E-02 221 -222 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
c Na plate can
2515 26 7.872422E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=27 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2516 3 6.867137E-02 224 -225 105 -106 107 -108 u=27 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2517 4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=27 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2518 10 8.1484E-02 226 -227 21 -22 23 -24 u=27 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate
c Plate core
2519 35 3.99151E-02 228 -229 101 -102 103 -104 u=27 imp:n=1 TMP=2.5301E-08
c Pu canning
2520 36 6.72170E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=27 imp:n=1 TMP=2.5301E-08

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Na plate
c Na plate core
2521  25 2.3191E-02 231 -232 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
C Na plate can
2522  26 7.872422E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=27 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2523  3 6.867137E-02 234 -235 105 -106 107 -108 u=27 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2524  4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=27 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2525  25 2.3191E-02 237 -238 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
C Na plate can
2526  26 7.872422E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=27 imp:n=1 TMP=2.5301E-08
c
c End of MZB Outer Core Cell C
c
c
c MZB Outer Core Cell D.
c
c Na plate
c Na plate core
2551  25 2.3191E-02 202 -203 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08
C Na plate can
2552  26 7.872422E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=28 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2553  3 6.867137E-02 205 -206 105 -106 107 -108 u=28 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2554  4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=28 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2555  25 2.3191E-02 208 -209 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08
C Na plate can
2556  26 7.872422E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=28 imp:n=1 TMP=2.5301E-08
c
c Pu plate VIII
C Plate core
2557  37 4.01503E-02 101 -102 103 -104 211 -212 u=28 imp:n=1 TMP=2.5301E-08
C Pu canning
2558  38 6.71396E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=28 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2559  7 8.607216E-02 213 -214 21 -22 23 -24 u=28 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2560  3 6.867137E-02 215 -216 105 -106 107 -108 u=28 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2561  4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=28 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2562  25 2.3191E-02 218 -219 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08
C Na plate can
2563  26 7.872422E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=28 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2564  25 2.3191E-02 221 -222 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08

```

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LIQUID METAL FAST REACTOR - LMFR
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```
C Na plate can
2565 26 7.872422E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=28 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2566 3 6.867137E-02 224 -225 105 -106 107 -108 u=28 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2567 4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=28 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2568 10 8.1484E-02 226 -227 21 -22 23 -24 u=28 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate VIII
C Plate core
2569 37 4.01503E-02 228 -229 101 -102 103 -104 u=28 imp:n=1 TMP=2.5301E-08
C Pu canning
2570 38 6.71396E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=28 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2571 25 2.3191E-02 231 -232 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08
C Na plate can
2572 26 7.872422E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=28 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2573 3 6.867137E-02 234 -235 105 -106 107 -108 u=28 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2574 4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=28 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2575 25 2.3191E-02 237 -238 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08
C Na plate can
2576 26 7.872422E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=28 imp:n=1 TMP=2.5301E-08
c
c End of MZA Core Cell D
c
c MZB Outer Core Cell G.
c
c Na plate
c Na plate core
2601 25 2.3191E-02 202 -203 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
C Na plate can
2602 20 7.87808E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=29 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2603 3 6.867137E-02 205 -206 105 -106 107 -108 u=29 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2604 4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=29 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2605 25 2.3191E-02 208 -209 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
C Na plate can
2606 20 7.87808E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=29 imp:n=1 TMP=2.5301E-08
c
c Pu plate XII
C Plate core
2607 43 4.02475E-02 101 -102 103 -104 211 -212 u=29 imp:n=1 TMP=2.5301E-08
C Pu canning
2608 44 6.55545E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=29 imp:n=1 TMP=2.5301E-08
c
c Steel plate
```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```
2609 7 8.607216E-02 213 -214 21 -22 23 -24 u=29 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2610 3 6.867137E-02 215 -216 105 -106 107 -108 u=29 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2611 4 6.5639E-02 214 -217 21 -22 23 -24 &
(-105:106:-107:108:-215:216) u=29 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2612 25 2.3191E-02 218 -219 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
c Na plate can
2613 20 7.87808E-02 217 -220 21 -22 23 -24 &
(-109:110:-111:112:-218:219) u=29 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2614 25 2.3191E-02 221 -222 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
c Na plate can
2615 20 7.87808E-02 220 -223 21 -22 23 -24 &
(-109:110:-111:112:-221:222) u=29 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2616 3 6.867137E-02 224 -225 105 -106 107 -108 u=29 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2617 4 6.5639E-02 223 -226 21 -22 23 -24 &
(-105:106:-107:108:-224:225) u=29 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2618 10 8.1484E-02 226 -227 21 -22 23 -24 u=29 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate XII
c Plate core
2619 43 4.02475E-02 228 -229 101 -102 103 -104 u=29 imp:n=1 TMP=2.5301E-08
c Pu canning
2620 44 6.55545E-02 227 -230 21 -22 23 -24 &
(-101:102:-103:104:-228:229) u=29 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2621 25 2.3191E-02 231 -232 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
c Na plate can
2622 20 7.87808E-02 230 -233 21 -22 23 -24 &
(-109:110:-111:112:-231:232) u=29 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2623 3 6.867137E-02 234 -235 105 -106 107 -108 u=29 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2624 4 6.5639E-02 233 -236 21 -22 23 -24 &
(-105:106:-107:108:-234:235) u=29 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2625 25 2.3191E-02 237 -238 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
c Na plate can
2626 20 7.87808E-02 236 -239 21 -22 23 -24 &
(-109:110:-111:112:-237:238) u=29 imp:n=1 TMP=2.5301E-08
c
c End of MZB Outer Core Cell G
c
c
c MZB Outer Core Cell BG.
c
c Na plate
c Na plate core
2651 25 2.3191E-02 202 -203 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
c Na plate can
2652 20 7.87808E-02 201 -204 21 -22 23 -24 &
(-109:110:-111:112:-202:203) u=30 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
```


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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```
c UO2 core
2653 3 6.867137E-02 205 -206 105 -106 107 -108 u=30 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2654 4 6.5639E-02 204 -207 21 -22 23 -24 &
(-105:106:-107:108:-205:206) u=30 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2655 25 2.3191E-02 208 -209 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
C Na plate can
2656 20 7.87808E-02 207 -210 21 -22 23 -24 &
(-109:110:-111:112:-208:209) u=30 imp:n=1 TMP=2.5301E-08
c
c Pu plate VI
C Plate core
2657 33 4.04903E-02 101 -102 103 -104 211 -212 u=30 imp:n=1 TMP=2.5301E-08
C Pu canning
2658 34 6.74722E-02 210 -213 21 -22 23 -24 &
(-101:102:-103:104:-211:212) u=30 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2659 7 8.607216E-02 213 -214 21 -22 23 -24 u=30 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2660 3 6.867137E-02 215 -216 105 -106 107 -108 u=30 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2661 4 6.5639E-02 214 -217 21 -22 23 -24 &
(-105:106:-107:108:-215:216) u=30 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2662 25 2.3191E-02 218 -219 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
C Na plate can
2663 20 7.87808E-02 217 -220 21 -22 23 -24 &
(-109:110:-111:112:-218:219) u=30 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2664 25 2.3191E-02 221 -222 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
C Na plate can
2665 20 7.87808E-02 220 -223 21 -22 23 -24 &
(-109:110:-111:112:-221:222) u=30 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2666 3 6.867137E-02 224 -225 105 -106 107 -108 u=30 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2667 4 6.5639E-02 223 -226 21 -22 23 -24 &
(-105:106:-107:108:-224:225) u=30 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2668 10 8.1484E-02 226 -227 21 -22 23 -24 u=30 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate
C Plate core
2669 33 4.04903E-02 228 -229 101 -102 103 -104 u=30 imp:n=1 TMP=2.5301E-08
C Pu canning
2670 34 6.74722E-02 227 -230 21 -22 23 -24 &
(-101:102:-103:104:-228:229) u=30 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2671 25 2.3191E-02 231 -232 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
C Na plate can
2672 20 7.87808E-02 230 -233 21 -22 23 -24 &
(-109:110:-111:112:-231:232) u=30 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2673 3 6.867137E-02 234 -235 105 -106 107 -108 u=30 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2674 4 6.5639E-02 233 -236 21 -22 23 -24 &
(-105:106:-107:108:-234:235) u=30 imp:n=1 TMP=2.5301E-08
```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Na plate
c Na plate core
2675 25 2.3191E-02 237 -238 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
C Na plate can
2676 20 7.87808E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=30 imp:n=1 TMP=2.5301E-08
c
c End of MZB Outer Core Cell BG
c
c MZB Outer Core Cell DG
c
c Na plate
c Na plate core
2701 25 2.3191E-02 202 -203 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2702 20 7.87808E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=31 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2703 3 6.867137E-02 205 -206 105 -106 107 -108 u=31 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2704 4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=31 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2705 25 2.3191E-02 208 -209 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2706 20 7.87808E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=31 imp:n=1 TMP=2.5301E-08
c
c Pu plate VIII
C Plate core
2707 37 4.01503E-02 101 -102 103 -104 211 -212 u=31 imp:n=1 TMP=2.5301E-08
C Pu canning
2708 38 6.71396E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=31 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2709 7 8.607216E-02 213 -214 21 -22 23 -24 u=31 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2710 3 6.867137E-02 215 -216 105 -106 107 -108 u=31 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2711 4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=31 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2712 25 2.3191E-02 218 -219 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2713 20 7.87808E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=31 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2714 25 2.3191E-02 221 -222 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2715 20 7.87808E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=31 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2716 3 6.867137E-02 224 -225 105 -106 107 -108 u=31 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2717 4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=31 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2718 10 8.1484E-02 226 -227 21 -22 23 -24 u=31 imp:n=1 TMP=2.5301E-08
c
c

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c Pu plate
C Plate core
2719 37 4.01503E-02 228 -229 101 -102 103 -104 u=31 imp:n=1 TMP=2.5301E-08
C Pu canning
2720 38 6.71396E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=31 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2721 25 2.3191E-02 231 -232 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2722 20 7.87808E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=31 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2723 3 6.867137E-02 234 -235 105 -106 107 -108 u=31 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2724 4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=31 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2725 25 2.3191E-02 237 -238 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2726 20 7.87808E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=31 imp:n=1 TMP=2.5301E-08
c
c End of MZB Outer Core Cell DG
c
c
c
c End of MZB Core Cells
c
c
c
c Axial blanket cell B11-1
c
c Na plate
c Na plate core
2801 5 2.3126E-02 402 -403 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2802 6 7.865043E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=44 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2803 8 4.7208E-02 404 -405 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2804 10 8.1484E-02 405 -406 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2805 5 2.3126E-02 407 -408 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2806 6 7.865043E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=44 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2807 7 8.607216E-02 409 -410 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2808 8 4.7208E-02 410 -411 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2809 5 2.3126E-02 412 -413 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2810 6 7.865043E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=44 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2811 10 8.1484E-02 414 -415 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core

```

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```

2812   5 2.3126E-02 416 -417 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2813   6 7.865043E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=44 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2814   7 8.607216E-02 418 -419 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2815   8 4.7208E-02 419 -420 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2816   5 2.3126E-02 421 -422 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2817   6 7.865043E-02 420 -423 21 -22 23 -24 &
      (-109:110:-111:112:-421:422) u=44 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2818  10 8.1484E-02 423 -424 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2819   5 2.3126E-02 425 -426 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2820   6 7.865043E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=44 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2821   8 4.7208E-02 427 -428 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2822   7 8.607216E-02 428 -429 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2823   5 2.3126E-02 430 -431 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2824   6 7.865043E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=44 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2825   8 4.7208E-02 432 -433 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8
2826  10 8.1484E-02 433 -434 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2827   5 2.3126E-02 435 -436 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2828   6 7.865043E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=44 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B11-1
c
c
c Axial blanket cell B11-1A
c
c Na plate
c Na plate core
2831  25 2.3191E-02 402 -403 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2832  26 7.872422E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=45 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2833   8 4.7208E-02 404 -405 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8

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```

2834 10 8.1484E-02 405 -406 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2835 25 2.3191E-02 407 -408 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2836 26 7.872422E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=45 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2837 7 8.607216E-02 409 -410 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2838 8 4.7208E-02 410 -411 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2839 25 2.3191E-02 412 -413 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2840 26 7.872422E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=45 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2841 10 8.1484E-02 414 -415 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2842 25 2.3191E-02 416 -417 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2843 26 7.872422E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=45 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2844 7 8.607216E-02 418 -419 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2845 8 4.7208E-02 419 -420 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2846 25 2.3191E-02 421 -422 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2847 26 7.872422E-02 420 -423 21 -22 23 -24 &
      (-109:110:-111:112:-421:422) u=45 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2848 10 8.1484E-02 423 -424 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2849 25 2.3191E-02 425 -426 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2850 26 7.872422E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=45 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2851 8 4.7208E-02 427 -428 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2852 7 8.607216E-02 428 -429 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2853 25 2.3191E-02 430 -431 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2854 26 7.872422E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=45 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2855 8 4.7208E-02 432 -433 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c

```

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```
c Graphite plate GI8
2856 10 8.1484E-02 433 -434 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2857 25 2.3191E-02 435 -436 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
c Na plate can
2858 26 7.872422E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=45 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B11-1A
c
c
c Axial blanket cell B11-1AG
c
c Na plate
c Na plate core
2861 25 2.3191E-02 402 -403 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
c Na plate can
2862 20 7.87808E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=46 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2863 8 4.7208E-02 404 -405 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2864 10 8.1484E-02 405 -406 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2865 25 2.3191E-02 407 -408 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
c Na plate can
2866 20 7.87808E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=46 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2867 7 8.607216E-02 409 -410 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2868 8 4.7208E-02 410 -411 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2869 25 2.3191E-02 412 -413 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
c Na plate can
2870 20 7.87808E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=46 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2871 10 8.1484E-02 414 -415 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2872 25 2.3191E-02 416 -417 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
c Na plate can
2873 20 7.87808E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=46 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2874 7 8.607216E-02 418 -419 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2875 8 4.7208E-02 419 -420 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2876 25 2.3191E-02 421 -422 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
c Na plate can
2877 20 7.87808E-02 420 -423 21 -22 23 -24 &
      (-109:110:-111:112:-421:422) u=46 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2878 10 8.1484E-02 423 -424 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
```

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```

c Na plate
c Na plate core
2879 25 2.3191E-02 425 -426 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
C Na plate can
2880 20 7.87808E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=46 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2881 8 4.7208E-02 427 -428 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2882 7 8.607216E-02 428 -429 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2883 25 2.3191E-02 430 -431 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
C Na plate can
2884 20 7.87808E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=46 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2885 8 4.7208E-02 432 -433 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8
2886 10 8.1484E-02 433 -434 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2887 25 2.3191E-02 435 -436 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
C Na plate can
2888 20 7.87808E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=46 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B11-1AG
c
c Radial Blanket Central Range B11-3
c
c Graphite plate GII8
2901 11 8.5125E-02 501 -502 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2902 25 2.3191E-02 503 -504 109 -110 111 -112 u=51 imp:n=1 TMP=2.5301E-08
C Na plate can
2903 26 7.872422E-02 502 -505 21 -22 23 -24 &
      (-109:110:-111:112:-503:504) u=51 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2904 11 8.5125E-02 505 -506 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2905 7 8.607216E-02 506 -507 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c U2 plate
2906 9 4.7925E-02 507 -508 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2907 11 8.5125E-02 508 -509 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2908 25 2.3191E-02 510 -511 109 -110 111 -112 u=51 imp:n=1 TMP=2.5301E-08
C Na plate can
2909 26 7.872422E-02 509 -512 21 -22 23 -24 &
      (-109:110:-111:112:-510:511) u=51 imp:n=1 TMP=2.5301E-08
c
c MST8 plate
c
2910 27 8.4980E-02 512 -513 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2911 11 8.5125E-02 513 -514 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c

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```

c Na plate
c Na plate core
2912 25 2.3191E-02 515 -516 109 -110 111 -112 u=51 imp:n=1 TMP=2.5301E-08
C Na plate can
2913 26 7.872422E-02 514 -517 21 -22 23 -24 &
      (-109:110:-111:112:-515:516) u=51 imp:n=1 TMP=2.5301E-08
c
c      End of Central Section of the Radial blanket B11-3
c
c
c Radial Blanket Central Range B11-3A
c
c Graphite plate GII8
2916 11 8.5125E-02 501 -502 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2917 25 2.3191E-02 503 -504 109 -110 111 -112 u=52 imp:n=1 TMP=2.5301E-08
C Na plate can
2918 26 7.872422E-02 502 -505 21 -22 23 -24 &
      (-109:110:-111:112:-503:504) u=52 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2919 11 8.5125E-02 505 -506 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2920 7 8.607216E-02 506 -507 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c U2 plate
2921 9 4.7925E-02 507 -508 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2922 11 8.5125E-02 508 -509 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2923 25 2.3191E-02 510 -511 109 -110 111 -112 u=52 imp:n=1 TMP=2.5301E-08
C Na plate can
2924 26 7.872422E-02 509 -512 21 -22 23 -24 &
      (-109:110:-111:112:-510:511) u=52 imp:n=1 TMP=2.5301E-08
c
c MST8 plate
c
2925 27 8.4980E-02 512 -513 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2926 11 8.5125E-02 513 -514 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2927 25 2.3191E-02 515 -516 109 -110 111 -112 u=52 imp:n=1 TMP=2.5301E-08
C Na plate can
2928 26 7.872422E-02 514 -517 21 -22 23 -24 &
      (-109:110:-111:112:-515:516) u=52 imp:n=1 TMP=2.5301E-08
c
c      End of Central Section of the Radial blanket B11-3A
c
c
c Radial Blanket Central Range B11-3G
c Includes the sodium plate NASTDM4 and graphite plate GIII8
c Graphite plate GII8
2931 11 8.5125E-02 501 -502 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2932 25 2.3191E-02 503 -504 109 -110 111 -112 u=53 imp:n=1 TMP=2.5301E-08
C Na plate can
2933 26 7.872422E-02 502 -505 21 -22 23 -24 &
      (-109:110:-111:112:-503:504) u=53 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2934 11 8.5125E-02 505 -506 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2935 7 8.607216E-02 506 -507 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c

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```

c U2 plate
2936 9 4.7925E-02 507 -508 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2937 11 8.5125E-02 508 -509 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2938 25 2.3191E-02 510 -511 109 -110 111 -112 u=53 imp:n=1 TMP=2.5301E-08
C Na plate can
2939 26 7.872422E-02 509 -512 21 -22 23 -24 &
      (-109:110:-111:112:-510:511) u=53 imp:n=1 TMP=2.5301E-08
c
c MST8 plate
c
2940 27 8.4980E-02 512 -513 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2941 11 8.5125E-02 513 -514 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2942 25 2.3191E-02 515 -516 109 -110 111 -112 u=53 imp:n=1 TMP=2.5301E-08
C Na plate can
2943 26 7.872422E-02 514 -517 21 -22 23 -24 &
      (-109:110:-111:112:-515:516) u=53 imp:n=1 TMP=2.5301E-08
c
c
      End of Central Section of the Radial blanket B11-3G
c
c
      Upper and Lower Section of the radial Blanket
c
c ALG8
2951 29 2.6752E-02 601 -603 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c AL2034
2952 30 1.106986E-01 603 -604 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c GII8
2953 11 8.5125E-02 604 -605 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c ALG8
2954 29 2.6752E-02 605 -606 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c U2 plate
2955 9 4.7925E-02 606 -607 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c ALG8
2956 29 2.6752E-02 607 -608 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c GII8
2957 11 8.5125E-02 608 -609 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c AL2034
2958 30 1.106986E-01 609 -610 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c MST2 (MST8) plate
c
2959 27 8.4980E-02 610 -611 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2960 29 2.6752E-02 611 -612 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c GII8
2961 11 8.5125E-02 612 -613 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2962 29 2.6752E-02 613 -615 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c U2 plate
2963 9 4.7925E-02 615 -616 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c

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```

c
c AL2034
2964 30 1.106986E-01 616 -617 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2965 29 2.6752E-02 617 -618 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c GII8
2966 11 8.5125E-02 618 -619 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c MST8 plate
c
2967 27 8.4980E-02 619 -620 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2968 29 2.6752E-02 620 -621 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c End of upper and lower radial blanket sections
c
c c Lower Plenum Cell
c
c ALSC3 plate
2971 28 4.7627E-02 7 -33 21 -22 23 -24 u=71 imp:n=1 TMP=2.5301E-08
c
c MST1 plate
c
2972 27 8.4980E-02 33 -34 21 -22 23 -24 u=71 imp:n=1 TMP=2.5301E-08
c
c ALSC3 plate
2973 28 4.7627E-02 34 -35 21 -22 23 -24 u=71 imp:n=1 TMP=2.5301E-08
c
c MST3 plate
c
2974 27 8.4980E-02 35 -36 21 -22 23 -24 u=71 imp:n=1 TMP=2.5301E-08
c
c ALSC3 plate
c
2975 28 4.7627E-02 36 -37 21 -22 23 -24 u=71 imp:n=1 TMP=2.5301E-08
c
c Upper Plenum Cell
c
c ALSC3 plate
c
2981 28 4.7627E-02 7 -33 21 -22 23 -24 u=72 imp:n=1 TMP=2.5301E-08
c
c MST3 plate
c
2982 27 8.4980E-02 33 -38 21 -22 23 -24 u=72 imp:n=1 TMP=2.5301E-08
c
c ALSC3 plate
2983 28 4.7627E-02 38 -39 21 -22 23 -24 u=72 imp:n=1 TMP=2.5301E-08
c
c MST1 plate
c
2984 27 8.4980E-02 39 -36 21 -22 23 -24 u=72 imp:n=1 TMP=2.5301E-08
c
c ALSC3 plate
2985 28 4.7627E-02 36 -37 21 -22 23 -24 u=72 imp:n=1 TMP=2.5301E-08
c
c Cell data complete
c
c Array data
c
c
c Form the region surrounding groups of 5x5 elements, containing grids
c
c
3001 0 89 -90 91 -92 (-85:86:-87:88) -71 u=100 imp:n=1
c
3002 19 7.403935E-02 89 -90 91 -92 (-85:86:-87:88) 71 -72 u=100 imp:n=1
c

```

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```

3003  0 89 -90 91 -92 (-85:86:-87:88) 72 -73 u=100 imp:n=1
c
3004  19 7.403935E-02 89 -90 91 -92 (-85:86:-87:88) 73 -74 u=100 imp:n=1
c
3005  0 89 -90 91 -92 (-85:86:-87:88) 74 u=100 imp:n=1
c
c -----
c
c                               Form arrays of 5x5 elements
c
c Central array of 5x5 core elements type 1
c
c
3011    0   1 -2 3 -4 u=201 lat=1
      fill=-2:2 -2:2 0:0
      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
      imp:n=1
c
3012  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=101 imp:n=1
c
3013  0 7 -16 85 -86 87 -88 fill=201 u=101 imp:n=1
c
c -----
c
c                               ROW 0 the central row, working from the centre
c
c First Left Central array of 5x5 core elements
c
c
3014    0   1 -2 3 -4 u=202 lat=1
      fill=-2:2 -2:2 0:0
      2 1 1 1 1
      2 1 1 1 1
      2 1 1 1 1
      2 1 1 1 1
      2 1 1 1 1
      2 1 1 1 1
      imp:n=1
c
3015  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=102 imp:n=1
c
3016  0 7 -16 85 -86 87 -88 fill=202 u=102 imp:n=1
c
c
c First Right Central array of 5x5 core elements
c
c
3017    0   1 -2 3 -4 u=203 lat=1
      fill=-2:2 -2:2 0:0
      1 1 1 1 2
      1 1 1 1 2
      1 1 1 1 2
      1 1 1 1 2
      1 1 1 1 2
      1 1 1 1 2
      imp:n=1
c
3018  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=103 imp:n=1
c
3019  0 7 -16 85 -86 87 -88 fill=203 u=103 imp:n=1
c
c left edge inner core array of 5x5 elements in Row 0
c
3021    0   1 -2 3 -4 u=204 lat=1
      fill=-2:2 -2:2 0:0
      6 4 4 3 2
      5 4 4 3 2
      5 4 4 3 2
      5 4 4 3 2
      5 4 4 3 2
      5 4 4 3 2

```

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```

        imp:n=1
c
c
c Surround material
c
3022    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=104 imp:n=1
c
c
3023    0 7 -16 85 -86 87 -88 fill=204 u=104 imp:n=1
c
c right edge inner core array of 5x5 core elements in Row 0
c
3031      0   1 -2 3 -4 u=205 lat=1
        fill=-2:2 -2:2 0:0
        2 3 4 4 6
        2 3 4 4 5
        2 3 4 4 5
        2 3 4 4 5
        2 3 4 4 5
        imp:n=1
c
c
c Surround material
c
3032    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=105 imp:n=1
c
c
3033    0 7 -16 85 -86 87 -88 fill=205 u=105 imp:n=1
c
c Left outer core array in row 0
c
3041      0   1 -2 3 -4 u=206 lat=1
        fill=-2:2 -2:2 0:0
        16 16 16 8 7
        16 16 16 8 7
        16 16 16 8 7
        16 16 16 8 7
        16 16 16 8 7
        imp:n=1
c
c Surround material
c
3042    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=106 imp:n=1
c
c
3043    0 7 -16 85 -86 87 -88 fill=206 u=106 imp:n=1
c
c
c Right outer core array in row 0
c
3051      0   1 -2 3 -4 u=207 lat=1
        fill=-2:2 -2:2 0:0
        7 8 16 16 16
        7 8 16 16 16
        7 8 16 16 16
        7 8 16 16 16
        7 8 16 16 16
        imp:n=1
c
c
c Surround material
c
3052    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=107 imp:n=1
c
c
3053    0 7 -16 85 -86 87 -88 fill=207 u=107 imp:n=1
c
c
c Left blanket array in row 0
c
3061      0   1 -2 3 -4 u=208 lat=1
        fill=-2:2 -2:2 0:0
        19 19 16 16 16
        19 19 16 16 16
        19 19 16 16 16
        19 19 16 16 16
        19 19 16 16 16

```

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```

        imp:n=1
c
c
c Surround material
c
3062    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=108 imp:n=1
c
c
3063    0 7 -16 85 -86 87 -88 fill=208 u=108 imp:n=1
c
c
c Right blanket array in Row 0
c
c
3064    0    1 -2 3 -4 u=209 lat=1
        fill=-2:2 -2:2 0:0
        16 16 16 19 19
        16 16 16 19 19
        16 16 16 19 19
        16 16 16 19 19
        16 16 16 19 19
        imp:n=1
c
c Surround material
c
3065    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=109 imp:n=1
c
3066    0 7 -16 85 -86 87 -88 fill=209 u=109 imp:n=1
c
c left and right shield array
c
3067    0    1 -2 3 -4 u=210 lat=1
        fill=-2:2 -2:2 0:0
        19 19 19 19 19
        19 19 19 19 19
        19 19 19 19 19
        19 19 19 19 19
        19 19 19 19 19
        imp:n=1
c
c Surround material
c
3068    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=110 imp:n=1
c
3069    0 7 -16 85 -86 87 -88 fill=210 u=110 imp:n=1
c
c -----
c
c           Row 1. the line below the central line
c
c
c Central array of 5x5 core elements
c
c
3074    0    1 -2 3 -4 u=211 lat=1
        fill=-2:2 -2:2 0:0
        1 1 1 1 1
        1 1 1 1 1
        1 1 1 1 1
        1 1 1 1 1
        2 2 2 2 2
        imp:n=1
c
3075    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=111 imp:n=1
c
3076    0 7 -16 85 -86 87 -88 fill=211 u=111 imp:n=1
c
c
c
c First Left Central array of 5x5 core elements
c
c
3077    0    1 -2 3 -4 u=212 lat=1
        fill=-2:2 -2:2 0:0
        2 1 1 1 1
        2 2 1 1 1

```

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```

2 2 2 1 1
3 2 2 2 2
4 3 2 2 2
imp:n=1
c
3078 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=112 imp:n=1
c
3079 0 7 -16 85 -86 87 -88 fill=212 u=112 imp:n=1
c
c
c
c First Right Central array of 5x5 core elements
c
c
3080 0 1 -2 3 -4 u=213 lat=1
fill=-2:2 -2:2 0:0
1 1 1 2 2
1 1 1 2 2
1 1 2 2 2
1 2 2 2 3
2 2 2 3 4
imp:n=1
c
3081 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=113 imp:n=1
c
3082 0 7 -16 85 -86 87 -88 fill=213 u=113 imp:n=1
c
c
c
c Next left inner core array of 5x5 elements in Row 1
c
3083 0 1 -2 3 -4 u=214 lat=1
fill=-2:2 -2:2 0:0
6 4 4 4 2
6 5 4 4 2
7 5 4 4 2
7 6 5 4 4
8 7 6 5 4
imp:n=1
c
c
c Surround material
c
3084 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=114 imp:n=1
c
c
3085 0 7 -16 85 -86 87 -88 fill=214 u=114 imp:n=1
c
c Next right inner core array of 5x5 core elements in Row 1
c
3091 0 1 -2 3 -4 u=215 lat=1
fill=-2:2 -2:2 0:0
2 4 4 4 6
2 4 4 5 6
2 4 4 5 7
4 4 5 6 7
4 5 6 7 8
imp:n=1
c
c
c Surround material
c
3092 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=115 imp:n=1
c
c
3093 0 7 -16 85 -86 87 -88 fill=215 u=115 imp:n=1
c
c Left outer core array in row 1
c
3101 0 1 -2 3 -4 u=216 lat=1
fill=-2:2 -2:2 0:0
16 16 16 11 7
16 16 16 9 8
16 16 16 16 8
16 16 16 16 8
16 16 16 16 6

```

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```

        imp:n=1
c
c Surround material
c
3102    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=116 imp:n=1
c
3103    0 7 -16 85 -86 87 -88 fill=216 u=116 imp:n=1
c
c
c Right outer core array in row 1
c
3111    0 1 -2 3 -4 u=217 lat=1
        fill=-2:2 -2:2 0:0
        7 11 16 16 16
        7 9 16 16 16
        8 16 16 16 16
        11 16 16 16 16
        9 16 16 16 16
        imp:n=1
c
c
c Surround material
c
3112    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=117 imp:n=1
c
c
3113    0 7 -16 85 -86 87 -88 fill=217 u=117 imp:n=1
c
c
c Left blanket array in row 1
c
3121    0 1 -2 3 -4 u=218 lat=1
        fill=-2:2 -2:2 0:0
        19 19 16 16 16
        19 19 19 16 16
        19 19 19 16 16
        19 19 19 16 16
        19 19 19 16 16
        imp:n=1
c
c
c Surround material
c
3122    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=118 imp:n=1
c
c
3123    0 7 -16 85 -86 87 -88 fill=218 u=118 imp:n=1
c
c
c Right blanket array in Row 1
c
c
3124    0 1 -2 3 -4 u=219 lat=1
        fill=-2:2 -2:2 0:0
        16 16 16 19 19
        16 16 19 19 19
        16 16 19 19 19
        16 16 19 19 19
        16 16 19 19 19
        imp:n=1
c
c Surround material
c
3125    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=119 imp:n=1
c
3126    0 7 -16 85 -86 87 -88 fill=219 u=119 imp:n=1
c
c
c Left shield array in row 1
c
3127    0 1 -2 3 -4 u=220 lat=1
        fill=-2:2 -2:2 0:0
        20 20 20 19 19
        20 20 20 20 19
        20 20 20 20 20
        20 20 20 20 20

```

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```

20 20 20 20 20
imp:n=1
c
c
c Surround material
c
3128  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=120 imp:n=1
c
c
c
3129  0 7 -16 85 -86 87 -88 fill=220 u=120 imp:n=1
c
c -----
c
c
c
c          Row 2. the line above the central line
c
c
c
c Central array of 5x5 core elements
c
c
3134  0  1 -2 3 -4 u=221 lat=1
      fill=-2:2 -2:2 0:0
      2 2 2 2 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
      imp:n=1
c
3135  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=121 imp:n=1
c
3136  0 7 -16 85 -86 87 -88 fill=221 u=121 imp:n=1
c
c
c
c First Left Central array of 5x5 core elements
c
c
3137  0  1 -2 3 -4 u=222 lat=1
      fill=-2:2 -2:2 0:0
      4 3 2 2 2
      3 2 2 2 1
      2 2 2 1 1
      2 2 1 1 1
      2 2 1 1 1
      imp:n=1
c
3138  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=122 imp:n=1
c
3139  0 7 -16 85 -86 87 -88 fill=222 u=122 imp:n=1
c
c
c
c First Right Central array of 5x5 core elements
c
c
3140  0  1 -2 3 -4 u=223 lat=1
      fill=-2:2 -2:2 0:0
      2 2 2 3 4
      2 2 2 2 3
      1 1 2 2 2
      1 1 1 2 2
      1 1 1 2 2
      imp:n=1
c
3141  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=123 imp:n=1
c
3142  0 7 -16 85 -86 87 -88 fill=223 u=123 imp:n=1
c
c
c
c First left inner-outer core array of 5x5 elements in Row 2
c
3143  0  1 -2 3 -4 u=224 lat=1

```


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```

fill=-2:2 -2:2 0:0
8 7 6 5 4
7 6 5 4 4
7 5 4 4 2
6 5 4 4 2
6 4 4 4 2
imp:n=1
c
c
c Surround material
c
3144 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=124 imp:n=1
c
c
3145 0 7 -16 85 -86 87 -88 fill=224 u=124 imp:n=1
c
c First right inner-outer core array of 5x5 core elements in Row 2
c
3151 0 1 -2 3 -4 u=225 lat=1
fill=-2:2 -2:2 0:0
4 5 6 7 8
4 4 5 6 7
2 4 4 5 7
2 4 4 5 6
2 4 4 4 6
imp:n=1
c
c
c Surround material
c
3152 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=125 imp:n=1
c
c
3153 0 7 -16 85 -86 87 -88 fill=225 u=125 imp:n=1
c
c Left outer core array in row 2
c
3161 0 1 -2 3 -4 u=226 lat=1
fill=-2:2 -2:2 0:0
16 16 16 16 9
16 16 16 16 11
16 16 16 16 8
16 16 16 9 8
16 16 16 11 7
imp:n=1
c
c Surround material
c
3162 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=126 imp:n=1
c
3163 0 7 -16 85 -86 87 -88 fill=226 u=126 imp:n=1
c
c
c Right outer core array in row 2
c
3171 0 1 -2 3 -4 u=227 lat=1
fill=-2:2 -2:2 0:0
16 16 16 16 16
8 16 16 16 16
8 16 16 16 16
8 9 16 16 16
8 11 16 16 16
imp:n=1
c
c
c Surround material
c
3172 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=127 imp:n=1
c
c
3173 0 7 -16 85 -86 87 -88 fill=227 u=127 imp:n=1
c
c
c Left blanket array in row 2
c
3181 0 1 -2 3 -4 u=228 lat=1

```

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```

fill=-2:2 -2:2 0:0
19 19 19 16 16
19 19 19 16 16
19 19 19 16 16
19 19 19 16 16
19 19 19 16 16
19 19 16 16 16
imp:n=1
c
c
c Surround material
c
3182  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=128 imp:n=1
c
c
3183  0 7 -16 85 -86 87 -88 fill=228 u=128 imp:n=1
c
c
c Right blanket array in Row 2
c
c
3184  0 1 -2 3 -4 u=229 lat=1
fill=-2:2 -2:2 0:0
16 16 19 19 19
16 16 19 19 19
16 16 19 19 19
16 16 19 19 19
16 16 16 19 19
imp:n=1
c
c Surround material
c
3185  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=129 imp:n=1
c
3186  0 7 -16 85 -86 87 -88 fill=229 u=129 imp:n=1
c
c
c Left blanket array in row 2
c
3187  0 1 -2 3 -4 u=230 lat=1
fill=-2:2 -2:2 0:0
20 20 20 20 19
20 20 20 20 19
20 20 20 20 19
20 20 20 20 19
20 20 20 20 19
imp:n=1
c
c
c Surround material
c
3188  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=130 imp:n=1
c
c
3189  0 7 -16 85 -86 87 -88 fill=230 u=130 imp:n=1
c
c -----
c
c Row 3 - two rows below the central row Column 1
c
c Central array in row
c
c
3201  0 1 -2 3 -4 u=231 lat=1
fill=-2:2 -2:2 0:0
2 2 2 2 2
3 3 3 3 3
4 4 4 4 4
4 4 4 4 4
6 5 5 5 6
imp:n=1
c
3202  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=131 imp:n=1
c
3203  0 7 -16 85 -86 87 -88 fill=231 u=131 imp:n=1
c
c Array left of centre in Row 3 Column 2

```

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```

c
c
3211    0    1 -2 3 -4 u=232 lat=1
        fill=-2:2 -2:2 0:0
        4 4 3 3 2
        5 4 4 4 4
        6 5 4 4 4
        7 6 5 5 4
        8 7 7 6 6
        imp:n=1
c
3212    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=132 imp:n=1
c
3213    0 7 -16 85 -86 87 -88 fill=232 u=132 imp:n=1
c
c
c Array right of centre in Row 3 column 3
c
c
3221    0    1 -2 3 -4 u=233 lat=1
        fill=-2:2 -2:2 0:0
        2 3 4 4 4
        4 4 4 4 5
        4 4 4 5 6
        4 5 5 6 7
        6 6 7 7 8
        imp:n=1
c
3222    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=133 imp:n=1
c
3223    0 7 -16 85 -86 87 -88 fill=233 u=133 imp:n=1
c
c
c array in column 4 of Row 3
c
3231    0    1 -2 3 -4 u=234 lat=1
        fill=-2:2 -2:2 0:0
        9 7 6 5 4
        16 8 7 6 5
        16 16 8 7 6
        16 16 16 8 8
        16 16 16 16 11
        imp:n=1
c
c
c Surround material
c
3232    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=134 imp:n=1
c
c
3233    0 7 -16 85 -86 87 -88 fill=234 u=134 imp:n=1
c
c
c
c array in column 5 of Row 3
c
3241    0    1 -2 3 -4 u=235 lat=1
        fill=-2:2 -2:2 0:0
        4 5 7 8 11
        5 6 7 8 16
        10 7 8 16 16
        7 8 16 16 16
        9 16 16 16 16
        imp:n=1
c
c
c Surround material
c
3242    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=135 imp:n=1
c
c
3243    0 7 -16 85 -86 87 -88 fill=235 u=135 imp:n=1
c
c
c array in column 6 of Row 3
c

```

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```

3251    0    1 -2 3 -4 u=236 lat=1
        fill=-2:2 -2:2 0:0
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        19 16 16 16 16
        imp:n=1

c
c
c Surround material
c
3252    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=136 imp:n=1
c
c
3253    0 7 -16 85 -86 87 -88 fill=236 u=136 imp:n=1
c
c
c
c array in column 7 of Row 3
c
3261    0    1 -2 3 -4 u=237 lat=1
        fill=-2:2 -2:2 0:0
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 19
        imp:n=1

c
c
c Surround material
c
3262    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=137 imp:n=1
c
c
3263    0 7 -16 85 -86 87 -88 fill=237 u=137 imp:n=1
c
c
c
c Array Column 8 of row 3
c
3271    0    1 -2 3 -4 u=238 lat=1
        fill=-2:2 -2:2 0:0
        20 19 19 19 16
        20 19 19 19 16
        20 20 19 19 19
        20 20 19 19 19
        20 20 19 19 19
        imp:n=1

c
c
c Surround material
c
3272    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=138 imp:n=1
c
c
3273    0 7 -16 85 -86 87 -88 fill=238 u=138 imp:n=1
c
c
c Right blanket array in Column 9 of row 3
c
c
3281    0    1 -2 3 -4 u=239 lat=1
        fill=-2:2 -2:2 0:0
        16 19 19 19 20
        16 19 19 19 20
        19 19 19 19 20
        19 19 19 20 20
        19 19 19 20 20
        imp:n=1

c
c Surround material
c
3282    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=139 imp:n=1
c

```

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CRIT-BUCK-SPEC-REAC-RRATE

```

3283  0 7 -16 85 -86 87 -88 fill=239 u=139 imp:n=1
c
c -----
c
c
c Row 4 - two rows above the central row
c
c Central array in row 4
c
c
3291  0 1 -2 3 -4 u=241 lat=1
      fill=-2:2 -2:2 0:0
      6 5 5 5 6
      4 4 4 4 4
      4 4 4 4 4
      3 3 3 3 3
      2 2 2 2 2
      imp:n=1
c
3292  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=141 imp:n=1
c
3293  0 7 -16 85 -86 87 -88 fill=241 u=141 imp:n=1
c
c Array left of centre in Row 4 Column 2
c
c
3301  0 1 -2 3 -4 u=242 lat=1
      fill=-2:2 -2:2 0:0
      8 7 7 6 6
      7 6 5 5 4
      6 5 4 4 4
      5 4 4 4 4
      4 4 4 3 2
      imp:n=1
c
3302  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=142 imp:n=1
c
3303  0 7 -16 85 -86 87 -88 fill=242 u=142 imp:n=1
c
c
c Array right of centre in Row 4 Column 3
c
c
3311  0 1 -2 3 -4 u=243 lat=1
      fill=-2:2 -2:2 0:0
      6 6 7 7 8
      4 5 5 6 7
      4 4 4 5 6
      4 4 4 4 5
      2 3 3 4 4
      imp:n=1
c
3312  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=143 imp:n=1
c
3313  0 7 -16 85 -86 87 -88 fill=243 u=143 imp:n=1
c
c
c array in column 4 of Row 4
c
3321  0 1 -2 3 -4 u=244 lat=1
      fill=-2:2 -2:2 0:0
      16 16 16 16 9
      16 16 16 8 7
      16 16 8 7 10
      16 8 7 6 5
      11 8 7 5 4
      imp:n=1
c
c
c Surround material
c
3322  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=144 imp:n=1
c
c
3323  0 7 -16 85 -86 87 -88 fill=244 u=144 imp:n=1
c

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c
c array in column 5 of Row 4
c
3331    0    1 -2 3 -4 u=245 lat=1
        fill=-2:2 -2:2 0:0
        11 16 16 16 16
        8 8 16 16 16
        6 7 8 16 16
        5 6 7 8 16
        4 5 6 8 9
        imp:n=1

c
c
c Surround material
c
3332    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=145 imp:n=1
c
c
3333    0 7 -16 85 -86 87 -88 fill=245 u=145 imp:n=1
c
c
c array in column 6 of Row 4
c
3341    0    1 -2 3 -4 u=246 lat=1
        fill=-2:2 -2:2 0:0
        19 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        imp:n=1

c
c
c Surround material
c
3342    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=146 imp:n=1
c
c
3343    0 7 -16 85 -86 87 -88 fill=246 u=146 imp:n=1
c
c
c
c array in column 7 of Row 4
c
3351    0    1 -2 3 -4 u=247 lat=1
        fill=-2:2 -2:2 0:0
        16 16 16 16 19
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        imp:n=1

c
c
c Surround material
c
3352    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=147 imp:n=1
c
c
3353    0 7 -16 85 -86 87 -88 fill=247 u=147 imp:n=1
c
c
c
c Array Column 8 of row 4
c
3361    0    1 -2 3 -4 u=248 lat=1
        fill=-2:2 -2:2 0:0
        20 20 19 19 19
        20 20 19 19 19
        20 19 19 19 19
        20 19 19 19 16
        20 19 19 19 16
        imp:n=1

c
c

```

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```

c Surround material
c
3362   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=148 imp:n=1
c
c
3363   0 7 -16 85 -86 87 -88 fill=248 u=148 imp:n=1
c
c
c Right blanket array in Column 9 of row 4
c
c
3371     0   1 -2 3 -4 u=249 lat=1
        fill=-2:2 -2:2 0:0
        19 19 19 20 20
        19 19 19 20 20
        19 19 19 19 20
        16 19 19 19 20
        16 19 19 19 20
        imp:n=1
c
c Surround material
c
3372   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=149 imp:n=1
c
3373   0 7 -16 85 -86 87 -88 fill=249 u=149 imp:n=1
c
c -----
c -----
c -----
c Row 5 - three rows below the central row
c
c Central array in row 5 column 1
c
c
3381     0   1 -2 3 -4 u=251 lat=1
        fill=-2:2 -2:2 0:0
        7 7 7 7 7
        8 8 8 8 8
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        imp:n=1
c
3382   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=151 imp:n=1
c
3383   0 7 -16 85 -86 87 -88 fill=251 u=151 imp:n=1
c
c Array left of centre in Row 5 Column 2
c
c
3391     0   1 -2 3 -4 u=252 lat=1
        fill=-2:2 -2:2 0:0
        9 11 8 8 7
        16 16 16 9 11
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        imp:n=1
c
3392   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=152 imp:n=1
c
3393   0 7 -16 85 -86 87 -88 fill=252 u=152 imp:n=1
c
c
c Array right of centre in Row 5 column 3
c
c
3401     0   1 -2 3 -4 u=253 lat=1
        fill=-2:2 -2:2 0:0
        7 8 8 8 16
        11 9 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        imp:n=1

```

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```

c
3402  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=153 imp:n=1
c
3403  0 7 -16 85 -86 87 -88 fill=253 u=153 imp:n=1
c
c
c array in column 4 of Row 5
c
3411  0 1 -2 3 -4 u=254 lat=1
      fill=-2:2 -2:2 0:0
      16 16 16 16 16
      16 16 16 16 16
      16 16 16 16 16
      16 16 16 16 16
      19 16 16 16 16
      imp:n=1
c
c
c Surround material
c
3412  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=154 imp:n=1
c
c
3413  0 7 -16 85 -86 87 -88 fill=254 u=154 imp:n=1
c
c
c array in column 5 of Row 5
c
3421  0 1 -2 3 -4 u=255 lat=1
      fill=-2:2 -2:2 0:0
      16 16 16 16 16
      16 16 16 16 16
      16 16 16 16 16
      16 16 16 16 16
      16 16 16 16 19
      imp:n=1
c
c
c Surround material
c
3422  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=155 imp:n=1
c
c
3423  0 7 -16 85 -86 87 -88 fill=255 u=155 imp:n=1
c
c
c array in column 6 of Row 5
c
3431  0 1 -2 3 -4 u=256 lat=1
      fill=-2:2 -2:2 0:0
      19 19 16 16 16
      19 19 19 16 16
      19 19 19 19 16
      19 19 19 19 19
      91 19 19 19 19
      imp:n=1
c
c
c Surround material
c
3432  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=156 imp:n=1
c
c
3433  0 7 -16 85 -86 87 -88 fill=256 u=156 imp:n=1
c
c
c array in column 7 of Row 5
c
3434  0 1 -2 3 -4 u=257 lat=1
      fill=-2:2 -2:2 0:0
      16 16 16 19 19
      16 16 19 19 19
      16 19 19 19 19
      19 19 19 19 19

```


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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

19 19 19 19 91
imp:n=1
c
c
c Surround material
c
3435 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=157 imp:n=1
c
c
c
3436 0 7 -16 85 -86 87 -88 fill=257 u=157 imp:n=1
c
c
c
c array in column 8 of Row 5
c
3437 0 1 -2 3 -4 u=258 lat=1
      fill=-2:2 -2:2 0:0
      20 20 19 19 19
      20 20 20 20 19
      20 20 20 20 20
      20 20 20 20 20
      20 20 20 20 20
      imp:n=1
c
c
c Surround material
c
3438 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=158 imp:n=1
c
c
c
3439 0 7 -16 85 -86 87 -88 fill=258 u=158 imp:n=1
c
c
c
c array in column 9 of Row 5
c
3440 0 1 -2 3 -4 u=259 lat=1
      fill=-2:2 -2:2 0:0
      19 19 19 20 20
      19 20 20 20 20
      20 20 20 20 20
      20 20 20 20 20
      20 20 20 20 20
      imp:n=1
c
c
c Surround material
c
3441 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=159 imp:n=1
c
c
c
3442 0 7 -16 85 -86 87 -88 fill=259 u=159 imp:n=1
c
c -----
c -----
c
c Row 6 - three rows above the central row
c
c Central array in row 6 column 1
c
c
3451 0 1 -2 3 -4 u=261 lat=1
      fill=-2:2 -2:2 0:0
      16 16 16 16 16
      16 16 16 16 16
      16 16 16 16 16
      8 8 8 8 8
      7 7 7 7 7
      imp:n=1
c
3452 0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=161 imp:n=1
c
3453 0 7 -16 85 -86 87 -88 fill=261 u=161 imp:n=1
c
c Array left of centre in Row 6 Column 2

```

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LIQUID METAL FAST REACTOR - LMFR
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```

c
c
3461    0    1 -2 3 -4 u=262 lat=1
        fill=-2:2 -2:2 0:0
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 9 11
        16 8 8 8 7
        imp:n=1
c
3462    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=162 imp:n=1
c
3463    0 7 -16 85 -86 87 -88 fill=262 u=162 imp:n=1
c
c
c Array right of centre in Row 6 column 3
c
c
3471    0    1 -2 3 -4 u=263 lat=1
        fill=-2:2 -2:2 0:0
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        11 9 16 16 16
        7 8 8 11 9
        imp:n=1
c
3472    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=163 imp:n=1
c
3473    0 7 -16 85 -86 87 -88 fill=263 u=163 imp:n=1
c
c
c array in column 4 of Row 6
c
3481    0    1 -2 3 -4 u=264 lat=1
        fill=-2:2 -2:2 0:0
        19 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        imp:n=1
c
c
c Surround material
c
3482    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=164 imp:n=1
c
c
3483    0 7 -16 85 -86 87 -88 fill=264 u=164 imp:n=1
c
c
c
c array in column 5 of Row 6
c
3491    0    1 -2 3 -4 u=265 lat=1
        fill=-2:2 -2:2 0:0
        16 16 16 16 19
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        imp:n=1
c
c
c Surround material
c
3492    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=165 imp:n=1
c
c
3493    0 7 -16 85 -86 87 -88 fill=265 u=165 imp:n=1
c
c
c array in column 6 of Row 6
c

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

3494    0    1 -2 3 -4 u=266 lat=1
        fill=-2:2 -2:2 0:0
        19 19 19 19 19
        19 19 19 19 19
        19 19 19 19 16
        19 19 19 16 16
        19 19 16 16 16
        imp:n=1

c
c
c Surround material
c
3495    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=166 imp:n=1
c
c
3496    0 7 -16 85 -86 87 -88 fill=266 u=166 imp:n=1
c
c
c
c array in column 7 of Row 6
c
3497    0    1 -2 3 -4 u=267 lat=1
        fill=-2:2 -2:2 0:0
        19 19 19 19 19
        19 19 19 19 19
        16 19 19 19 19
        16 16 19 19 19
        16 16 16 19 19
        imp:n=1

c
c
c Surround material
c
3498    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=167 imp:n=1
c
c
3499    0 7 -16 85 -86 87 -88 fill=267 u=167 imp:n=1
c
c
c
c array in column 8 of Row 6
c
3501    0    1 -2 3 -4 u=268 lat=1
        fill=-2:2 -2:2 0:0
        20 20 20 20 20
        20 20 20 20 20
        20 20 20 20 20
        20 20 20 20 19
        20 20 20 19 19
        imp:n=1

c
c
c Surround material
c
3502    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=168 imp:n=1
c
c
3503    0 7 -16 85 -86 87 -88 fill=268 u=168 imp:n=1
c
c
c
c array in column 9 of Row 6
c
3504    0    1 -2 3 -4 u=269 lat=1
        fill=-2:2 -2:2 0:0
        20 20 20 20 20
        20 20 20 20 20
        20 20 20 20 20
        19 20 20 20 20
        19 19 20 20 20
        imp:n=1

c
c
c Surround material
c
3505    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=169 imp:n=1

```

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LIQUID METAL FAST REACTOR - LMFR
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```

c
c
3506  0 7 -16 85 -86 87 -88 fill=269 u=169 imp:n=1
c
c -----
c
c
c Row 7 - four rows below the central row
c
c Central array in row 7 column 1
c
c
3521  0 1 -2 3 -4 u=271 lat=1
      fill=-2:2 -2:2 0:0
      16 16 16 16 16
      16 16 16 16 16
      16 16 16 16 16
      19 19 19 19 19
      19 19 19 19 19
      imp:n=1
c
3522  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=171 imp:n=1
c
3523  0 7 -16 85 -86 87 -88 fill=271 u=171 imp:n=1
c
c Array left of centre in Row 7 Column 2
c
c
3531  0 1 -2 3 -4 u=272 lat=1
      fill=-2:2 -2:2 0:0
      16 16 16 16 16
      16 16 16 16 16
      19 19 19 19 16
      19 19 19 19 19
      19 19 19 19 19
      imp:n=1
c
3532  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=172 imp:n=1
c
3533  0 7 -16 85 -86 87 -88 fill=272 u=172 imp:n=1
c
c
c Array right of centre in Row 7 column 3
c
c
3541  0 1 -2 3 -4 u=273 lat=1
      fill=-2:2 -2:2 0:0
      16 16 16 16 16
      16 16 16 16 16
      16 19 19 19 19
      19 19 19 19 19
      19 19 19 19 19
      imp:n=1
c
3542  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=173 imp:n=1
c
3543  0 7 -16 85 -86 87 -88 fill=273 u=173 imp:n=1
c
c
c array in column 4 of Row 7
c
3551  0 1 -2 3 -4 u=274 lat=1
      fill=-2:2 -2:2 0:0
      19 19 19 16 16
      19 19 19 19 19
      19 19 19 19 19
      91 91 19 19 19
      91 91 91 91 91
      imp:n=1
c
c
c Surround material
c
3552  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=174 imp:n=1
c
c

```

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LIQUID METAL FAST REACTOR - LMFR
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```

3553   0 7 -16 85 -86 87 -88 fill=274 u=174 imp:n=1
c
c
c
c array in column 5 of Row 7
c
3554   0   1 -2 3 -4 u=275 lat=1
      fill=-2:2 -2:2 0:0
      16 16 19 19 19
      19 19 19 19 19
      19 19 19 19 19
      19 19 19 91 91
      91 91 91 91 91
      imp:n=1
c
c
c Surround material
c
3555   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=175 imp:n=1
c
c
c
3556   0 7 -16 85 -86 87 -88 fill=275 u=175 imp:n=1
c
c
c array in column 6 of Row 7
c
3557   0   1 -2 3 -4 u=276 lat=1
      fill=-2:2 -2:2 0:0
      91 91 91 19 19
      91 91 91 91 19
      91 91 91 91 91
      91 91 91 91 91
      91 91 91 91 91
      imp:n=1
c
c
c Surround material
c
3558   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=176 imp:n=1
c
c
c
3559   0 7 -16 85 -86 87 -88 fill=276 u=176 imp:n=1
c
c
c
c array in column 7 of Row 7
c
3560   0   1 -2 3 -4 u=277 lat=1
      fill=-2:2 -2:2 0:0
      19 19 91 91 91
      19 91 91 91 91
      91 91 91 91 91
      91 91 91 91 91
      91 91 91 91 91
      imp:n=1
c
c
c Surround material
c
3561   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=177 imp:n=1
c
c
c
3562   0 7 -16 85 -86 87 -88 fill=277 u=177 imp:n=1
c
c
c array in column 8 of Row 7
c
3563   0   1 -2 3 -4 u=278 lat=1
      fill=-2:2 -2:2 0:0
      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
      imp:n=1
c

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Surround material
c
3564   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=178 imp:n=1
c
c
3565   0 7 -16 85 -86 87 -88 fill=278 u=178 imp:n=1
c
c
c -----
c -----
c -----
c
c Row 8 - four rows above the central row
c
c Central array in row 8 column 1
c
c
3571     0   1 -2 3 -4 u=281 lat=1
        fill=-2:2 -2:2 0:0
        19 19 19 19 19
        19 19 19 19 19
        16 16 16 16 16
        16 16 16 16 16
        16 16 16 16 16
        imp:n=1
c
3572   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=181 imp:n=1
c
3573   0 7 -16 85 -86 87 -88 fill=281 u=181 imp:n=1
c
c Array left of centre in Row 8 Column 2
c
c
3581     0   1 -2 3 -4 u=282 lat=1
        fill=-2:2 -2:2 0:0
        19 19 19 19 19
        19 19 19 19 19
        19 19 19 19 16
        16 16 16 16 16
        16 16 16 16 16
        imp:n=1
c
3582   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=182 imp:n=1
c
3583   0 7 -16 85 -86 87 -88 fill=282 u=182 imp:n=1
c
c
c Array right of centre in Row 8 column 3
c
c
3591     0   1 -2 3 -4 u=283 lat=1
        fill=-2:2 -2:2 0:0
        19 19 19 19 19
        19 19 19 19 19
        16 19 19 19 19
        16 16 16 16 16
        16 16 16 16 16
        imp:n=1
c
3592   0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=183 imp:n=1
c
3593   0 7 -16 85 -86 87 -88 fill=283 u=183 imp:n=1
c
c
c array in column 4 of Row 8
c
c
3594     0   1 -2 3 -4 u=284 lat=1
        fill=-2:2 -2:2 0:0
        20 20 20 20 20
        19 19 19 19 19
        19 19 19 19 19
        19 19 19 19 19
        19 19 19 16 16
        imp:n=1

```

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CRIT-BUCK-SPEC-REAC-RRATE

```

c
c
c Surround material
c
3595  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=184 imp:n=1
c
c
3596  0 7 -16 85 -86 87 -88 fill=284 u=184 imp:n=1
c
c
c
c array in column 5 of Row 8
c
3597  0 1 -2 3 -4 u=285 lat=1
      fill=-2:2 -2:2 0:0
      20 20 20 20 20
      19 19 19 19 19
      19 19 19 19 19
      19 19 19 19 19
      16 16 19 19 19
      imp:n=1
c
c
c Surround material
c
3598  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=185 imp:n=1
c
c
3599  0 7 -16 85 -86 87 -88 fill=285 u=185 imp:n=1
c
c -----
c
c Row 9 Central Array
c
c Central Array of Reflector and Graphite elements
c
3601  0 1 -2 3 -4 u=291 lat=1
      fill=-2:2 -2:2 0:0
      19 19 19 19 19
      91 91 91 91 91
      91 91 91 91 91
      91 91 91 91 91
      91 91 91 91 91
      imp:n=1
c
c
c Surround material
c
3602  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=191 imp:n=1
c
c
3603  0 7 -16 85 -86 87 -88 fill=291 u=191 imp:n=1
c
c
c
c Left Array of Reflector and Graphite elements
c
3604  0 1 -2 3 -4 u=292 lat=1
      fill=-2:2 -2:2 0:0
      91 91 91 19 19
      91 91 91 91 91
      91 91 91 91 91
      91 91 91 91 91
      91 91 91 91 91
      imp:n=1
c
c
c Surround material
c
3605  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=192 imp:n=1
c
c
3606  0 7 -16 85 -86 87 -88 fill=292 u=192 imp:n=1
c
c
c Left Array of Reflector and Graphite elements

```

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```

c
3607    0    1 -2 3 -4 u=293 lat=1
        fill=-2:2 -2:2 0:0
        19 19 91 91 91
        91 91 91 91 91
        91 91 91 91 91
        91 91 91 91 91
        91 91 91 91 91
        imp:n=1

c
c
c Surround material
c
3608    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=193 imp:n=1
c
c
3609    0 7 -16 85 -86 87 -88 fill=293 u=193 imp:n=1
c
c
c Array of Graphite elements
c
3610    0    1 -2 3 -4 u=294 lat=1
        fill=-2:2 -2:2 0:0
        91 91 91 91 91
        91 91 91 91 91
        91 91 91 91 91
        91 91 91 91 91
        91 91 91 91 91
        imp:n=1

c
c
c Surround material
c
3611    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=194 imp:n=1
c
c
3612    0 7 -16 85 -86 87 -88 fill=294 u=194 imp:n=1
c
c
c -----
c
c Row 10 Central array
c
c Central Array of Reflector elements
c
3631    0    1 -2 3 -4 u=295 lat=1
        fill=-2:2 -2:2 0:0
        20 20 20 20 20
        20 20 20 20 20
        20 20 20 20 20
        20 20 20 20 20
        19 19 19 19 19
        imp:n=1

c
c
c Surround material
c
3632    0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=195 imp:n=1
c
c
3633    0 7 -16 85 -86 87 -88 fill=295 u=195 imp:n=1
c
c
c Left Array of Reflector elements
c
3634    0    1 -2 3 -4 u=296 lat=1
        fill=-2:2 -2:2 0:0
        20 20 20 20 20
        20 20 20 20 20
        20 20 20 20 20
        20 20 20 20 20
        20 20 20 19 19
        imp:n=1

c
c
c Surround material

```


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LIQUID METAL FAST REACTOR - LMFR
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```

c
3635  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=196 imp:n=1
c
c
3636  0 7 -16 85 -86 87 -88 fill=296 u=196 imp:n=1
c
c Right Array of Reflector elements
c
3637  0 1 -2 3 -4 u=297 lat=1
      fill=-2:2 -2:2 0:0
      20 20 20 20 20
      20 20 20 20 20
      20 20 20 20 20
      20 20 20 20 20
      19 19 20 20 20
      imp:n=1

c
c
c Surround material
c
3638  0 89 -90 91 -92 (-85:86:-87:88) fill=100 u=197 imp:n=1
c
c
3639  0 7 -16 85 -86 87 -88 fill=297 u=197 imp:n=1
c
c
c -----
c

c
c ----- SURFACE CARDS -----
c
c MZA Core and MZB Outer Core Element cell surfaces
1      px -2.68605
2      px 2.68605
3      py -2.68605
4      py 2.68605
7      pz 0.0 $ Assembly lower limit
8      pz 30.0 $ End Lower Packing, Start Plenum
9      pz 63.0048 $ End Plenum, Start Lower Axial Blanket
10     pz 97.9512 $ End Lower Blanket, Start Core Fuel
11     pz 187.9008 $ End Core Fuel, Start Upper Axial Blanket
12     pz 222.8472 $ End Upper Blanket, Start Upper Plenum
13     pz 255.852 $ End Upper Plenum, Start Upper Packing
16     pz 285.0 $ Assembly upper axial limit
17     cz 132.9 $ Assembly outer radius
21     px -2.5335 $ Nominal half-width of plates
22     px 2.5335
23     py -2.5335
24     py 2.5335
28     px -2.54 $ Radial shield half-width
29     px 2.54
30     py -2.54
31     py 2.54
c
c
c axial heights in the lower plenum
33     pz 7.62 $ alsc3
34     pz 10.1585 $ mst1
35     pz 17.7785 $ alsc3
36     pz 25.3848 $ mst3
37     pz 33.0048 $ alsc3
c different axial heights in the upper plenum
38     pz 15.2263 $ mst3
39     pz 22.8463 $ alsc3 / mst1
c
c cell subdivisions in the axial blanket and core cells of MZA elements
c
c 9      pz 63.0048 $ End Plenum, Start Lower Axial Blanket
41     pz 71.7414
42     pz 80.478
43     pz 89.2146
c 10 pz 97.9512 $ lower axial blanket / core
44     pz 105.447
45     pz 112.9428
46     pz 120.4386

```

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```

47      pz 127.9344
48      pz 135.4302
49      pz 142.926
50      pz 150.4218
51      pz 157.9176
52      pz 165.4134
53      pz 172.9092
54      pz 180.405
c 11      pz 187.9008 $ core / upper axial blanket
56      pz 196.6374
57      pz 205.374
58      pz 214.1106
c 12      pz 222.8472 $ axial blanket / plenum
c
c
62      px -2.551 $ sheath inner half-width
63      px 2.551
64      py -2.551
65      py 2.551
66      px -2.6272 $ sheath outer half-width
67      px 2.6272
68      py -2.6272
69      py 2.6272
c
c
c Grid plate heights
c
71      pz 62.3
72      pz 92.7
73      pz 193.1
74      pz 223.5
c
c coordinates of the elements in 5x5 arrays
c 81      px -8.05815
c 82      px 8.05815
c 83      py -8.05815
c 84      py 8.05815
85      px -13.43025
86      px 13.43025
87      py -13.43025
88      py 13.43025
89      px -13.5635
90      px 13.5635
91      py -13.5635
92      py 13.5635
c
c
c plate inner core widths
c
101     px -2.3355 $ Pu metal plate core width
102     px 2.3355
103     py -2.3355
104     py 2.3355
105     px -2.4255 $ UO2 plate core width
106     px 2.4255
107     py -2.4255
108     py 2.4255
109     px -2.4815 $ Na plate core width
110     px 2.4815
111     py -2.4815
112     py 2.4815
113     px -2.4765 $ MOX plate PUIV4
114     px 2.4765
115     py -2.4765
116     py 2.4765
c
c
c MZA Core Cell Axial heights
c
201     pz 0
202     pz 0.03683
203     pz 0.57917 $ Na
204     pz 0.616
205     pz 0.65283
206     pz 1.20707 $ UO2
207     pz 1.2439

```

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208	pz	1.28073	
209	pz	1.82307	\$ Na
210	pz	1.8599	
211	pz	1.90562	
212	pz	2.14068	\$ Pu
213	pz	2.1864	
214	pz	2.5036	\$ SS
215	pz	2.54043	
216	pz	3.09467	\$ UO2
217	pz	3.1315	
218	pz	3.16833	
219	pz	3.71067	\$ Na
220	pz	3.7475	
221	pz	3.78433	
222	pz	4.32667	\$ Na
223	pz	4.3635	
224	pz	4.40033	
225	pz	4.95457	\$ UO2
226	pz	4.9914	
227	pz	5.3094	\$ GI8
228	pz	5.35512	
229	pz	5.59018	\$ Pu
230	pz	5.6359	
231	pz	5.67273	
232	pz	6.21507	\$ Na
233	pz	6.2519	
234	pz	6.28873	
235	pz	6.84297	\$ UO2
236	pz	6.8798	
237	pz	6.91663	
238	pz	7.45897	\$ Na
239	pz	7.4958	

c

c MZB Inner core cell axial heights

c

301	pz	0	
302	pz	0.03683	
303	pz	0.57917	\$ na
304	pz	0.616	
305	pz	0.65283	
306	pz	1.21047	\$ uo2
307	pz	1.2473	
308	pz	1.28413	
309	pz	1.82647	\$ na
310	pz	1.8633	
311	pz	1.90902	
312	pz	2.14408	\$ puix8
313	pz	2.1898	
314	pz	2.22663	
315	pz	2.76897	\$ na
316	pz	2.8058	
317	pz	2.84263	
318	pz	3.40027	\$ uo2
319	pz	3.4371	
320	pz	3.47393	
321	pz	4.01627	\$ na
322	pz	4.0531	
323	pz	4.3703	\$ ssbr8
324	pz	4.40713	
325	pz	4.96477	\$ uo2
326	pz	5.0016	
327	pz	5.03843	
328	pz	5.58077	\$ na
329	pz	5.6176	
330	pz	5.65494	
331	pz	6.20806	\$ puiv4
332	pz	6.2454	
333	pz	6.28223	
334	pz	6.82457	\$ na
335	pz	6.8614	
336	pz	6.89823	
337	pz	7.45587	\$ uo2
338	pz	7.4927	
339	pz	7.52953	
340	Pz	8.07187	\$ na
341	pz	8.1087	

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Axial blanket cells
c
401 pz 0
402 pz 0.03683
403 pz 0.57917 $ na
404 pz 0.616
405 pz 0.933 $ u8
406 pz 1.251 $ g
407 pz 1.28783
408 pz 1.83017 $ na
409 pz 1.867
410 pz 2.1842 $ ss
411 pz 2.5012 $ u8
412 pz 2.53803
413 pz 3.08037 $ na
414 pz 3.1172
415 pz 3.4352 $ g
416 pz 3.47203
417 pz 4.01437 $ na
418 pz 4.0512
419 pz 4.3684 $ ss
420 pz 4.6854 $ u8
421 pz 4.72223
422 pz 5.26457 $ na
423 pz 5.3014
424 pz 5.6194 $ g
425 pz 5.65623
426 pz 6.19857 $ na
427 pz 6.2354
428 pz 6.5524 $ u8
429 pz 6.8696 $ ss
430 pz 6.90643
431 pz 7.44877 $ na
432 pz 7.4856
433 pz 7.8036 $ g
434 pz 8.1206 $ u8
435 pz 8.15743
436 pz 8.69977 $ na
437 pz 8.7366
c
c Inner (axially) radial blanket cells
c
501 pz 0
502 pz 0.31775 $ g
503 pz 0.35458
504 pz 0.89692 $ na
505 pz 0.93375
506 pz 1.2515 $ g
507 pz 1.5751 $ ss
508 pz 2.8474 $ u2
509 pz 3.16515 $ g
510 pz 3.20198
511 pz 3.74432 $ na
512 pz 3.78115
513 pz 4.09585 $ mst
514 pz 4.4136 $ g
515 pz 4.45043
516 pz 4.99277 $ na
517 pz 5.0296
c
c Upper and lower sections of the radial blanket
c
601 pz 0
c 602 pz 0.317 $ al
603 pz 0.634 $ al
604 pz 1.2657 $ al2o3
605 pz 1.58345 $ gii
606 pz 1.90045 $ al
607 pz 3.17275 $ u2
608 pz 3.48975 $ al
609 pz 3.8075 $ gii
610 pz 4.4392 $ al2o3
611 pz 5.711 $ mst2
612 pz 6.028 $ al
613 pz 6.34575 $ gii

```

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```
c 614      pz      6.66275  $ al
615      pz      6.97975  $ al
616      pz      8.25205  $ u2
617      pz      8.88375  $ al2o3
618      pz      9.20075  $ al
619      pz      9.5185   $ gii
620      pz      9.8332   $ mst8
621      pz      10.1502  $ al
```

```
c
c heights of cells in the MZB inner core elements
```

```
c
701      pz      97.9512  $ First core cell lower boundary
702      pz      106.0599
703      pz      114.1686
704      pz      122.2773
705      pz      130.386
706      pz      138.4947
707      pz      146.6034
708      pz      154.7121
709      pz      162.8208
710      pz      170.9295
711      pz      179.0382
712      pz      187.1469  $ Core upper boundary
713      pz      195.8835
714      pz      204.6201
715      pz      213.3567
716      pz      222.0933  $ Axial blanket upper boundary
717      pz      255.0981
```

```
c
c Heights of cells in the radial blanket
```

```
c
801      pz      30.0    $ Packing
802      pz      63.0048  $ End Lower plenum/
803      pz      73.155
804      pz      83.3052
805      pz      93.4554  $ End Lower Blanket
806      pz      98.485
807      pz      103.5146
808      pz      108.5442
809      pz      113.5738
810      pz      118.6034
811      pz      123.633
812      pz      128.6626
813      pz      133.6922
814      pz      138.7218
815      pz      143.7514
816      pz      148.781
817      pz      153.8106
818      pz      158.8402
819      pz      163.8698
820      pz      168.8994
821      pz      173.929
822      pz      178.9586
823      pz      183.9882
824      pz      189.0178
825      pz      194.0474  $ End Middle Blanket
826      pz      204.1976
827      pz      214.3478
828      pz      224.498  $ End Upper Blanket
829      pz      257.5028  $ End Upper plenum
830      pz      285.0    $ Top of assembly
```

```
c
c Width of the array
```

```
c
901      px      -74.5
902      px       74.5
903      py      -74.5
904      py       74.5
```

```
c
c -----
```

```
c
c
c ----- TALLY CARDS -----
```

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LIQUID METAL FAST REACTOR - LMFR
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c --- MATERIALS CARDS FOR JEFF-3.1 ---

c

c Region Compositions

C MATERIAL 1 Pu metal plate PUV8 core

c

m1	92238.31c	1.3318E-06
	94238.31c	2.9103E-05
	94239.31c	2.9328E-02
	94240.31c	6.7928E-03
	94241.31c	1.0119E-03
	94242.31c	1.6639E-04
	95241.31c	9.4236E-05
	1001.31c	1.7475E-04
	6000.31c	2.5027E-04
	7014.31c	1.3413E-05
	8016.31c	5.0640E-05
	13027.31c	2.1760E-05
	14028.31c	2.3831E-05
	25055.31c	1.0687E-06
	24050.31c	2.2568E-07
	24052.31c	4.3521E-06
	24053.31c	4.9349E-07
	24054.31c	1.2284E-07
	26054.31c	9.7085E-07
	26056.31c	1.5240E-05
	26057.31c	3.5197E-07
	26058.31c	4.6840E-08
	28058.31c	8.0358E-06
	28060.31c	3.0954E-06
	28061.31c	1.3455E-07
	28062.31c	4.2902E-07
	28064.31c	1.0926E-07
	31000.31c	2.2424E-03
	42092.31c	2.9375E-07
	42094.31c	1.9583E-07
	42095.31c	2.9375E-07
	42096.31c	2.9375E-07
	42097.31c	1.9583E-07
	42098.31c	4.8958E-07
	42100.31c	1.9583E-07

c total 4.023746E-02

c MATERIAL 2 PuV8 plate canning

c

m2	1001.31c	1.3404E-05
	6000.31c	9.2801E-05
	14028.31c	4.1625E-04
	15031.31c	1.8432E-05
	16032.31c	9.3252E-06
	25055.31c	7.5220E-04
	24050.31c	4.0213E-04
	24052.31c	7.7546E-03
	24053.31c	8.7931E-04
	24054.31c	2.1888E-04
	26054.31c	2.0054E-03
	26056.31c	3.1481E-02
	26057.31c	7.2703E-04
	26058.31c	9.6754E-05
	28058.31c	3.0905E-03
	28060.31c	1.1905E-03
	28061.31c	5.1748E-05
	28062.31c	1.6500E-04
	28064.31c	4.2019E-05
	29063.31c	1.1638E-02
	29065.31c	4.9880E-03

c total 6.6033E-02

C MATERIAL 3 UO2 plate UO24R4 core

c

m3	1001.31c	2.4503E-05
	6000.31c	3.0842E-05
	8016.31c	4.5733E-02
	13027.31c	3.3911E-06
	14028.31c	1.3190E-05
	26054.31c	3.8771E-07
	26056.31c	6.0862E-06
	26057.31c	1.4056E-07
	26058.31c	1.8706E-08

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```

92234.31c 1.1871E-06
92235.31c 1.6462E-04
92238.31c 2.2694E-02
c total 6.867137E-02
c MATERIAL 4 UO2 plate UO2R4 canning
c
m4 1001.31c 1.7335E-05
    6000.31c 1.4546E-04
    14028.31c 6.0964E-04
    15031.31c 2.2563E-05
    16032.31c 2.1792E-05
    25055.31c 9.7951E-04
    24050.31c 5.3726E-04
    24052.31c 1.0361E-02
    24053.31c 1.1748E-03
    24054.31c 2.9243E-04
    26054.31c 2.5374E-03
    26056.31c 3.9831E-02
    26057.31c 9.1988E-04
    26058.31c 1.2242E-04
    28058.31c 4.0937E-03
    28060.31c 1.5769E-03
    28061.31c 6.8547E-05
    28062.31c 2.1856E-04
    28064.31c 5.5660E-05
    29063.31c 5.7122E-04
    29065.31c 2.4481E-04
    47107.31c 6.3840E-04
    47109.31c 5.9840E-04
c total 6.5639E-02
C MATERIAL 5 sodium plate NASTBR4 core
c
m5 1001.31c 2.1098E-06
    3006.31c 2.8720E-08
    3007.31c 3.5424E-07
    5010.31c 2.9500E-08
    5011.31c 1.1802E-07
    8016.31c 1.9937E-06
    11023.31c 2.3119E-02
    19039.31c 4.6230E-07
    20040.31c 1.7244E-06
    26054.31c 2.2256E-09
    26056.31c 3.4937E-08
    26057.31c 8.0685E-10
    26058.31c 1.0738E-10
c total 2.3126E-02
c MATERIAL 6 Sodium plate NASTBR4 canning
c
m6 1001.31c 2.1496E-05
    6000.31c 2.1646E-04
    14028.31c 6.0171E-04
    15031.31c 2.7979E-05
    16032.31c 2.7023E-05
    25055.31c 1.0806E-03
    24050.31c 6.5175E-04
    24052.31c 1.2568E-02
    24053.31c 1.4252E-03
    24054.31c 3.5475E-04
    26054.31c 3.1596E-03
    26056.31c 4.9599E-02
    26057.31c 1.1454E-03
    26058.31c 1.5244E-04
    28058.31c 4.9357E-03
    28060.31c 1.9012E-03
    28061.31c 8.2645E-05
    28062.31c 2.6351E-04
    28064.31c 6.7108E-05
    28064.31c 6.5701E-05
    41093.31c 3.0316E-04
c total 7.865043E-02
C MATERIAL 7 STSTBR8 steel plate
c
m7 1001.31c 2.3265E-05
    6000.31c 7.8091E-04
    13027.31c 1.7381E-04
    14028.31c 1.3358E-03

```

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```

22048.31c    2.9384E-04
25055.31c    9.3901E-04
24050.31c    7.0932E-04
24052.31c    1.3679E-02
24053.31c    1.5510E-03
24054.31c    3.8609E-04
26054.31c    3.4063E-03
26056.31c    5.3472E-02
26057.31c    1.2349E-03
26058.31c    1.6434E-04
28058.31c    5.2766E-03
28060.31c    2.0326E-03
28061.31c    8.8354E-05
28062.31c    2.8171E-04
28064.31c    7.1743E-05
29063.31c    5.1661E-05
29065.31c    2.2140E-05
42092.31c    1.4665E-05
42094.31c    9.7764E-06
42095.31c    1.4665E-05
42096.31c    1.4665E-05
42097.31c    9.7764E-06
42098.31c    2.4441E-05
42100.31c    9.7764E-06
c total 8.607216E-02
c
C MATERIAL 8 U8 metal plate
m8    1001.31c    4.4048E-05
      6000.31c    4.9283E-04
      14028.31c    2.1076E-04
      26054.31c    6.1951E-06
      26056.31c    9.7250E-05
      26057.31c    2.2459E-06
      26058.31c    2.9889E-08
      92235.31c    3.3369E-04
      92238.31c    4.6021E-02
c total 4.7208E-02
C MATERIAL 9 U2 metal plate
m9    1001.31c    4.3899E-05
      6000.31c    4.6047E-04
      14028.31c    1.9692E-04
      26054.31c    5.7884E-06
      26056.31c    9.0866E-05
      26057.31c    2.0985E-06
      26058.31c    2.7927E-08
      92235.31c    3.3962E-04
      92238.31c    4.6785E-02
c total 4.7925E-02
c MATERIAL 10 Graphite plate GI8
m10   1001.31c    4.8551E-05
      6000.31c    8.1417E-02
      16032.31c    1.2207E-05
      26054.31c    3.5851E-07
      26056.31c    5.6278E-06
      26057.31c    1.2997E-07
      26058.31c    1.7297E-08
c Total 8.1484E-02
c MATERIAL 11 Graphite plate GII8
m11   1001.31c    2.0286E-05
      6000.31c    8.5101E-02
      16032.31c    1.2751E-06
      26054.31c    1.0700E-07
      26056.31c    1.6796E-06
      26057.31c    3.8790E-08
      26058.31c    5.1623E-09
c total 8.5125E-02
c Steel radial shield
m12   1001.31c    4.6306E-05
      6000.31c    6.8972E-04
      14028.31c    3.1158E-04
      15031.31c    4.2944E-05
      16032.31c    3.7110E-05
      25055.31c    7.1275E-04
      26054.31c    4.9065E-03
      26056.31c    7.4517E-02
      26057.31c    1.7491E-03

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LIQUID METAL FAST REACTOR - LMFR
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```

26058.31c 2.5903E-04
c total 8.32720E-02
c
c radial shield void surround low density
ml3 1001.31c 4.6306E-08
    6000.31c 6.8972E-07
    14028.31c 3.1158E-07
    15031.31c 4.2944E-08
    16032.31c 3.7110E-08
    25055.31c 7.1275E-07
    26054.31c 4.9065E-06
    26056.31c 7.4517E-05
    26057.31c 1.7491E-06
    26058.31c 2.5903E-07
c total 8.32720E-05
c
c Axial shield
ml4 1001.31c 2.5700E-05
    6000.31c 5.1066E-04
    13027.31c 1.3989E-04
    22048.31c 3.9416E-05
    24050.31c 1.2213E-06
    24052.31c 2.2823E-05
    24053.31c 2.5531E-06
    24054.31c 6.2449E-07
    25055.31c 3.2634E-04
    26054.31c 5.0496E-03
    26056.31c 7.6690E-02
    26057.31c 1.8001E-03
    26058.31c 2.6658E-04
    28058.31c 1.2564E-06
    28060.31c 4.6968E-07
    28061.31c 2.2000E-08
    28062.31c 6.2769E-08
    28064.31c 1.6774E-08
    29063.31c 3.1184E-05
    29065.31c 1.3364E-05
    42092.31c 1.4753E-06
    42094.31c 9.8355E-07
    42095.31c 1.4753E-06
    42096.31c 1.4753E-06
    42097.31c 9.8355E-07
    42098.31c 2.4589E-06
    42100.31c 9.8355E-07
c total 8.4932E-02
c
c Assembly Axial Padding at bottom and top of elements
ml6 1001.31c 3.1777E-05
    6000.31c 9.9996E-05
    13027.31c 8.3095E-06
    24050.31c 6.9087E-08
    24052.31c 1.2911E-06
    24053.31c 1.4442E-07
    24054.31c 3.5326E-08
    25055.31c 1.0785E-04
    26054.31c 1.9605E-03
    26056.31c 2.9775E-02
    26057.31c 6.9890E-04
    26058.31c 1.0350E-04
    28058.31c 1.5636E-07
    28060.31c 5.8452E-08
    28061.31c 2.7378E-09
    28062.31c 7.8115E-09
    28064.31c 2.0875E-09
    29063.31c 6.5270E-06
    29065.31c 2.7973E-06
c Total 3.279692E-02
c
c
c Stainless steel wrapper material
c
ml7 1001.31c 2.3206E-05
    6000.31c 7.7892E-04
    13027.31c 3.4674E-04
    14028.31c 9.9933E-04
    22048.31c 2.9311E-04

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ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

23000.31c 9.1827E-05
25055.31c 1.1921E-03
24050.31c 6.9970E-04
24052.31c 1.3493E-02
24053.31c 1.5300E-03
24054.31c 3.8086E-04
26054.31c 3.3097E-03
26056.31c 5.1952E-02
26057.31c 1.1998E-03
26058.31c 1.5967E-04
28058.31c 6.1314E-03
28060.31c 2.3618E-03
28061.31c 1.0266E-04
28062.31c 3.2734E-04
28064.31c 8.3365E-05
29063.31c 5.1532E-05
29065.31c 2.7973E-05
42092.31c 2.1941E-05
42094.31c 1.4627E-05
42095.31c 2.1941E-05
42096.31c 2.1941E-05
42097.31c 1.4627E-05
42098.31c 3.6568E-05
42100.31c 1.4627E-05
c Total 8.5677E-02
c
c
c mild steel wrapper material
c m18      1001.31c 7.5725E-05
c          6000.31c 2.3828E-04
c          13027.31c 1.9802E-05
c          24050.31c 1.6463E-07
c          24052.31c 3.0767E-06
c          24053.31c 3.4414E-07
c          24054.31c 8.4182E-08
c          25055.31c 2.5701E-04
c          26054.31c 4.6718E-03
c          26056.31c 7.0954E-02
c          26057.31c 1.6655E-03
c          26058.31c 2.4664E-04
c          28058.31c 3.7260E-07
c          28060.31c 1.3929E-07
c          28061.31c 6.5242E-09
c          28062.31c 1.8615E-08
c          28064.31c 4.9746E-09
c          29063.31c 1.5554E-05
c          29065.31c 6.6660E-06
c          29063.31c 2.2220E-05
c Total 18 7.81552E-02
c
c
c Superlattice grid plate
c
c m19      1001.31c 2.4442E-04
c          6000.31c 2.9057E-04
c          14028.31c 4.3858E-05
c          15031.31c 1.3256E-05
c          16032.31c 4.3530E-05
c          25055.31c 2.5785E-04
c          26054.31c 4.2756E-03
c          26056.31c 6.7114E-02
c          26057.31c 1.5500E-03
c          26058.31c 2.0627E-04
c Total 19 7.403935E-02
c
c MATERIAL 20 Sodium plate NASTDM4 canning
c m20      1001.31c 2.1522E-05
c          6000.31c 2.1672E-04
c          14028.31c 7.8781E-04
c          15031.31c 3.2216E-05
c          16032.31c 1.6234E-05
c          25055.31c 1.2635E-03
c          24050.31c 6.9316E-04
c          24052.31c 1.3367E-02
c          24053.31c 1.5157E-03
c          24054.31c 3.7729E-04

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ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

26054.31c	3.0543E-03
26056.31c	4.7945E-02
26057.31c	1.1073E-03
26058.31c	1.4735E-04
28058.31c	5.3745E-03
28060.31c	2.0703E-03
28061.31c	8.9992E-05
28062.31c	2.8694E-04
28064.31c	7.3074E-05
41093.31c	3.4089E-04
c total 20	7.87808E-02
C MATERIAL 21 Pu metal plate PUIX8 core	
c	
m21	92238.31c 5.2779E-06
	94238.31c 3.5515E-05
	94239.31c 2.8995E-02
	94240.31c 6.9474E-03
	94241.31c 1.1413E-03
	94242.31c 1.8046E-04
	95241.31c 5.9252E-05
	1001.31c 1.5145E-04
	6000.31c 2.8155E-04
	7014.31c 9.2216E-06
	8016.31c 5.7245E-05
	13027.31c 2.3065E-05
	14028.31c 2.8430E-05
	25055.31c 1.7099E-06
	24050.31c 2.6493E-07
	24052.31c 5.1090E-06
	24053.31c 5.7931E-07
	24054.31c 1.4420E-07
	26054.31c 7.6195E-07
	26056.31c 1.1961E-05
	26057.31c 2.7623E-07
	26058.31c 3.6762E-08
	28058.31c 1.8251E-05
	28060.31c 7.0304E-06
	28061.31c 3.0561E-07
	28062.31c 9.7441E-07
	28064.31c 2.4815E-07
	31000.31c 2.1190E-03
c total	4.0082E-02
c MATERIAL 22 Pu plate PUIX8 canning	
c	
m22	1001.31c 1.3771E-05
	6000.31c 1.1312E-04
	14028.31c 3.6529E-04
	15031.31c 1.3425E-05
	25055.31c 8.5801E-04
	24050.31c 4.0780E-04
	24052.31c 7.8640E-03
	24053.31c 8.9172E-04
	24054.31c 2.2197E-04
	26054.31c 2.0740E-03
	26056.31c 3.2557E-02
	26057.31c 7.5188E-04
	26058.31c 1.0006E-04
	28058.31c 2.8303E-03
	28060.31c 1.0902E-03
	28061.31c 4.7391E-05
	28062.31c 1.5110E-04
	28064.31c 3.8482E-05
	29063.31c 1.1638E-02
	29065.31c 4.9880E-03
c total	6.7015E-02
C MATERIAL 23 UO2 plate UO23R4 core	
m23	1001.31c 3.1012E-05
	6000.31c 1.1970E-05
	8016.31c 4.6295E-02
	13027.31c 3.4753E-06
	14028.31c 2.3148E-05
	25055.31c 1.1378E-07
	26054.31c 7.8510E-08
	26056.31c 1.2324E-06
	26057.31c 2.8462E-08
	26058.31c 3.7878E-09

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

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28058.31c 8.7016E-07
28060.31c 3.3518E-07
28061.31c 1.4570E-08
28062.31c 4.6456E-08
28064.31c 1.1831E-08
c 42000.66c 3.2579E-07
42092.31c 4.8869E-08
42094.31c 3.2579E-08
42095.31c 4.8869E-08
42096.31c 4.8869E-08
42097.31c 3.2579E-08
42098.31c 8.1448E-08
42100.31c 3.2579E-08
92235.31c 1.6647E-04
92238.31c 2.2980E-02
c total 6.951414E-02
c MATERIAL 24 UO2 plate UO23R4 canning
m24 1001.31c 1.9269E-05
6000.31c 1.2483E-04
14028.31c 6.2774E-04
15031.31c 3.4147E-04
16032.31c 3.5123E-05
25055.31c 8.3300E-04
24050.31c 5.8462E-04
24052.31c 1.1274E-02
24053.31c 1.2784E-03
24054.31c 3.1821E-04
26054.31c 2.7490E-03
26056.31c 4.3153E-02
26057.31c 9.9659E-04
26058.31c 1.3263E-04
28058.31c 5.5846E-03
28060.31c 2.1512E-03
28061.31c 9.3509E-05
28062.31c 2.9815E-04
28064.31c 7.5930E-05
c total 7.067127E-02
C MATERIAL 25 sodium plate NASTDL4 and NASTDM4 core
m25 1001.31c 1.3418E-05
8016.31c 5.6353E-06
11023.31c 2.3168E-02
20040.31c 3.5994E-06
26054.31c 9.4595E-09
26056.31c 1.4849E-07
26057.31c 3.4294E-09
26058.31c 4.5639E-11
c total 2.3191E-02
c MATERIAL 26 Sodium plate NASTDL4 canning (see m20 for the DM can)
m26 1001.31c 2.4319E-05
6000.31c 2.8978E-04
14028.31c 6.0218E-04
15031.31c 3.2445E-05
16032.31c 3.2865E-05
25055.31c 1.3425E-03
24050.31c 6.3446E-04
24052.31c 1.2235E-02
24053.31c 1.3873E-03
24054.31c 3.4534E-04
26054.31c 3.1836E-03
26056.31c 4.9976E-02
26057.31c 1.1542E-03
26058.31c 1.5360E-04
28058.31c 4.7807E-03
28060.31c 1.8415E-03
28061.31c 8.0049E-05
28062.31c 2.5523E-04
28064.31c 6.5000E-05
41093.31c 3.0815E-04
c total 7.872422E-02
c
C M27 Mild Steel MST3
m27 1001.31c 2.8087E-05
6000.31c 5.1066E-04
13027.31c 1.3989E-04
22048.31c 3.9416E-05
25055.31c 3.2634E-04

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LIQUID METAL FAST REACTOR - LMFR
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24050.31c	1.1828E-06
24052.31c	2.2809E-05
24053.31c	2.5864E-06
24054.31c	6.4380E-07
26054.31c	4.8985E-03
26056.31c	7.6895E-02
26057.31c	1.7758E-03
26058.31c	2.3633E-04
28058.31c	3.2836E-05
28060.31c	1.2648E-05
28061.31c	5.4982E-07
28062.31c	1.7531E-06
28064.31c	4.4645E-07
29063.31c	3.1184E-05
29065.31c	1.3364E-05
42092.31c	1.4753E-06
42094.31c	9.8355E-07
42095.31c	1.4753E-06
42096.31c	1.4753E-06
42097.31c	9.8355E-07
42098.31c	2.4589E-06
42100.31c	9.8355E-07
c Total atoms 8.4980E-02	
c	
c M28 Aluminium plate ALSC3	
m28	
13027.31c	4.7590E-02
14028.31c	4.5790E-06
25055.31c	9.3634E-07
26054.31c	1.7498E-06
26056.31c	2.7467E-05
26057.31c	6.3434E-07
26058.31c	8.4420E-08
29063.31c	1.2750E-06
29065.31c	5.4640E-07
c Total 4.7627E-02	
c	
c M29 Aluminium plate ALG8	
m29	
13027.31c	2.6704E-02
14028.31c	1.0296E-05
25055.31c	6.5793E-07
26054.31c	2.1261E-06
26056.31c	3.3375E-05
26057.31c	7.7077E-07
26058.31c	1.0257E-07
29063.31c	3.1854E-07
29065.31c	1.3651E-07
c Total 2.6752E-02	
c	
c MATERIAL 30 AL2O34	
m30	
1001.31c	5.1483E-05
5010.31c	4.5063E-06
5011.31c	1.6599E-05
8016.31c	6.6386E-02
13027.31c	4.4240E-02
c Total 1.106986E-01	
c	
c Material 31 the UPuO2 plate PUIV4 core	
c	
m31	
6000.31c	6.2771E-05
8016.31c	4.2860E-02
13027.31c	2.7943E-05
14028.31c	2.6845E-05
26054.31c	7.8908E-07
26056.31c	1.2387E-05
26057.31c	2.8607E-07
26058.31c	3.8070E-08
28058.31c	8.7452E-06
28060.31c	3.3686E-06
28061.31c	1.4643E-07
28062.31c	4.6689E-07
28064.31c	1.1890E-07
92234.31c	7.4340E-07
92235.31c	1.1548E-04
92238.31c	1.5938E-02
93237.31c	2.4466E-07

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LIQUID METAL FAST REACTOR - LMFR
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94239.31c	4.7730E-03
94240.31c	5.3344E-04
94241.31c	5.0303E-05
94242.31c	4.7919E-06
95241.31c	2.6204E-05
c	
c Total	6.4446E-02
c material 32 The UPuO2 plate PUIV4 canning	
m32	1001.31c 2.0111E-05
6000.31c	1.6876E-04
14028.31c	5.9180E-04
15031.31c	2.6177E-05
16032.31c	2.5282E-05
25055.31c	1.0995E-03
24050.31c	6.0639E-04
24052.31c	1.1694E-02
24053.31c	1.3260E-03
24054.31c	3.3006E-04
26054.31c	2.9475E-03
26056.31c	4.6270E-02
26057.31c	1.0686E-03
26058.31c	1.4221E-04
28058.31c	4.6976E-03
28060.31c	1.8095E-03
28061.31c	7.8659E-05
28062.31c	2.5080E-04
28064.31c	6.3871E-05
29063.31c	1.9854E-04
29065.31c	8.5090E-05
c	
c Total	7.3500E-02
c	
c	
C MATERIAL 33 Pu metal plate PUVI8 core	
c	
m33	92238.31c 2.4663E-07
94238.31c	3.6995E-05
94239.31c	2.8972E-02
94240.31c	7.3421E-03
94241.31c	1.1537E-03
94242.31c	2.0132E-04
95241.31c	8.6769E-05
1001.31c	1.0485E-04
6000.31c	2.2876E-04
7014.31c	2.4312E-05
8016.31c	3.5962E-05
13027.31c	1.7408E-05
25055.31c	1.0687E-06
24050.31c	1.3737E-07
24052.31c	2.6491E-06
24053.31c	3.0038E-07
24054.31c	7.4772E-08
26054.31c	1.1307E-06
26056.31c	1.7749E-05
26057.31c	4.0990E-07
26058.31c	5.4549E-08
28058.31c	4.6308E-06
28060.31c	1.7838E-06
28061.31c	7.7540E-08
28062.31c	2.4723E-07
28064.31c	6.2963E-08
31000.31c	2.2555E-03
c total	33 4.04903E-02
c MATERIAL 34 PuVI8 plate canning	
c	
m34	1001.31c 1.3955E-05
6000.31c	1.1413E-04
14028.31c	3.6853E-04
15031.31c	1.3545E-05
16032.31c	9.3252E-06
25055.31c	8.6563E-04
24050.31c	4.1142E-04
24052.31c	7.9338E-03
24053.31c	8.9963E-04
24054.31c	2.2394E-04
26054.31c	2.0924E-03

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

26056.31c 3.2846E-02
26057.31c 7.5855E-04
26058.31c 1.0095E-04
28058.31c 2.8554E-03
28060.31c 1.0999E-03
28061.31c 4.7812E-05
28062.31c 1.5245E-04
28064.31c 3.8823E-05
29063.31c 1.1638E-02
29065.31c 4.9880E-03
c total 34 6.74722E-02

```

```

c
C MATERIAL 35 Pu metal plate PUVII8 core

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```

c
m35      92238.31c 9.3720E-07
          94238.31c 3.1569E-05
          94239.31c 2.9028E-02
          94240.31c 6.9606E-03
          94241.31c 1.1476E-03
          94242.31c 1.8725E-04
          95241.31c 5.3467E-05
          1001.31c 1.3980E-04
          6000.31c 2.0335E-04
          7014.31c 6.7066E-06
          8016.31c 5.4310E-05
          13027.31c 1.6973E-05
          14028.31c 1.0870E-05
          25055.31c 8.5494E-07
          24050.31c 1.7662E-07
          24052.31c 3.4059E-06
          24053.31c 3.8621E-07
          24054.31c 9.6135E-08
          26054.31c 6.1449E-07
          26056.31c 9.6461E-06
          26057.31c 2.2277E-07
          26058.31c 2.9646E-08
          28058.31c 6.1291E-06
          28060.31c 2.3609E-06
          28061.31c 1.0263E-07
          28062.31c 3.2722E-07
          28064.31c 8.3333E-08
          31000.31c 2.0492E-03

```

```

c total 35 3.99151E-02
c MATERIAL 36 PuVII8 plate canning

```

```

c
m36      1001.31c 1.3771E-05
          6000.31c 1.1357E-04
          14028.31c 3.6675E-04
          15031.31c 1.3479E-05
          25055.31c 8.6145E-04
          24050.31c 4.0943E-04
          24052.31c 7.8955E-03
          24053.31c 8.9529E-04
          24054.31c 2.2286E-04
          26054.31c 2.0823E-03
          26056.31c 3.2687E-02
          26057.31c 7.5489E-04
          26058.31c 1.0046E-04
          28058.31c 2.8417E-03
          28060.31c 1.0946E-03
          28061.31c 4.7581E-05
          28062.31c 1.5171E-04
          28064.31c 3.8636E-05
          29063.31c 1.1638E-02
          29065.31c 4.9880E-03

```

```

c total 36 6.72170E-02
c
C MATERIAL 37 Pu metal plate PUVIII8 core

```

```

c
m37      92238.31c 6.9057E-07
          94238.31c 3.0583E-05
          94239.31c 2.9035E-02
          94240.31c 6.9371E-03
          94241.31c 1.1574E-03
          94242.31c 1.8773E-04
          95241.31c 4.4181E-05

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

1001.31c  1.2815E-04
6000.31c  4.2429E-04
7014.31c  2.4312E-05
8016.31c  8.8804E-05
13027.31c 2.3065E-05
14028.31c  1.4215E-05
25055.31c  1.4962E-06
24050.31c  1.5700E-07
24052.31c  3.0275E-06
24053.31c  3.4330E-07
24054.31c  8.5455E-08
26054.31c  9.5858E-07
26056.31c  1.5048E-05
26057.31c  3.4751E-07
26058.31c  4.6247E-08
28058.31c  5.8567E-06
28060.31c  2.2560E-06
28061.31c  9.8066E-08
28062.31c  3.1268E-07
28064.31c  7.9630E-08
31000.31c  2.0247E-03
c total 37 4.01503E-02
c MATERIAL 38 PuVIII8 plate canning
c CR 9.4087E-03 FE 3.5570E-02 NI 4.1678E-03
m38  1001.31c  1.3771E-05
      6000.31c  1.1340E-04
      14028.31c 3.6619E-04
      15031.31c  1.3461E-05
      25055.31c  8.6013E-04
      24050.31c  4.0881E-04
      24052.31c  7.8835E-03
      24053.31c  8.9392E-04
      24054.31c  2.2252E-04
      26054.31c  2.0791E-03
      26056.31c  3.2637E-02
      26057.31c  7.5372E-04
      26058.31c  1.0031E-04
      28058.31c  2.8373E-03
      28060.31c  1.0929E-03
      28061.31c  4.7509E-05
      28062.31c  1.5148E-04
      28064.31c  3.8577E-05
      29063.31c  1.1638E-02
      29065.31c  4.9880E-03
c total 38 6.71396E-02
c
c MATERIAL 39 PUX8 Plutonium metal plate core
m39  92238.31c  1.4305E-06
      94238.31c  3.4035E-05
      94239.31c  2.9107E-02
      94240.31c  6.9117E-03
      94241.31c  1.1359E-03
      94242.31c  1.8531E-04
      95241.31c  3.3658E-05
      1001.31c  1.0485E-04
      6000.31c  2.9524E-04
      7014.31c  1.0060E-05
      8016.31c  4.5503E-05
      13027.31c  2.1760E-05
      14028.31c  1.5887E-05
      25055.31c  1.0687E-06
      24050.31c  1.8643E-07
      24052.31c  3.5952E-06
      24053.31c  4.0767E-07
      24054.31c  1.0148E-07
      26054.31c  8.7254E-07
      26056.31c  1.3697E-05
      26057.31c  3.1632E-07
      26058.31c  4.2096E-08
      28058.31c  1.1032E-05
      28060.31c  4.2498E-06
      28061.31c  1.8473E-07
      28062.31c  5.8901E-07
      28064.31c  1.5000E-07
      31000.31c  2.2417E-03
C TOTAL 39 4.01805E-02

```


ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```
C
c MATERIAL 40 PUX8 Plutonium metal plate can
c
m40      1001.31c  1.3587E-05
        6000.31c  1.2050E-04
        14028.31c 5.2025E-04
        15031.31c  2.6701E-05
        16032.31c  1.5471E-05
        22048.31c  5.7590E-06
        25055.31c  8.5308E-04
        24050.31c  4.3310E-04
        24052.31c  8.3520E-03
        24053.31c  9.4705E-04
        24054.31c  2.3574E-04
        26054.31c  1.9782E-03
        26056.31c  3.1053E-02
        26057.31c  7.1715E-04
        26058.31c  9.5439E-05
        28058.31c  3.2937E-03
        28060.31c  1.2688E-03
        28061.31c  5.5152E-05
        28062.31c  1.7585E-04
        28064.31c  4.4783E-05
        29063.31c  1.1808E-02
        29065.31c  5.0600E-03
c total 40 6.70733E-02
c
C MATERIAL 41 PUXI8 Plutonium metal plate core
c
m41      92238.31c  6.9057E-07
        94238.31c  3.7488E-05
        94239.31c  2.8990E-02
        94240.31c  6.9709E-03
        94241.31c  1.1546E-03
        94242.31c  1.8482E-04
        95241.31c  3.0855E-05
        1001.31c  1.7475E-04
        6000.31c  2.2876E-04
        7014.31c  1.1737E-05
        8016.31c  4.1833E-05
        13027.31c  1.8713E-05
        14028.31c  1.8396E-05
        25055.31c  1.0687E-06
        24050.31c  2.6493E-07
        24052.31c  5.1090E-06
        24053.31c  5.7931E-07
        24054.31c  1.4420E-07
        26054.31c  1.3027E-06
        26056.31c  2.0449E-05
        26057.31c  4.7226E-07
        26058.31c  6.2849E-08
        28058.31c  1.1986E-05
        28060.31c  4.6169E-06
        28061.31c  2.0069E-07
        28062.31c  6.3989E-07
        28064.31c  1.6296E-07
        31000.31c  2.2490E-03
c total 41 4.01596E-02
c
c Material 42 PUXI8 can
m42      1001.31c  1.3404E-05
        6000.31c  1.1825E-04
        14028.31c  5.1057E-04
        15031.31c  2.6205E-05
        16032.31c  1.5188E-05
        22048.31c  5.6508E-06
        25055.31c  8.3722E-04
        24050.31c  4.2505E-04
        24052.31c  8.1967E-03
        24053.31c  9.2943E-04
        24054.31c  2.3136E-04
        26054.31c  1.9414E-03
        26056.31c  3.0476E-02
        26057.31c  7.0382E-04
        26058.31c  9.3665E-05
        28058.31c  3.2325E-03
```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

28060.31c 1.2452E-03
28061.31c 5.4126E-05
28062.31c 1.7258E-04
28064.31c 4.3950E-05
29063.31c 1.1808E-02
29065.31c 5.0600E-03
C total 42 6.61403E-02
c
c C MATERIAL 43 PUXII8 Plutonium metal plate core
c
m43      92238.31c 1.6771E-06
94238.31c 3.6995E-05
94239.31c 2.9064E-02
94240.31c 6.8990E-03
94241.31c 1.1606E-03
94242.31c 1.7997E-04
95241.31c 2.7359E-05
1001.31c 1.7475E-04
6000.31c 2.6298E-04
7014.31c 6.7066E-06
8016.31c 4.1833E-05
13027.31c 1.7408E-05
14028.31c 2.2159E-05
25055.31c 8.5494E-07
24050.31c 4.0230E-07
24052.31c 7.7580E-06
24053.31c 8.7970E-07
24054.31c 2.1898E-07
26054.31c 8.7254E-07
26056.31c 1.3697E-05
26057.31c 3.1632E-07
26058.31c 4.2096E-08
28058.31c 1.6208E-05
28060.31c 6.2435E-06
28061.31c 2.7140E-07
28062.31c 8.6534E-07
28064.31c 2.2038E-07
31000.31c 2.3032E-03
c total 43 4.02475E-02
c
c Material 44 PUXII8 can
c
m44      1001.31c 1.3220E-05
6000.31c 1.1685E-04
14028.31c 5.0450E-04
15031.31c 2.5895E-05
16032.31c 1.5004E-05
22048.31c 5.5851E-06
25055.31c 8.2726E-04
24050.31c 4.1999E-04
24052.31c 8.0991E-03
24053.31c 9.1838E-04
24054.31c 2.2860E-04
26054.31c 1.9183E-03
26056.31c 3.0114E-02
26057.31c 6.9545E-04
26058.31c 9.2551E-05
28058.31c 3.1940E-03
28060.31c 1.2304E-03
28061.31c 5.3482E-05
28062.31c 1.7052E-04
28064.31c 4.3427E-05
29063.31c 1.1808E-02
29065.31c 5.0600E-03
c Total 44 6.55545E-02
c
c Graphite reflector material
m45      1001.31c 2.2500E-04
6000.31c 8.6550E-02
c total 45 8.6775E-02
c --- MODE CARDS ---
c
c
mode n
kcode 20000 1.0 100 1000
ksrc 0.0 0.0 100.0 0.0 0.0 112.0 0.0 0.0 124.3 0.0 0.0 136.3

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```
0.0 0.0 148.6 0.0 0.0 160.6 0.0 0.0 173.0 0.0 0.0 185.0
27.0 0.0 100.0 27.0 0.0 112.0 27.0 0.0 124.3 27.0 0.0 136.3
27.0 0.0 148.6 27.0 0.0 160.6 27.0 0.0 173.0 27.0 0.0 185.0
-27.0 0.0 100.0 -27.0 0.0 112.0 -27.0 0.0 124.3 -27.0 0.0 136.3
-27.0 0.0 148.6 -27.0 0.0 160.6 -27.0 0.0 173.0 -27.0 0.0 185.0
0.0 27.0 100.0 0.0 27.0 112.0 0.0 27.0 124.3 0.0 27.0 136.3
0.0 27.0 148.6 0.0 27.0 160.6 0.0 27.0 173.0 0.0 27.0 185.0
0.0 -27.0 100.0 0.0 -27.0 112.0 0.0 -27.0 124.3 0.0 -27.0 136.3
0.0 -27.0 148.6 0.0 -27.0 160.6 0.0 -27.0 173.0 0.0 -27.0 185.0
27.0 27.0 100.0 27.0 27.0 112.0 27.0 27.0 124.3 27.0 27.0 136.3
27.0 27.0 148.6 27.0 27.0 160.6 27.0 27.0 173.0 27.0 27.0 185.0
-27.0 27.0 100.0 -27.0 27.0 112.0 -27.0 27.0 124.3 -27.0 27.0 136.3
-27.0 27.0 148.6 -27.0 27.0 160.6 -27.0 27.0 173.0 -27.0 27.0 185.0
27.0 -27.0 100.0 27.0 -27.0 112.0 27.0 -27.0 124.3 27.0 -27.0 136.3
27.0 -27.0 148.6 27.0 -27.0 160.6 27.0 -27.0 173.0 27.0 -27.0 185.0
-27.0 -27.0 100.0 -27.0 -27.0 112.0 -27.0 -27.0 124.3 -27.0 -27.0 136.3
-27.0 -27.0 148.6 -27.0 -27.0 160.6 -27.0 -27.0 173.0 -27.0 -27.0 185.0
8.1 8.1 100.0 8.1 8.1 112.0 8.1 8.1 124.3 8.1 8.1 136.3
8.1 8.1 148.6 8.1 8.1 160.6 8.1 8.1 173.0 8.1 8.1 185.0
-8.1 8.1 100.0 -8.1 8.1 112.0 -8.1 8.1 124.3 -8.1 8.1 136.3
-8.1 8.1 148.6 -8.1 8.1 160.6 -8.1 8.1 173.0 -8.1 8.1 185.0
8.1 -8.1 100.0 8.1 -8.1 112.0 8.1 -8.1 124.3 8.1 -8.1 136.3
8.1 -8.1 148.6 8.1 -8.1 160.6 8.1 -8.1 173.0 8.1 -8.1 185.0
-8.1 -8.1 100.0 -8.1 -8.1 112.0 -8.1 -8.1 124.3 -8.1 -8.1 136.3
-8.1 -8.1 148.6 -8.1 -8.1 160.6 -8.1 -8.1 173.0 -8.1 -8.1 185.0
70.5 0.0 107.5 70.5 0.0 118.5 70.5 0.0 130.0 70.5 0.0 141.0
70.5 0.0 152.5 70.5 0.0 163.5 70.5 0.0 175.0 70.5 0.0 186.0
-70.5 0.0 107.5 -70.5 0.0 118.5 -70.5 0.0 130.0 -70.5 0.0 141.0
-70.5 0.0 152.5 -70.5 0.0 163.5 -70.5 0.0 175.0 -70.5 0.0 186.0
0.0 70.5 107.5 0.0 70.5 118.5 0.0 70.5 130.0 0.0 70.5 141.0
0.0 70.5 152.5 0.0 70.5 163.5 0.0 70.5 175.0 0.0 70.5 186.0
0.0 -70.5 107.5 0.0 -70.5 118.5 0.0 -70.5 130.0 0.0 -70.5 141.0
0.0 -70.5 152.5 0.0 -70.5 163.5 0.0 -70.5 175.0 0.0 -70.5 186.0
70.5 70.5 107.5 70.5 70.5 118.5 70.5 70.5 130.0 70.5 70.5 141.0
70.5 70.5 152.5 70.5 70.5 163.5 70.5 70.5 175.0 70.5 70.5 186.0
-70.5 70.5 107.5 -70.5 70.5 118.5 -70.5 70.5 130.0 -70.5 70.5 141.0
-70.5 70.5 152.5 -70.5 70.5 163.5 -70.5 70.5 175.0 -70.5 70.5 186.0
70.5 -70.5 107.5 70.5 -70.5 118.5 70.5 -70.5 130.0 70.5 -70.5 141.0
70.5 -70.5 152.5 70.5 -70.5 163.5 70.5 -70.5 175.0 70.5 -70.5 186.0
-70.5 -70.5 107.5 -70.5 -70.5 118.5 -70.5 -70.5 130.0 -70.5 -70.5 141.0
-70.5 -70.5 152.5 -70.5 -70.5 163.5 -70.5 -70.5 175.0 -70.5 -70.5 186.0
48.8 48.8 107.5 48.8 48.8 118.5 48.8 48.8 130.0 48.8 48.8 141.0
48.8 48.8 152.5 48.8 48.8 163.5 48.8 48.8 175.0 48.8 48.8 186.0
-48.8 48.8 107.5 -48.8 48.8 118.5 -48.8 48.8 130.0 -48.8 48.8 141.0
-48.8 48.8 152.5 -48.8 48.8 163.5 -48.8 48.8 175.0 -48.8 48.8 186.0
48.8 -48.8 107.5 48.8 -48.8 118.5 48.8 -48.8 130.0 48.8 -48.8 141.0
48.8 -48.8 152.5 48.8 -48.8 163.5 48.8 -48.8 175.0 48.8 -48.8 186.0
-48.8 -48.8 107.5 -48.8 -48.8 118.5 -48.8 -48.8 130.0 -48.8 -48.8 141.0
-48.8 -48.8 152.5 -48.8 -48.8 163.5 -48.8 -48.8 175.0 -48.8 -48.8 186.0
```

print

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

MCNP JEFF-3.1 Model C of MZB

```

Zebra Assembly MZB detailed model C. Regular mesh. Smeared wrapper.
c Jeff3.1.
c The experimental value of k-effective to be used with this model is
c      1.0044 +/- 0.0012
c See www.zebra.webnik.org for details.
c
c ----- Elements of the assembly -----
c
c
c --- MZB Inner Core Element A (C12-30A)
c
c Lower padding
c
111      16 3.279692E-02 -8 21 -22 23 -24 u=1 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
112      0  8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=1 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
121      0  9 -41 21 -22 23 -24 fill=41 (0 0 63.0048) u=1 imp:n=1
c
122      0  41 -42 21 -22 23 -24 fill=41 (0 0 71.7414) u=1 imp:n=1
c
123      0  42 -43 21 -22 23 -24 fill=41 (0 0 80.478) u=1 imp:n=1
c
124      0  43 -10 21 -22 23 -24 fill=41 (0 0 89.2146) u=1 imp:n=1
c
c
c The 11 MZB Inner Core Cells
c
151      0  10 -702 21 -22 23 -24 fill=21 (0 0 97.9512) u=1 imp:n=1
c
152      0  702 -703 21 -22 23 -24 fill=21 (0 0 106.0599) u=1 imp:n=1
c
153      0  703 -704 21 -22 23 -24 fill=21 (0 0 114.1686) u=1 imp:n=1
c
154      0  704 -705 21 -22 23 -24 fill=21 (0 0 122.2773) u=1 imp:n=1
c
155      0  705 -706 21 -22 23 -24 fill=21 (0 0 130.386) u=1 imp:n=1
c
156      0  706 -707 21 -22 23 -24 fill=21 (0 0 138.4947) u=1 imp:n=1
c
157      0  707 -708 21 -22 23 -24 fill=21 (0 0 146.6034) u=1 imp:n=1
c
158      0  708 -709 21 -22 23 -24 fill=21 (0 0 154.7121) u=1 imp:n=1
c
159      0  709 -710 21 -22 23 -24 fill=21 (0 0 162.8208) u=1 imp:n=1
c
160      0  710 -711 21 -22 23 -24 fill=21 (0 0 170.9295) u=1 imp:n=1
c
161      0  711 -712 21 -22 23 -24 fill=21 (0 0 179.0382) u=1 imp:n=1
c
c 712      pz      $ Core upper boundary
c
c Upper Axial Blanket. 4 Cells
c
181      0  712 -713 21 -22 23 -24 fill=41 (0 0 187.1469) u=1 imp:n=1
c
182      0  713 -714 21 -22 23 -24 fill=41 (0 0 195.8835 ) u=1 imp:n=1
c
183      0  714 -715 21 -22 23 -24 fill=41 (0 0 204.6201) u=1 imp:n=1
c
184      0  715 -716 21 -22 23 -24 fill=41 (0 0 213.3567) u=1 imp:n=1
c
c Upper Plenum
c
186      0  716 -717 21 -22 23 -24 fill=72 (0 0 222.0933) u=1 imp:n=1
c
c Upper padding
c
188      16 3.279692E-02 717 -16 21 -22 23 -24 u=1 imp:n=1 TMP=2.5301E-08

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c
c Wrapper region
c
191      17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=1 imp:n=1
c
c 191      0 62 -63 64 -65 (-21:22:-23:24) u=1 imp:n=1
c wrapper
c 192      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=1 imp:n=1 &
      TMP=2.5301E-08
c gap outside wrapper
c 193      0  1 -2 3 -4 (-66:67:-68:69) u=1 imp:n=1
c
c End of Inner Core Element A
c
c --- MZB Inner Core Element B (C12-30B)
c
c Lower padding
c
211      16 3.279692E-02 -8 21 -22 23 -24 u=2 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
212      0  8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=2 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
221      0  9 -41 21 -22 23 -24 fill=41 (0 0 63.0048) u=2 imp:n=1
c
222      0  41 -42 21 -22 23 -24 fill=41 (0 0 71.7414) u=2 imp:n=1
c
223      0  42 -43 21 -22 23 -24 fill=41 (0 0 80.478) u=2 imp:n=1
c
224      0  43 -10 21 -22 23 -24 fill=41 (0 0 89.2146) u=2 imp:n=1
c
c
c The 11 MZB Inner Core Cells
c
251      0  10 -702 21 -22 23 -24 fill=22 (0 0 97.9512) u=2 imp:n=1
c
252      0  702 -703 21 -22 23 -24 fill=22 (0 0 106.0599) u=2 imp:n=1
c
253      0  703 -704 21 -22 23 -24 fill=22 (0 0 114.1686) u=2 imp:n=1
c
254      0  704 -705 21 -22 23 -24 fill=22 (0 0 122.2773) u=2 imp:n=1
c
255      0  705 -706 21 -22 23 -24 fill=22 (0 0 130.386) u=2 imp:n=1
c
256      0  706 -707 21 -22 23 -24 fill=22 (0 0 138.4947) u=2 imp:n=1
c
257      0  707 -708 21 -22 23 -24 fill=22 (0 0 146.6034) u=2 imp:n=1
c
258      0  708 -709 21 -22 23 -24 fill=22 (0 0 154.7121) u=2 imp:n=1
c
259      0  709 -710 21 -22 23 -24 fill=22 (0 0 162.8208) u=2 imp:n=1
c
260      0  710 -711 21 -22 23 -24 fill=22 (0 0 170.9295) u=2 imp:n=1
c
261      0  711 -712 21 -22 23 -24 fill=22 (0 0 179.0382) u=2 imp:n=1
c
c 712      pz      $ Core upper boundary
c
c Upper Axial Blanket. 4 Cells
c
281      0  712 -713 21 -22 23 -24 fill=41 (0 0 187.1469) u=2 imp:n=1
c
282      0  713 -714 21 -22 23 -24 fill=41 (0 0 195.8835 ) u=2 imp:n=1
c
283      0  714 -715 21 -22 23 -24 fill=41 (0 0 204.6201) u=2 imp:n=1
c
284      0  715 -716 21 -22 23 -24 fill=41 (0 0 213.3567) u=2 imp:n=1
c
c Upper Plenum
c
286      0  716 -717 21 -22 23 -24 fill=72 (0 0 222.0933) u=2 imp:n=1
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c Upper padding
c
288      16 3.279692E-02 717 -16 21 -22 23 -24 u=2 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
c
c
291      17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=2 imp:n=1
c
c 291      0 62 -63 64 -65 (-21:22:-23:24) u=2 imp:n=1
c wrapper
c 292      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=2 imp:n=1 &
c      TMP=2.5301E-08
c gap outside wrapper
c 293      0  1 -2 3 -4 (-66:67:-68:69) u=2 imp:n=1
c
c End of Inner Core Element B
c
c --- MZB Inner Core Element BG
c
c Lower padding
c
311      16 3.279692E-02 -8 21 -22 23 -24 u=3 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
312      0  8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=3 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
321      0  9 -41 21 -22 23 -24 fill=42 (0 0 63.0048) u=3 imp:n=1
c
322      0  41 -42 21 -22 23 -24 fill=42 (0 0 71.7414) u=3 imp:n=1
c
323      0  42 -43 21 -22 23 -24 fill=42 (0 0 80.478) u=3 imp:n=1
c
324      0  43 -10 21 -22 23 -24 fill=42 (0 0 89.2146) u=3 imp:n=1
c
c
c The 11 MZB Inner Core Cells
c
351      0  10 -702 21 -22 23 -24 fill=23 (0 0 97.9512) u=3 imp:n=1
c
352      0  702 -703 21 -22 23 -24 fill=23 (0 0 106.0599) u=3 imp:n=1
c
353      0  703 -704 21 -22 23 -24 fill=23 (0 0 114.1686) u=3 imp:n=1
c
354      0  704 -705 21 -22 23 -24 fill=23 (0 0 122.2773) u=3 imp:n=1
c
355      0  705 -706 21 -22 23 -24 fill=23 (0 0 130.386) u=3 imp:n=1
c
356      0  706 -707 21 -22 23 -24 fill=23 (0 0 138.4947) u=3 imp:n=1
c
357      0  707 -708 21 -22 23 -24 fill=23 (0 0 146.6034) u=3 imp:n=1
c
358      0  708 -709 21 -22 23 -24 fill=23 (0 0 154.7121) u=3 imp:n=1
c
359      0  709 -710 21 -22 23 -24 fill=23 (0 0 162.8208) u=3 imp:n=1
c
360      0  710 -711 21 -22 23 -24 fill=23 (0 0 170.9295) u=3 imp:n=1
c
361      0  711 -712 21 -22 23 -24 fill=23 (0 0 179.0382) u=3 imp:n=1
c
c 712      pz      $ Core upper boundary
c
c Upper Axial Blanket. 4 Cells
c
381      0  712 -713 21 -22 23 -24 fill=42 (0 0 187.1469) u=3 imp:n=1
c
382      0  713 -714 21 -22 23 -24 fill=42 (0 0 195.8835 ) u=3 imp:n=1
c
383      0  714 -715 21 -22 23 -24 fill=42 (0 0 204.6201) u=3 imp:n=1
c
384      0  715 -716 21 -22 23 -24 fill=42 (0 0 213.3567) u=3 imp:n=1
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c Upper Plenum
c
386 0 716 -717 21 -22 23 -24 fill=72 (0 0 222.0933) u=3 imp:n=1
c
c Upper padding
c
388 16 3.279692E-02 717 -16 21 -22 23 -24 u=3 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
c
c
391 17 3.595949E-02 1 -2 3 -4 (-21:22:-23:24) u=3 imp:n=1
c
c 391 0 62 -63 64 -65 (-21:22:-23:24) u=3 imp:n=1
c wrapper
c 392 17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=3 imp:n=1 &
c TMP=2.5301E-08
c gap outside wrapper
c 393 0 1 -2 3 -4 (-66:67:-68:69) u=3 imp:n=1
c
c End of Inner Core Element BG
c
c --- MZB Inner Core Element D (C12-30D)
c
c Lower padding
c
411 16 3.279692E-02 -8 21 -22 23 -24 u=4 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
412 0 8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=4 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
421 0 9 -41 21 -22 23 -24 fill=42 (0 0 63.0048) u=4 imp:n=1
c
422 0 41 -42 21 -22 23 -24 fill=42 (0 0 71.7414) u=4 imp:n=1
c
423 0 42 -43 21 -22 23 -24 fill=42 (0 0 80.478) u=4 imp:n=1
c
424 0 43 -10 21 -22 23 -24 fill=42 (0 0 89.2146) u=4 imp:n=1
c
c
c The 11 MZB Inner Core Cells
c
451 0 10 -702 21 -22 23 -24 fill=24 (0 0 97.9512) u=4 imp:n=1
c
452 0 702 -703 21 -22 23 -24 fill=24 (0 0 106.0599) u=4 imp:n=1
c
453 0 703 -704 21 -22 23 -24 fill=24 (0 0 114.1686) u=4 imp:n=1
c
454 0 704 -705 21 -22 23 -24 fill=24 (0 0 122.2773) u=4 imp:n=1
c
455 0 705 -706 21 -22 23 -24 fill=24 (0 0 130.386) u=4 imp:n=1
c
456 0 706 -707 21 -22 23 -24 fill=24 (0 0 138.4947) u=4 imp:n=1
c
457 0 707 -708 21 -22 23 -24 fill=24 (0 0 146.6034) u=4 imp:n=1
c
458 0 708 -709 21 -22 23 -24 fill=24 (0 0 154.7121) u=4 imp:n=1
c
459 0 709 -710 21 -22 23 -24 fill=24 (0 0 162.8208) u=4 imp:n=1
c
460 0 710 -711 21 -22 23 -24 fill=24 (0 0 170.9295) u=4 imp:n=1
c
461 0 711 -712 21 -22 23 -24 fill=24 (0 0 179.0382) u=4 imp:n=1
c
c 712 pz $ Core upper boundary
c
c Upper Axial Blanket. 4 Cells
c
481 0 712 -713 21 -22 23 -24 fill=42 (0 0 187.1469) u=4 imp:n=1
c
482 0 713 -714 21 -22 23 -24 fill=42 (0 0 195.8835 ) u=4 imp:n=1
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

483      0  714 -715 21 -22 23 -24 fill=42  (0 0 204.6201) u=4 imp:n=1
c
484      0  715 -716 21 -22 23 -24 fill=42  (0 0 213.3567) u=4 imp:n=1
c
c  Upper Plenum
c
486      0  716 -717 21 -22 23 -24 fill=72  (0 0 222.0933) u=4 imp:n=1
c
c  Upper padding
c
488      16 3.279692E-02 717 -16 21 -22 23 -24 u=4 imp:n=1 TMP=2.5301E-08
c
c
c  Wrapper region
c
c
491      17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=4 imp:n=1
c
c 491      0 62 -63 64 -65 (-21:22:-23:24) u=4 imp:n=1
c wrapper
c 492      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=4 imp:n=1 &
c      TMP=2.5301E-08
c gap outside wrapper
c 493      0  1 -2 3 -4 (-66:67:-68:69) u=4 imp:n=1
c
c  End of Inner Core Element D
c
c --- MZB Outer Core Element A
c
c  Lower padding
511      like 111 but u=5 imp:n=1 TMP=2.5301E-08
c
c  Lower Plenum
c
512      0  8 -9 21 -22 23 -24 fill=71  (0 0 30.0) u=5 imp:n=1
c
c  Lower Axial Blanket comprising 4 cells
c
521      0  9 -41 21 -22 23 -24 fill=44  (0 0 63.0048) u=5 imp:n=1
c
522      0  41 -42 21 -22 23 -24 fill=44  (0 0 71.7414) u=5 imp:n=1
c
523      0  42 -43 21 -22 23 -24 fill=44  (0 0 80.478) u=5 imp:n=1
c
524      0  43 -10 21 -22 23 -24 fill=44  (0 0 89.2146) u=5 imp:n=1
c
c
c
c  The 12 core cells
c
551      0  10 -44 21 -22 23 -24 fill=25  (0 0 97.9512) u=5 imp:n=1
c
552      0  44 -45 21 -22 23 -24 fill=25  (0 0 105.447) u=5 imp:n=1
c
553      0  45 -46 21 -22 23 -24 fill=25  (0 0 112.9428) u=5 imp:n=1
c
554      0  46 -47 21 -22 23 -24 fill=25  (0 0 120.4386) u=5 imp:n=1
c
555      0  47 -48 21 -22 23 -24 fill=25  (0 0 127.9344) u=5 imp:n=1
c
556      0  48 -49 21 -22 23 -24 fill=25  (0 0 135.4302) u=5 imp:n=1
c
557      0  49 -50 21 -22 23 -24 fill=25  (0 0 142.926) u=5 imp:n=1
c
558      0  50 -51 21 -22 23 -24 fill=25  (0 0 150.4218) u=5 imp:n=1
c
559      0  51 -52 21 -22 23 -24 fill=25  (0 0 157.9176) u=5 imp:n=1
c
560      0  52 -53 21 -22 23 -24 fill=25  (0 0 165.4134) u=5 imp:n=1
c
561      0  53 -54 21 -22 23 -24 fill=25  (0 0 172.9092) u=5 imp:n=1
c
562      0  54 -11 21 -22 23 -24 fill=25  (0 0 180.405) u=5 imp:n=1
c
c  Upper Axial Blanket. 4 Cells
c

```


ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
581  0  11 -56 21 -22 23 -24 fill=44  (0 0 187.9008) u=5 imp:n=1
c
582  0  56 -57 21 -22 23 -24 fill=44  (0 0 196.6374 ) u=5 imp:n=1
c
583  0  57 -58 21 -22 23 -24 fill=44  (0 0 205.374) u=5 imp:n=1
c
584  0  58 -12 21 -22 23 -24 fill=44  (0 0 214.1106) u=5 imp:n=1
c
c Upper Plenum
c
586  0  12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=5 imp:n=1
c
c Upper padding
c
588  16 3.279692E-02 13 -16 21 -22 23 -24 u=5 imp:n=1 TMP=2.5301E-08
c
c
c
c Wrapper region
c
591  17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=5 imp:n=1
c
c 591  0 62 -63 64 -65 (-21:22:-23:24) u=5 imp:n=1
c wrapper
c 592  17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=5 imp:n=1 &
c      TMP=2.5301E-08
c gap outside wrapper
c 593  0  1 -2 3 -4 (-66:67:-68:69) u=5 imp:n=1
c
c End of Outer Core Element A
c
c
c --- MZB Outer Core Element B
c
c Lower padding
611  like 111 but u=6 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
612  0  8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=6 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
621  0  9 -41 21 -22 23 -24 fill=45  (0 0 63.0048) u=6 imp:n=1
c
622  0  41 -42 21 -22 23 -24 fill=45  (0 0 71.7414) u=6 imp:n=1
c
623  0  42 -43 21 -22 23 -24 fill=45  (0 0 80.478) u=6 imp:n=1
c
624  0  43 -10 21 -22 23 -24 fill=45  (0 0 89.2146) u=6 imp:n=1
c
c
c
c The 12 core cells
c
651  0  10 -44 21 -22 23 -24 fill=26 (0 0 97.9512) u=6 imp:n=1
c
652  0  44 -45 21 -22 23 -24 fill=26 (0 0 105.447) u=6 imp:n=1
c
653  0  45 -46 21 -22 23 -24 fill=26 (0 0 112.9428) u=6 imp:n=1
c
654  0  46 -47 21 -22 23 -24 fill=26 (0 0 120.4386) u=6 imp:n=1
c
655  0  47 -48 21 -22 23 -24 fill=26 (0 0 127.9344) u=6 imp:n=1
c
656  0  48 -49 21 -22 23 -24 fill=26 (0 0 135.4302) u=6 imp:n=1
c
657  0  49 -50 21 -22 23 -24 fill=26 (0 0 142.926) u=6 imp:n=1
c
658  0  50 -51 21 -22 23 -24 fill=26 (0 0 150.4218) u=6 imp:n=1
c
659  0  51 -52 21 -22 23 -24 fill=26 (0 0 157.9176) u=6 imp:n=1
c
660  0  52 -53 21 -22 23 -24 fill=26 (0 0 165.4134) u=6 imp:n=1
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

661    0  53 -54 21 -22 23 -24 fill=26 (0 0 172.9092) u=6 imp:n=1
c
662    0  54 -11 21 -22 23 -24 fill=26 (0 0 180.405) u=6 imp:n=1
c
c  Upper Axial Blanket. 4 Cells
c
c
681    0  11 -56 21 -22 23 -24 fill=45 (0 0 187.9008) u=6 imp:n=1
c
682    0  56 -57 21 -22 23 -24 fill=45 (0 0 196.6374 ) u=6 imp:n=1
c
683    0  57 -58 21 -22 23 -24 fill=45 (0 0 205.374) u=6 imp:n=1
c
684    0  58 -12 21 -22 23 -24 fill=45 (0 0 214.1106) u=6 imp:n=1
c
c  Upper Plenum
c
686    0  12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=6 imp:n=1
c
c  Upper padding
c
688      16 3.279692E-02 13 -16 21 -22 23 -24 u=6 imp:n=1 TMP=2.5301E-08
c
c
c  Wrapper region
c
691      17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=6 imp:n=1
c
c 691      0 62 -63 64 -65 (-21:22:-23:24) u=6 imp:n=1
c wrapper
c 692      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=6 imp:n=1 &
c      TMP=2.5301E-08
c gap outside wrapper
c 693      0  1 -2 3 -4 (-66:67:-68:69) u=6 imp:n=1
c
c  End of Outer Core Element B
c
c
c --- MZB Outer Core Element C
c
c  Lower padding
711      like 111 but u=7 imp:n=1 TMP=2.5301E-08
c
c  Lower Plenum
c
712      0  8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=7 imp:n=1
c
c  Lower Axial Blanket comprising 4 cells
c
721      0  9 -41 21 -22 23 -24 fill=45 (0 0 63.0048) u=7 imp:n=1
c
722      0  41 -42 21 -22 23 -24 fill=45 (0 0 71.7414) u=7 imp:n=1
c
723      0  42 -43 21 -22 23 -24 fill=45 (0 0 80.478) u=7 imp:n=1
c
724      0  43 -10 21 -22 23 -24 fill=45 (0 0 89.2146) u=7 imp:n=1
c
c
c
c  The 12 core cells
c
751      0  10 -44 21 -22 23 -24 fill=27 (0 0 97.9512) u=7 imp:n=1
c
752      0  44 -45 21 -22 23 -24 fill=27 (0 0 105.447) u=7 imp:n=1
c
753      0  45 -46 21 -22 23 -24 fill=27 (0 0 112.9428) u=7 imp:n=1
c
754      0  46 -47 21 -22 23 -24 fill=27 (0 0 120.4386) u=7 imp:n=1
c
755      0  47 -48 21 -22 23 -24 fill=27 (0 0 127.9344) u=7 imp:n=1
c
756      0  48 -49 21 -22 23 -24 fill=27 (0 0 135.4302) u=7 imp:n=1
c
757      0  49 -50 21 -22 23 -24 fill=27 (0 0 142.926) u=7 imp:n=1
c
758      0  50 -51 21 -22 23 -24 fill=27 (0 0 150.4218) u=7 imp:n=1

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
759    0  51 -52 21 -22 23 -24 fill=27 (0 0 157.9176) u=7 imp:n=1
c
760    0  52 -53 21 -22 23 -24 fill=27 (0 0 165.4134) u=7 imp:n=1
c
761    0  53 -54 21 -22 23 -24 fill=27 (0 0 172.9092) u=7 imp:n=1
c
762    0  54 -11 21 -22 23 -24 fill=27 (0 0 180.405) u=7 imp:n=1
c
c   Upper Axial Blanket.  4 Cells
c
c
781    0  11 -56 21 -22 23 -24 fill=45  (0 0 187.9008) u=7 imp:n=1
c
782    0  56 -57 21 -22 23 -24 fill=45  (0 0 196.6374 ) u=7 imp:n=1
c
783    0  57 -58 21 -22 23 -24 fill=45  (0 0 205.374) u=7 imp:n=1
c
784    0  58 -12 21 -22 23 -24 fill=45  (0 0 214.1106) u=7 imp:n=1
c
c   Upper Plenum
c
786    0  12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=7 imp:n=1
c
c   Upper padding
c
788    16 3.279692E-02 13 -16 21 -22 23 -24 u=7 imp:n=1 TMP=2.5301E-08
c
c
c   Wrapper region
c
791    17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=7 imp:n=1
c
c 791    0 62 -63 64 -65 (-21:22:-23:24) u=7 imp:n=1
c wrapper
c 792    17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=7 imp:n=1 &
c      TMP=2.5301E-08
c gap outside wrapper
c 793    0  1 -2 3 -4 (-66:67:-68:69) u=7 imp:n=1
c
c End of Outer Core Element C
c
c
c --- MZB Outer Core Element D
c
c Lower padding
811    like 111 but u=8 imp:n=1 TMP=2.5301E-08
c
c Lower Plenum
c
812    0  8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=8 imp:n=1
c
c Lower Axial Blanket comprising 4 cells
c
821    0  9 -41 21 -22 23 -24 fill=45  (0 0 63.0048) u=8 imp:n=1
c
822    0  41 -42 21 -22 23 -24 fill=45  (0 0 71.7414) u=8 imp:n=1
c
823    0  42 -43 21 -22 23 -24 fill=45  (0 0 80.478) u=8 imp:n=1
c
824    0  43 -10 21 -22 23 -24 fill=45  (0 0 89.2146) u=8 imp:n=1
c
c
c
c The 12 core cells
c
851    0  10 -44 21 -22 23 -24 fill=28 (0 0 97.9512) u=8 imp:n=1
c
852    0  44 -45 21 -22 23 -24 fill=28 (0 0 105.447) u=8 imp:n=1
c
853    0  45 -46 21 -22 23 -24 fill=28 (0 0 112.9428) u=8 imp:n=1
c
854    0  46 -47 21 -22 23 -24 fill=28 (0 0 120.4386) u=8 imp:n=1
c
855    0  47 -48 21 -22 23 -24 fill=28 (0 0 127.9344) u=8 imp:n=1
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

856    0  48 -49 21 -22 23 -24 fill=28 (0 0 135.4302) u=8 imp:n=1
c
857    0  49 -50 21 -22 23 -24 fill=28 (0 0 142.926) u=8 imp:n=1
c
858    0  50 -51 21 -22 23 -24 fill=28 (0 0 150.4218) u=8 imp:n=1
c
859    0  51 -52 21 -22 23 -24 fill=28 (0 0 157.9176) u=8 imp:n=1
c
860    0  52 -53 21 -22 23 -24 fill=28 (0 0 165.4134) u=8 imp:n=1
c
861    0  53 -54 21 -22 23 -24 fill=28 (0 0 172.9092) u=8 imp:n=1
c
862    0  54 -11 21 -22 23 -24 fill=28 (0 0 180.405) u=8 imp:n=1
c
c   Upper Axial Blanket. 4 Cells
c
c
c
881    0  11 -56 21 -22 23 -24 fill=45 (0 0 187.9008) u=8 imp:n=1
c
882    0  56 -57 21 -22 23 -24 fill=45 (0 0 196.6374 ) u=8 imp:n=1
c
883    0  57 -58 21 -22 23 -24 fill=45 (0 0 205.374) u=8 imp:n=1
c
884    0  58 -12 21 -22 23 -24 fill=45 (0 0 214.1106) u=8 imp:n=1
c
c   Upper Plenum
c
886    0  12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=8 imp:n=1
c
c   Upper padding
c
888    16 3.279692E-02 13 -16 21 -22 23 -24 u=8 imp:n=1 TMP=2.5301E-08
c
c
c   Wrapper region
c
891    17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=8 imp:n=1
c
c 891    0 62 -63 64 -65 (-21:22:-23:24) u=8 imp:n=1
c wrapper
c 892    17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=8 imp:n=1 &
c      TMP=2.5301E-08
c gap outside wrapper
c 893    0  1 -2 3 -4 (-66:67:-68:69) u=8 imp:n=1
c
c   End of Outer Core Element D
c
c
c   --- MZB Outer Core Element G
c
c   Lower padding
911    like 111 but u=9 imp:n=1 TMP=2.5301E-08
c
c   Lower Plenum
c
912    0  8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=9 imp:n=1
c
c   Lower Axial Blanket comprising 4 cells
c
921    0  9 -41 21 -22 23 -24 fill=46 (0 0 63.0048) u=9 imp:n=1
c
922    0  41 -42 21 -22 23 -24 fill=46 (0 0 71.7414) u=9 imp:n=1
c
923    0  42 -43 21 -22 23 -24 fill=46 (0 0 80.478) u=9 imp:n=1
c
924    0  43 -10 21 -22 23 -24 fill=46 (0 0 89.2146) u=9 imp:n=1
c
c
c
c   The 12 core cells
c
951    0  10 -44 21 -22 23 -24 fill=29 (0 0 97.9512) u=9 imp:n=1
c
952    0  44 -45 21 -22 23 -24 fill=29 (0 0 105.447) u=9 imp:n=1
c
953    0  45 -46 21 -22 23 -24 fill=29 (0 0 112.9428) u=9 imp:n=1

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
954    0  46 -47 21 -22 23 -24 fill=29 (0 0 120.4386) u=9 imp:n=1
c
955    0  47 -48 21 -22 23 -24 fill=29 (0 0 127.9344) u=9 imp:n=1
c
956    0  48 -49 21 -22 23 -24 fill=29 (0 0 135.4302) u=9 imp:n=1
c
957    0  49 -50 21 -22 23 -24 fill=29 (0 0 142.926) u=9 imp:n=1
c
958    0  50 -51 21 -22 23 -24 fill=29 (0 0 150.4218) u=9 imp:n=1
c
959    0  51 -52 21 -22 23 -24 fill=29 (0 0 157.9176) u=9 imp:n=1
c
960    0  52 -53 21 -22 23 -24 fill=29 (0 0 165.4134) u=9 imp:n=1
c
961    0  53 -54 21 -22 23 -24 fill=29 (0 0 172.9092) u=9 imp:n=1
c
962    0  54 -11 21 -22 23 -24 fill=29 (0 0 180.405) u=9 imp:n=1
c
c  Upper Axial Blanket. 4 Cells
c
c
981    0  11 -56 21 -22 23 -24 fill=46 (0 0 187.9008) u=9 imp:n=1
c
982    0  56 -57 21 -22 23 -24 fill=46 (0 0 196.6374 ) u=9 imp:n=1
c
983    0  57 -58 21 -22 23 -24 fill=46 (0 0 205.374) u=9 imp:n=1
c
984    0  58 -12 21 -22 23 -24 fill=46 (0 0 214.1106) u=9 imp:n=1
c
c  Upper Plenum
c
986    0  12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=9 imp:n=1
c
c  Upper padding
c
988      16 3.279692E-02 13 -16 21 -22 23 -24 u=9 imp:n=1 TMP=2.5301E-08
c
c
c  Wrapper region
c
991      17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=9 imp:n=1
c
c 991      0 62 -63 64 -65 (-21:22:-23:24) u=9 imp:n=1
c  wrapper
c 992      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=9 imp:n=1 &
c      TMP=2.5301E-08
c  gap outside wrapper
c 993      0  1 -2 3 -4 (-66:67:-68:69) u=9 imp:n=1
c
c  End of Outer Core Element G
c
c
c --- MZB Outer Core Element E=BG
c
c  Lower padding
1011    like 111 but u=10 imp:n=1 TMP=2.5301E-08
c
c  Lower Plenum
c
1012    0  8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=10 imp:n=1
c
c  Lower Axial Blanket comprising 4 cells
c
1021    0  9 -41 21 -22 23 -24 fill=46 (0 0 63.0048) u=10 imp:n=1
c
1022    0  41 -42 21 -22 23 -24 fill=46 (0 0 71.7414) u=10 imp:n=1
c
1023    0  42 -43 21 -22 23 -24 fill=46 (0 0 80.478) u=10 imp:n=1
c
1024    0  43 -10 21 -22 23 -24 fill=46 (0 0 89.2146) u=10 imp:n=1
c
c
c
c  The 12 core cells
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

1051    0  10 -44 21 -22 23 -24 fill=30 (0 0 97.9512) u=10 imp:n=1
c
1052    0  44 -45 21 -22 23 -24 fill=30 (0 0 105.447) u=10 imp:n=1
c
1053    0  45 -46 21 -22 23 -24 fill=30 (0 0 112.9428) u=10 imp:n=1
c
1054    0  46 -47 21 -22 23 -24 fill=30 (0 0 120.4386) u=10 imp:n=1
c
1055    0  47 -48 21 -22 23 -24 fill=30 (0 0 127.9344) u=10 imp:n=1
c
1056    0  48 -49 21 -22 23 -24 fill=30 (0 0 135.4302) u=10 imp:n=1
c
1057    0  49 -50 21 -22 23 -24 fill=30 (0 0 142.926) u=10 imp:n=1
c
1058    0  50 -51 21 -22 23 -24 fill=30 (0 0 150.4218) u=10 imp:n=1
c
1059    0  51 -52 21 -22 23 -24 fill=30 (0 0 157.9176) u=10 imp:n=1
c
1060    0  52 -53 21 -22 23 -24 fill=30 (0 0 165.4134) u=10 imp:n=1
c
1061    0  53 -54 21 -22 23 -24 fill=30 (0 0 172.9092) u=10 imp:n=1
c
1062    0  54 -11 21 -22 23 -24 fill=30 (0 0 180.405) u=10 imp:n=1
c
c  Upper Axial Blanket. 4 Cells
c
c
1081    0  11 -56 21 -22 23 -24 fill=46 (0 0 187.9008) u=10 imp:n=1
c
1082    0  56 -57 21 -22 23 -24 fill=46 (0 0 196.6374 ) u=10 imp:n=1
c
1083    0  57 -58 21 -22 23 -24 fill=46 (0 0 205.374) u=10 imp:n=1
c
1084    0  58 -12 21 -22 23 -24 fill=46 (0 0 214.1106) u=10 imp:n=1
c
c  Upper Plenum
c
1086    0  12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=10 imp:n=1
c
c  Upper padding
c
1088      16 3.279692E-02 13 -16 21 -22 23 -24 u=10 imp:n=1 TMP=2.5301E-08
c
c
c  Wrapper region
c
1091      17 3.595949E-02 1 -2 3 -4 (-21:22:-23:24) u=10 imp:n=1
c
c 1091      0 62 -63 64 -65 (-21:22:-23:24) u=10 imp:n=1
c wrapper
c 1092      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=10 imp:n=1 &
c      TMP=2.5301E-08
c gap outside wrapper
c 1093      0 1 -2 3 -4 (-66:67:-68:69) u=10 imp:n=1
c
c  End of Outer Core Element E=BG
c
c
c --- MZB Outer Core Element F=DG
c
c  Lower padding
1111      like 111 but u=11 imp:n=1 TMP=2.5301E-08
c
c  Lower Plenum
c
1112      0 8 -9 21 -22 23 -24 fill=71 (0 0 30.0) u=11 imp:n=1
c
c  Lower Axial Blanket comprising 4 cells
c
1121      0 9 -41 21 -22 23 -24 fill=46 (0 0 63.0048) u=11 imp:n=1
c
1122      0 41 -42 21 -22 23 -24 fill=46 (0 0 71.7414) u=11 imp:n=1
c
1123      0 42 -43 21 -22 23 -24 fill=46 (0 0 80.478) u=11 imp:n=1
c
1124      0 43 -10 21 -22 23 -24 fill=46 (0 0 89.2146) u=11 imp:n=1

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c
c
c The 12 core cells
c
1151    0  10 -44 21 -22 23 -24 fill=31 (0 0 97.9512) u=11 imp:n=1
c
1152    0  44 -45 21 -22 23 -24 fill=31 (0 0 105.447) u=11 imp:n=1
c
1153    0  45 -46 21 -22 23 -24 fill=31 (0 0 112.9428) u=11 imp:n=1
c
1154    0  46 -47 21 -22 23 -24 fill=31 (0 0 120.4386) u=11 imp:n=1
c
1155    0  47 -48 21 -22 23 -24 fill=31 (0 0 127.9344) u=11 imp:n=1
c
1156    0  48 -49 21 -22 23 -24 fill=31 (0 0 135.4302) u=11 imp:n=1
c
1157    0  49 -50 21 -22 23 -24 fill=31 (0 0 142.926) u=11 imp:n=1
c
1158    0  50 -51 21 -22 23 -24 fill=31 (0 0 150.4218) u=11 imp:n=1
c
1159    0  51 -52 21 -22 23 -24 fill=31 (0 0 157.9176) u=11 imp:n=1
c
1160    0  52 -53 21 -22 23 -24 fill=31 (0 0 165.4134) u=11 imp:n=1
c
1161    0  53 -54 21 -22 23 -24 fill=31 (0 0 172.9092) u=11 imp:n=1
c
1162    0  54 -11 21 -22 23 -24 fill=31 (0 0 180.405) u=11 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
c
1181    0  11 -56 21 -22 23 -24 fill=46 (0 0 187.9008) u=11 imp:n=1
c
1182    0  56 -57 21 -22 23 -24 fill=46 (0 0 196.6374 ) u=11 imp:n=1
c
1183    0  57 -58 21 -22 23 -24 fill=46 (0 0 205.374) u=11 imp:n=1
c
1184    0  58 -12 21 -22 23 -24 fill=46 (0 0 214.1106) u=11 imp:n=1
c
c Upper Plenum
c
1186    0  12 -13 21 -22 23 -24 fill=72 (0 0 222.8472) u=11 imp:n=1
c
c Upper padding
c
1188    16 3.279692E-02 13 -16 21 -22 23 -24 u=11 imp:n=1 TMP=2.5301E-08
c
c
c Wrapper region
c
1191    17 3.595949E-02 1 -2 3 -4 (-21:22:-23:24) u=11 imp:n=1
c
c 1191    0 62 -63 64 -65 (-21:22:-23:24) u=11 imp:n=1
c wrapper
c 1192    17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=11 imp:n=1 &
c TMP=2.5301E-08
c gap outside wrapper
c 1193    0 1 -2 3 -4 (-66:67:-68:69) u=11 imp:n=1
c
c End of Outer Core Element F=DG
c
c
c --- Radial Blanket Elements
c
c Element B11-1
c
c Lower padding
1211    like 111 but u=16 imp:n=1 TMP=2.5301E-08
c Lower Plenum
1212    like 112 but u=16 imp:n=1 TMP=2.5301E-08
c Radial blanket
c Lower Radial Blanket Section comprising 3 cells
c
1221    0 9 -803 21 -22 23 -24 fill=55 (0 0 63.0048) u=16 imp:n=1
c

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

1222      0  803 -804 21 -22 23 -24 fill=55 (0 0 73.155) u=16 imp:n=1
c
1223      0  804 -805 21 -22 23 -24 fill=55 (0 0 83.3052) u=16 imp:n=1
c
c
c The 20 Radial blanket Central Section Cells
c
1231      0  805 -806 21 -22 23 -24 fill=51 (0 0 93.4554) u=16 imp:n=1
c
1232      0  806 -807 21 -22 23 -24 fill=51 (0 0 98.485) u=16 imp:n=1
c
1233      0  807 -808 21 -22 23 -24 fill=51 (0 0 103.5146) u=16 imp:n=1
c
1234      0  808 -809 21 -22 23 -24 fill=51 (0 0 108.5442) u=16 imp:n=1
c
1235      0  809 -810 21 -22 23 -24 fill=51 (0 0 113.5738) u=16 imp:n=1
c
1236      0  810 -811 21 -22 23 -24 fill=51 (0 0 118.6034) u=16 imp:n=1
c
1237      0  811 -812 21 -22 23 -24 fill=51 (0 0 123.633) u=16 imp:n=1
c
1238      0  812 -813 21 -22 23 -24 fill=51 (0 0 128.6626) u=16 imp:n=1
c
1239      0  813 -814 21 -22 23 -24 fill=51 (0 0 133.6922) u=16 imp:n=1
c
1240      0  814 -815 21 -22 23 -24 fill=51 (0 0 138.7218) u=16 imp:n=1
c
1241      0  815 -816 21 -22 23 -24 fill=51 (0 0 143.7514) u=16 imp:n=1
c
1242      0  816 -817 21 -22 23 -24 fill=51 (0 0 148.781) u=16 imp:n=1
c
1243      0  817 -818 21 -22 23 -24 fill=51 (0 0 153.8106) u=16 imp:n=1
c
1244      0  818 -819 21 -22 23 -24 fill=51 (0 0 158.8402) u=16 imp:n=1
c
1245      0  819 -820 21 -22 23 -24 fill=51 (0 0 163.8698) u=16 imp:n=1
c
1246      0  820 -821 21 -22 23 -24 fill=51 (0 0 168.8994) u=16 imp:n=1
c
1247      0  821 -822 21 -22 23 -24 fill=51 (0 0 173.929) u=16 imp:n=1
c
1248      0  822 -823 21 -22 23 -24 fill=51 (0 0 178.9586) u=16 imp:n=1
c
1249      0  823 -824 21 -22 23 -24 fill=51 (0 0 183.9882) u=16 imp:n=1
c
1250      0  824 -825 21 -22 23 -24 fill=51 (0 0 189.0178) u=16 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
1261      0  825 -826 21 -22 23 -24 fill=55 (0 0 194.0474) u=16 imp:n=1
c
1262      0  826 -827 21 -22 23 -24 fill=55 (0 0 204.1976) u=16 imp:n=1
c
1263      0  827 -828 21 -22 23 -24 fill=55 (0 0 214.3478) u=16 imp:n=1
c
c Upper Plenum
1271      0  828 -829 21 -22 23 -24 fill=72 (0 0 224.498) u=16 imp:n=1
c
c Upper padding
1272      16 3.279692E-02 829 -16 21 -22 23 -24 u=16 imp:n=1 TMP=2.5301E-08
c
c Wrapper region
c
1280      17 3.595949E-02 1 -2 3 -4 (-21:22:-23:24) u=16 imp:n=1
c
c 1280      0 62 -63 64 -65 (-21:22:-23:24) u=16 imp:n=1
c wrapper
c 1281      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=16 imp:n=1 &
c TMP=2.5301E-08
c gap outside wrapper
c 1282      0 1 -2 3 -4 (-66:67:-68:69) u=16 imp:n=1
c
c End of Radial Blanket Element B11-1
c
c
c Element B11-1B

```


ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c
c Lower padding
1311    like 111 but u=17 imp:n=1 TMP=2.5301E-08
c Lower Plenum
1312    like 112 but u=17 imp:n=1 TMP=2.5301E-08
c Radial blanket
c Lower Radial Blanket Section comprising 3 cells
c
1321    0  9 -803 21 -22 23 -24 fill=55 (0 0 63.0048) u=17 imp:n=1
c
1322    0  803 -804 21 -22 23 -24 fill=55 (0 0 73.155) u=17 imp:n=1
c
1323    0  804 -805 21 -22 23 -24 fill=55 (0 0 83.3052) u=17 imp:n=1
c
c
c The 20 Radial blanket Central Section Cells
c
1331    0  805 -806 21 -22 23 -24 fill=52 (0 0 93.4554) u=17 imp:n=1
c
1332    0  806 -807 21 -22 23 -24 fill=52 (0 0 98.485) u=17 imp:n=1
c
1333    0  807 -808 21 -22 23 -24 fill=52 (0 0 103.5146) u=17 imp:n=1
c
1334    0  808 -809 21 -22 23 -24 fill=52 (0 0 108.5442) u=17 imp:n=1
c
1335    0  809 -810 21 -22 23 -24 fill=52 (0 0 113.5738) u=17 imp:n=1
c
1336    0  810 -811 21 -22 23 -24 fill=52 (0 0 118.6034) u=17 imp:n=1
c
1337    0  811 -812 21 -22 23 -24 fill=52 (0 0 123.633) u=17 imp:n=1
c
1338    0  812 -813 21 -22 23 -24 fill=52 (0 0 128.6626) u=17 imp:n=1
c
1339    0  813 -814 21 -22 23 -24 fill=52 (0 0 133.6922) u=17 imp:n=1
c
1340    0  814 -815 21 -22 23 -24 fill=52 (0 0 138.7218) u=17 imp:n=1
c
1341    0  815 -816 21 -22 23 -24 fill=52 (0 0 143.7514) u=17 imp:n=1
c
1342    0  816 -817 21 -22 23 -24 fill=52 (0 0 148.781) u=17 imp:n=1
c
1343    0  817 -818 21 -22 23 -24 fill=52 (0 0 153.8106) u=17 imp:n=1
c
1344    0  818 -819 21 -22 23 -24 fill=52 (0 0 158.8402) u=17 imp:n=1
c
1345    0  819 -820 21 -22 23 -24 fill=52 (0 0 163.8698) u=17 imp:n=1
c
1346    0  820 -821 21 -22 23 -24 fill=52 (0 0 168.8994) u=17 imp:n=1
c
1347    0  821 -822 21 -22 23 -24 fill=52 (0 0 173.929) u=17 imp:n=1
c
1348    0  822 -823 21 -22 23 -24 fill=52 (0 0 178.9586) u=17 imp:n=1
c
1349    0  823 -824 21 -22 23 -24 fill=52 (0 0 183.9882) u=17 imp:n=1
c
1350    0  824 -825 21 -22 23 -24 fill=52 (0 0 189.0178) u=17 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
1361    0  825 -826 21 -22 23 -24 fill=55 (0 0 194.0474) u=17 imp:n=1
c
1362    0  826 -827 21 -22 23 -24 fill=55 (0 0 204.1976) u=17 imp:n=1
c
1363    0  827 -828 21 -22 23 -24 fill=55 (0 0 214.3478) u=17 imp:n=1
c
c Upper Plenum
1371    0  828 -829 21 -22 23 -24 fill=72 (0 0 224.498) u=17 imp:n=1
c
c Upper padding
1372    16 3.279692E-02 829 -16 21 -22 23 -24 u=17 imp:n=1 TMP=2.5301E-08
c
c Wrapper region
c
1380    17 3.595949E-02 1 -2 3 -4 (-21:22:-23:24) u=17 imp:n=1
c
c 1380    0 62 -63 64 -65 (-21:22:-23:24) u=17 imp:n=1

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c wrapper
c 1381      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=17 imp:n=1 &
c          TMP=2.5301E-08
c gap outside wrapper
c 1382      0 1 -2 3 -4 (-66:67:-68:69) u=17 imp:n=1
c
c End of Radial Blanket Element B11-1B
c
c
c radial Blanket Element B11-1G
c
c Lower padding
1411      like 111 but u=18 imp:n=1 TMP=2.5301E-08
c Lower Plenum
1412      like 112 but u=18 imp:n=1 TMP=2.5301E-08
c Radial blanket
c Lower Radial Blanket Section comprising 3 cells
c
1421      0 9 -803 21 -22 23 -24 fill=55 (0 0 63.0048) u=18 imp:n=1
c
1422      0 803 -804 21 -22 23 -24 fill=55 (0 0 73.155) u=18 imp:n=1
c
1423      0 804 -805 21 -22 23 -24 fill=55 (0 0 83.3052) u=18 imp:n=1
c
c
c The 20 Radial blanket Central Section Cells
c
1431      0 805 -806 21 -22 23 -24 fill=53 (0 0 93.4554) u=18 imp:n=1
c
1432      0 806 -807 21 -22 23 -24 fill=53 (0 0 98.485) u=18 imp:n=1
c
1433      0 807 -808 21 -22 23 -24 fill=53 (0 0 103.5146) u=18 imp:n=1
c
1434      0 808 -809 21 -22 23 -24 fill=53 (0 0 108.5442) u=18 imp:n=1
c
1435      0 809 -810 21 -22 23 -24 fill=53 (0 0 113.5738) u=18 imp:n=1
c
1436      0 810 -811 21 -22 23 -24 fill=53 (0 0 118.6034) u=18 imp:n=1
c
1437      0 811 -812 21 -22 23 -24 fill=53 (0 0 123.633) u=18 imp:n=1
c
1438      0 812 -813 21 -22 23 -24 fill=53 (0 0 128.6626) u=18 imp:n=1
c
1439      0 813 -814 21 -22 23 -24 fill=53 (0 0 133.6922) u=18 imp:n=1
c
1440      0 814 -815 21 -22 23 -24 fill=53 (0 0 138.7218) u=18 imp:n=1
c
1441      0 815 -816 21 -22 23 -24 fill=53 (0 0 143.7514) u=18 imp:n=1
c
1442      0 816 -817 21 -22 23 -24 fill=53 (0 0 148.781) u=18 imp:n=1
c
1443      0 817 -818 21 -22 23 -24 fill=53 (0 0 153.8106) u=18 imp:n=1
c
1444      0 818 -819 21 -22 23 -24 fill=53 (0 0 158.8402) u=18 imp:n=1
c
1445      0 819 -820 21 -22 23 -24 fill=53 (0 0 163.8698) u=18 imp:n=1
c
1446      0 820 -821 21 -22 23 -24 fill=53 (0 0 168.8994) u=18 imp:n=1
c
1447      0 821 -822 21 -22 23 -24 fill=53 (0 0 173.929) u=18 imp:n=1
c
1448      0 822 -823 21 -22 23 -24 fill=53 (0 0 178.9586) u=18 imp:n=1
c
1449      0 823 -824 21 -22 23 -24 fill=53 (0 0 183.9882) u=18 imp:n=1
c
1450      0 824 -825 21 -22 23 -24 fill=53 (0 0 189.0178) u=18 imp:n=1
c
c Upper Axial Blanket. 4 Cells
c
1461      0 825 -826 21 -22 23 -24 fill=55 (0 0 194.0474) u=18 imp:n=1
c
1462      0 826 -827 21 -22 23 -24 fill=55 (0 0 204.1976) u=18 imp:n=1
c
1463      0 827 -828 21 -22 23 -24 fill=55 (0 0 214.3478) u=18 imp:n=1
c
c Upper Plenum

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

1471      0  828 -829 21 -22 23 -24 fill=72 (0 0 224.498) u=18 imp:n=1
c
c Upper padding
1472      16 3.279692E-02 829 -16 21 -22 23 -24 u=18 imp:n=1 TMP=2.5301E-08
c
c Wrapper region
c
1480      17 3.595949E-02  1 -2 3 -4 (-21:22:-23:24) u=18 imp:n=1
c
c 1480      0 62 -63 64 -65 (-21:22:-23:24) u=18 imp:n=1
c wrapper
c 1481      17 8.56823E-02 66 -67 68 -69 (-62:63:-64:65) u=18 imp:n=1 &
c          TMP=2.5301E-08
c gap outside wrapper
c 1482      0  1 -2 3 -4 (-66:67:-68:69) u=18 imp:n=1
c
c End of Radial Blanket Element  B11-1G
c
c --- Radial shield
c
1526      12 8.32720E-02 28 -29 30 -31 u=19 imp:n=1 TMP=2.5301E-08
c
1527      13 8.32720E-05 1 -2 3 -4 (-28:29:-30:31) u=19 imp:n=1
TMP=2.5301E-08
c
1600      13 8.32720E-05 1 -2 3 -4 u=20 imp:n=1 TMP=2.5301E-08
c
c
1619      0  1 -2 3 -4 u=100 lat=1
          fill=-24:24 -24:24 0:0
          20 48r
          20 19r 19 8r 20 19r
          20 15r 19 16r 20 15r
          20 13r 19 20r 20 13r
          20 11r 19 8r 16 6r 19 8r 20 11r
          20 9r 19 6r 16 14r 19 6r 20 9r
          20 8r 19 5r 16 18r 19 5r 20 8r
          20 7r 19 4r 16 22r 19 4r 20 7r
          20 6r 19 4r 16 24r 19 4r 20 6r
          20 6r 19 3r 16 26r 19 3r 20 6r
          20 5r 19 3r 16 9r 9 11 8 4r 11 9 16 9r 19 3r 20 5r
          20 4r 19 3r 16 8r 8 2r 7 6r 8 8 11 9 16 7r 19 3r 20 4r
          20 3r 19 3r 16 7r 9 8 7 7 6 2r 5 2r 6 2r 7 7 8 11 16 7r 19 3r 20 3r
          20 3r 19 2r 16 7r 8 7 7 6 5 5 4 6r 5 5 6 7 8 8 16 7r 19 2r 20 3r
          20 2r 19 3r 16 6r 8 7 10 6 5 4 10r 5 6 6 7 8 16 6r 19 3r 20 2r
          20 2r 19 2r 16 6r 8 7 6 5 5 4 3r 3 4r 4 3r 5 5 6 7 8 16 6r 19 2r 20 2r
          20 1r 19 3r 16 5r 11 8 7 5 4 3r 3 2 6r 3 3 4 2r 5 6 8 9 16 5r 19 3r 20 1r
          20 1r 19 2r 16 5r 9 8 7 6 5 4 4 3 2 10r 3 4 4 5 6 7 8 16 6r 19 2r 20 1r
          20 1r 19 2r 16 5r 11 7 6 5 4 4 3 2 2r 1 6r 2 2r 3 4 4 5 6 7 8
          16 5r 19 2r 20 1r
          20 1r 19 2r 16 5r 8 7 5 4 4 2 3r 1 8r 2 3r 4 4 5 7 8 16 5r 19 2r 20 1r
          20 1r 19 2r 16 4r 9 8 6 5 4 4 2 2r 1 10r 2 2r 4 4 5 6 8 9
          16 4r 19 2r 20 1r
          20 19 2r 16 5r 11 7 6 4 4 3 2 2 1 12r 2 2 3 4 4 6 8 11 16 5r 19 2r 20
          20 19 2r 16 5r 8 7 6 4 4 3 2 2 1 12r 2 2 3 4 4 6 7 8 16 5r 19 2r 20
          20 19 2r 16 5r 8 7 5 4 4 3 2 2 1 12r 2 2 3 4 4 5 7 8 16 5r 19 2r 20
          20 19 2r 16 5r 8 7 5 4 4 3 2 2 1 12r 2 2 3 4 4 5 7 8 16 5r 19 2r 20
          20 19 2r 16 5r 8 7 5 4 4 3 2 2 1 12r 2 2 3 4 4 5 7 8 16 5r 19 2r 20
          20 19 2r 16 5r 11 7 6 4 4 3 2 2 1 12r 2 2 3 4 4 6 7 11 16 5r 19 2r 20
          20 1r 19 2r 16 4r 9 8 6 5 4 4 2 2r 1 10r 2 2r 4 4 5 6 7 9
          16 4r 19 2r 20 1r
          20 1r 19 2r 16 5r 8 7 5 4 4 2 3r 1 8r 2 3r 4 4 5 7 8 16 5r 19 2r 20 1r
          20 1r 19 2r 16 5r 8 7 6 5 4 4 3 2 2r 1 6r 2 2r 3 4 4 5 6 7 11
          16 5r 19 2r 20 1r
          20 1r 19 2r 16 6r 8 7 6 5 4 4 3 2 10r 3 4 4 5 6 7 8 9 16 5r 19 2r 20 1r
          20 1r 19 3r 16 5r 9 7 6 5 4 3r 3 2 6r 3 3 4 2r 5 7 8 11 16 5r 19 3r 20 1r
          20 2r 19 2r 16 6r 8 7 6 5 4 3r 3 4r 4 3r 5 5 6 7 8 16 6r 19 2r 20 2r
          20 2r 19 3r 16 6r 8 7 6 6 5 4 10r 5 6 10 7 8 16 6r 19 3r 20 2r
          20 3r 19 2r 16 7r 8 8 7 6 5 5 4 6r 5 5 6 7 7 8 16 7r 19 2r 20 3r
          20 3r 19 3r 16 7r 11 8 7 7 6 2r 5 2r 6 2r 7 7 8 9 16 7r 19 3r 20 3r
          20 4r 19 3r 16 8r 9 11 8 8 7 6r 8 2r 16 7r 19 3r 20 4r
          20 5r 19 3r 16 9r 9 11 8 4r 11 9 16 9r 19 3r 20 5r
          20 6r 19 3r 16 26r 19 3r 20 6r
          20 6r 19 4r 16 24r 19 4r 20 6r
          20 7r 19 4r 16 22r 19 4r 20 7r

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

20 8r 19 5r 16 18r 19 5r 20 8r
20 9r 19 6r 16 14r 19 6r 20 9r
20 11r 19 8r 16 6r 19 8r 20 11r
20 13r 19 20r 20 13r
20 15r 19 16r 20 15r
20 19r 19 8r 20 19r
20 48r
imp:n=1
c
c --- Fuel Region
c
1629      0 7 -16 -17 fill=100 imp:n=1
c --- Universe
1630      0 (-7:16:17) imp:n=0
c
c ----- CELL CARDS -----
c
c MZB Inner Core Cell A
c
c Sodium Plate NASTDL4
c Na plate core
2001      25 2.3191E-02 302 -303 109 -110 111 -112 u=21  imp:n=1 TMP=2.5301E-08
c Na plate can
2002      26 7.872422E-02 301 -304 21 -22 23 -24 &
          (-109:110:-111:112:-302:303) u=21  imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2003      23 6.951414E-02 305 -306 105 -106 107 -108 u=21  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2004      24 7.067127E-02 304 -307 21 -22 23 -24 &
          (-105:106:-107:108:-305:306) u=21  imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2005      25 2.3191E-02 308 -309 109 -110 111 -112 u=21  imp:n=1 TMP=2.5301E-08
c Na plate can
2006      26 7.872422E-02 307 -310 21 -22 23 -24 &
          (-109:110:-111:112:-308:309) u=21  imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUIX8
c Plate core
2007      21 4.0082E-02 311 -312 101 -102 103 -104 u=21  imp:n=1 TMP=2.5301E-08
c Pu canning
2008      22 6.7015E-02 310 -313 21 -22 23 -24 &
          (-101:102:-103:104:-311:312) u=21  imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDL4
c Na plate core
2009      25 2.3191E-02 314 -315 109 -110 111 -112 u=21  imp:n=1 TMP=2.5301E-08
c Na plate can
2010      26 7.872422E-02 313 -316 21 -22 23 -24 &
          (-109:110:-111:112:-314:315) u=21  imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2011      23 6.951414E-02 317 -318 105 -106 107 -108 u=21  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2012      24 7.067127E-02 316 -319 21 -22 23 -24 &
          (-105:106:-107:108:-317:318) u=21  imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2013      25 2.3191E-02 320 -321 109 -110 111 -112 u=21  imp:n=1 TMP=2.5301E-08
c Na plate can
2014      26 7.872422E-02 319 -322 21 -22 23 -24 &
          (-109:110:-111:112:-320:321) u=21  imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2015      7 8.607216E-02 322 -323 21 -22 23 -24 u=21  imp:n=1 TMP=2.5301E-08
c
c
c UO2 plate

```

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LIQUID METAL FAST REACTOR - LMFR
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```

c UO2 core
2016 23 6.951414E-02 324 -325 105 -106 107 -108 u=21 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2017 24 7.067127E-02 323 -326 21 -22 23 -24 &
      (-105:106:-107:108:-324:325) u=21 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2018 25 2.3191E-02 327 -328 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2019 26 7.872422E-02 326 -329 21 -22 23 -24 &
      (-109:110:-111:112:-327:328) u=21 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUIV4
c Plate core
2020 31 6.44446E-02 330 -331 113 -114 115 -116 u=21 imp:n=1 TMP=2.5301E-08
c Pu canning
2021 32 7.3500E-02 329 -332 21 -22 23 -24 &
      (-113:114:-115:116:-330:331) u=21 imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDL4
c Na plate core
2022 25 2.3191E-02 333 -334 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2023 26 7.872422E-02 332 -335 21 -22 23 -24 &
      (-109:110:-111:112:-333:334) u=21 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2024 23 6.951414E-02 336 -337 105 -106 107 -108 u=21 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2025 24 7.067127E-02 335 -338 21 -22 23 -24 &
      (-105:106:-107:108:-336:337) u=21 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2026 25 2.3191E-02 339 -340 109 -110 111 -112 u=21 imp:n=1 TMP=2.5301E-08
c Na plate can
2027 26 7.872422E-02 338 -341 21 -22 23 -24 &
      (-109:110:-111:112:-339:340) u=21 imp:n=1 TMP=2.5301E-08
c
c End of Inner Core Cell A
c
c
c MZB Inner Core Axial Blanket Cell B12-30
c
c
c Na plate
c Na plate core
2031 25 2.3191E-02 402 -403 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
c Na plate can
2032 26 7.872422E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=41 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2033 8 4.7208E-02 404 -405 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2034 10 8.1484E-02 405 -406 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2035 25 2.3191E-02 407 -408 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
c Na plate can
2036 26 7.872422E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=41 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2037 7 8.607216E-02 409 -410 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2038 8 4.7208E-02 410 -411 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate

```

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

c Na plate core
2039 25 2.3191E-02 412 -413 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2040 26 7.872422E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=41 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2041 10 8.1484E-02 414 -415 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2042 25 2.3191E-02 416 -417 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2043 26 7.872422E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=41 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2044 7 8.607216E-02 418 -419 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2045 8 4.7208E-02 419 -420 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2046 25 2.3191E-02 421 -422 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2047 26 7.872422E-02 420 -423 21 -22 23 -24 &
      (-109:110:-111:112:-421:422) u=41 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2048 10 8.1484E-02 423 -424 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2049 25 2.3191E-02 425 -426 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2050 26 7.872422E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=41 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2051 8 4.7208E-02 427 -428 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2052 7 8.607216E-02 428 -429 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2053 25 2.3191E-02 430 -431 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2054 26 7.872422E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=41 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2055 8 4.7208E-02 432 -433 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8
2056 10 8.1484E-02 433 -434 21 -22 23 -24 u=41 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2057 25 2.3191E-02 435 -436 109 -110 111 -112 u=41 imp:n=1 TMP=2.5301E-08
C Na plate can
2058 26 7.872422E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=41 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B12-30
c
c
c MZB Inner Core Cell B
c
c Sodium Plate NASTDL4

```

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LIQUID METAL FAST REACTOR - LMFR
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```
c Na plate core
2101 25 2.3191E-02 302 -303 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2102 26 7.872422E-02 301 -304 21 -22 23 -24 &
      (-109:110:-111:112:-302:303) u=22 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2103 23 6.951414E-02 305 -306 105 -106 107 -108 u=22 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2104 24 7.067127E-02 304 -307 21 -22 23 -24 &
      (-105:106:-107:108:-305:306) u=22 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2105 25 2.3191E-02 308 -309 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2106 26 7.872422E-02 307 -310 21 -22 23 -24 &
      (-109:110:-111:112:-308:309) u=22 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUX8
C Plate core
2107 39 4.01805E-02 311 -312 101 -102 103 -104 u=22 imp:n=1 TMP=2.5301E-08
C Pu canning
2108 40 6.70733E-02 310 -313 21 -22 23 -24 &
      (-101:102:-103:104:-311:312) u=22 imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDL4
c Na plate core
2109 25 2.3191E-02 314 -315 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2110 26 7.872422E-02 313 -316 21 -22 23 -24 &
      (-109:110:-111:112:-314:315) u=22 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2111 23 6.951414E-02 317 -318 105 -106 107 -108 u=22 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2112 24 7.067127E-02 316 -319 21 -22 23 -24 &
      (-105:106:-107:108:-317:318) u=22 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2113 25 2.3191E-02 320 -321 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2114 26 7.872422E-02 319 -322 21 -22 23 -24 &
      (-109:110:-111:112:-320:321) u=22 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2115 7 8.607216E-02 322 -323 21 -22 23 -24 u=22 imp:n=1 TMP=2.5301E-08
c
c
c UO2 plate
c UO2 core
2116 23 6.951414E-02 324 -325 105 -106 107 -108 u=22 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2117 24 7.067127E-02 323 -326 21 -22 23 -24 &
      (-105:106:-107:108:-324:325) u=22 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2118 25 2.3191E-02 327 -328 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2119 26 7.872422E-02 326 -329 21 -22 23 -24 &
      (-109:110:-111:112:-327:328) u=22 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUIV4
C Plate core
2120 31 6.4446E-02 330 -331 113 -114 115 -116 u=22 imp:n=1 TMP=2.5301E-08
C Pu canning
2121 32 7.3500E-02 329 -332 21 -22 23 -24 &
      (-113:114:-115:116:-330:331) u=22 imp:n=1 TMP=2.5301E-08
```

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LIQUID METAL FAST REACTOR - LMFR
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```

c
c
c Sodium Plate NASTDL4
c Na plate core
2122 25 2.3191E-02 333 -334 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2123 26 7.872422E-02 332 -335 21 -22 23 -24 &
      (-109:110:-111:112:-333:334) u=22 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2124 23 6.951414E-02 336 -337 105 -106 107 -108 u=22 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2125 24 7.067127E-02 335 -338 21 -22 23 -24 &
      (-105:106:-107:108:-336:337) u=22 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDL4
c Na plate core
2126 25 2.3191E-02 339 -340 109 -110 111 -112 u=22 imp:n=1 TMP=2.5301E-08
C Na plate can
2127 26 7.872422E-02 338 -341 21 -22 23 -24 &
      (-109:110:-111:112:-339:340) u=22 imp:n=1 TMP=2.5301E-08
c
c End of Inner Core Cell B
c
c
c MZB Inner Core Cell BG
c
c Sodium Plate NASTDM4
c Na plate core
2201 25 2.3191E-02 302 -303 109 -110 111 -112 u=23 imp:n=1 TMP=2.5301E-08
C Na plate can
2202 20 7.87808E-02 301 -304 21 -22 23 -24 &
      (-109:110:-111:112:-302:303) u=23 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2203 23 6.951414E-02 305 -306 105 -106 107 -108 u=23 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2204 24 7.067127E-02 304 -307 21 -22 23 -24 &
      (-105:106:-107:108:-305:306) u=23 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2205 25 2.3191E-02 308 -309 109 -110 111 -112 u=23 imp:n=1 TMP=2.5301E-08
C Na plate can
2206 20 7.87808E-02 307 -310 21 -22 23 -24 &
      (-109:110:-111:112:-308:309) u=23 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUX8
C Plate core
2207 39 4.01805E-02 311 -312 101 -102 103 -104 u=23 imp:n=1 TMP=2.5301E-08
C Pu canning
2208 40 6.70733E-02 310 -313 21 -22 23 -24 &
      (-101:102:-103:104:-311:312) u=23 imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDM4
c Na plate core
2209 25 2.3191E-02 314 -315 109 -110 111 -112 u=23 imp:n=1 TMP=2.5301E-08
C Na plate can
2210 20 7.87808E-02 313 -316 21 -22 23 -24 &
      (-109:110:-111:112:-314:315) u=23 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2211 23 6.951414E-02 317 -318 105 -106 107 -108 u=23 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2212 24 7.067127E-02 316 -319 21 -22 23 -24 &
      (-105:106:-107:108:-317:318) u=23 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2213 25 2.3191E-02 320 -321 109 -110 111 -112 u=23 imp:n=1 TMP=2.5301E-08
C Na plate can

```


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LIQUID METAL FAST REACTOR - LMFR
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```

2214  20 7.87808E-02 319 -322 21 -22 23 -24 &
      (-109:110:-111:112:-320:321) u=23  imp:n=1  TMP=2.5301E-08
c
c
c Steel plate
2215  7 8.607216E-02 322 -323 21 -22 23 -24 u=23  imp:n=1  TMP=2.5301E-08
c
c
c UO2 plate
c UO2 core
2216  23 6.951414E-02 324 -325 105 -106 107 -108 u=23  imp:n=1  TMP=2.5301E-08
c UO2 plate can
2217  24 7.067127E-02 323 -326 21 -22 23 -24 &
      (-105:106:-107:108:-324:325) u=23  imp:n=1  TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2218  25 2.3191E-02 327 -328 109 -110 111 -112 u=23  imp:n=1  TMP=2.5301E-08
c Na plate can
2219  20 7.87808E-02 326 -329 21 -22 23 -24 &
      (-109:110:-111:112:-327:328) u=23  imp:n=1  TMP=2.5301E-08
c
c
c Pu plate PUIV4
c Plate core
2220  31 6.44446E-02 330 -331 113 -114 115 -116 u=23  imp:n=1  TMP=2.5301E-08
c Pu canning
2221  32 7.3500E-02 329 -332 21 -22 23 -24 &
      (-113:114:-115:116:-330:331) u=23  imp:n=1  TMP=2.5301E-08
c
c
c Sodium Plate NASTDM4
c Na plate core
2222  25 2.3191E-02 333 -334 109 -110 111 -112 u=23  imp:n=1  TMP=2.5301E-08
c Na plate can
2223  20 7.87808E-02 332 -335 21 -22 23 -24 &
      (-109:110:-111:112:-333:334) u=23  imp:n=1  TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2224  23 6.951414E-02 336 -337 105 -106 107 -108 u=23  imp:n=1  TMP=2.5301E-08
c UO2 plate can
2225  24 7.067127E-02 335 -338 21 -22 23 -24 &
      (-105:106:-107:108:-336:337) u=23  imp:n=1  TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2226  25 2.3191E-02 339 -340 109 -110 111 -112 u=23  imp:n=1  TMP=2.5301E-08
c Na plate can
2227  20 7.87808E-02 338 -341 21 -22 23 -24 &
      (-109:110:-111:112:-339:340) u=23  imp:n=1  TMP=2.5301E-08
c
c End of Inner Core Cell BG
c
c
c
c MZB Inner Core Axial Blanket Cell B12-30G
c
c
c Na plate DM
c Na plate core
2231  25 2.3191E-02 402 -403 109 -110 111 -112 u=42  imp:n=1  TMP=2.5301E-08
c Na plate can
2232  20 7.87808E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=42  imp:n=1  TMP=2.5301E-08
c
c U8 plate
2233  8 4.7208E-02 404 -405 21 -22 23 -24 u=42  imp:n=1  TMP=2.5301E-08
c
c Graphite plate GI8
2234  10 8.1484E-02 405 -406 21 -22 23 -24 u=42  imp:n=1  TMP=2.5301E-08
c
c Na plate DM
c Na plate core
2235  25 2.3191E-02 407 -408 109 -110 111 -112 u=42  imp:n=1  TMP=2.5301E-08
c Na plate can

```

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LIQUID METAL FAST REACTOR - LMFR
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2236 20 7.87808E-02 406 -409 21 -22 23 -24 &
(-109:110:-111:112:-407:408) u=42 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2237 7 8.607216E-02 409 -410 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2238 8 4.7208E-02 410 -411 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate DM
c Na plate core
2239 25 2.3191E-02 412 -413 109 -110 111 -112 u=42 imp:n=1 TMP=2.5301E-08
C Na plate can
2240 20 7.87808E-02 411 -414 21 -22 23 -24 &
(-109:110:-111:112:-412:413) u=42 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2241 10 8.1484E-02 414 -415 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate DM
c Na plate core
2242 25 2.3191E-02 416 -417 109 -110 111 -112 u=42 imp:n=1 TMP=2.5301E-08
C Na plate can
2243 20 7.87808E-02 415 -418 21 -22 23 -24 &
(-109:110:-111:112:-416:417) u=42 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2244 7 8.607216E-02 418 -419 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2245 8 4.7208E-02 419 -420 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate DM
c Na plate core
2246 25 2.3191E-02 421 -422 109 -110 111 -112 u=42 imp:n=1 TMP=2.5301E-08
C Na plate can
2247 20 7.87808E-02 420 -423 21 -22 23 -24 &
(-109:110:-111:112:-421:422) u=42 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2248 10 8.1484E-02 423 -424 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2249 25 2.3191E-02 425 -426 109 -110 111 -112 u=42 imp:n=1 TMP=2.5301E-08
C Na plate can
2250 20 7.87808E-02 424 -427 21 -22 23 -24 &
(-109:110:-111:112:-425:426) u=42 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2251 8 4.7208E-02 427 -428 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2252 7 8.607216E-02 428 -429 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate DM
c Na plate core
2253 25 2.3191E-02 430 -431 109 -110 111 -112 u=42 imp:n=1 TMP=2.5301E-08
C Na plate can
2254 20 7.87808E-02 429 -432 21 -22 23 -24 &
(-109:110:-111:112:-430:431) u=42 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2255 8 4.7208E-02 432 -433 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8
2256 10 8.1484E-02 433 -434 21 -22 23 -24 u=42 imp:n=1 TMP=2.5301E-08
c
c Na plate DM
c Na plate core
2257 25 2.3191E-02 435 -436 109 -110 111 -112 u=42 imp:n=1 TMP=2.5301E-08

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```

C Na plate can
2258 20 7.87808E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=42 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B12-30G
c
c
c MZB Inner Core Cell D
c
c Sodium Plate NASTDM4
c Na plate core
2301 25 2.3191E-02 302 -303 109 -110 111 -112 u=24 imp:n=1 TMP=2.5301E-08
C Na plate can
2302 20 7.87808E-02 301 -304 21 -22 23 -24 &
      (-109:110:-111:112:-302:303) u=24 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2303 23 6.951414E-02 305 -306 105 -106 107 -108 u=24 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2304 24 7.067127E-02 304 -307 21 -22 23 -24 &
      (-105:106:-107:108:-305:306) u=24 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2305 25 2.3191E-02 308 -309 109 -110 111 -112 u=24 imp:n=1 TMP=2.5301E-08
C Na plate can
2306 20 7.87808E-02 307 -310 21 -22 23 -24 &
      (-109:110:-111:112:-308:309) u=24 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUXI8
C Plate core
2307 41 4.01596E-02 311 -312 101 -102 103 -104 u=24 imp:n=1 TMP=2.5301E-08
C Pu canning
2308 42 6.61403E-02 310 -313 21 -22 23 -24 &
      (-101:102:-103:104:-311:312) u=24 imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDM4
c Na plate core
2309 25 2.3191E-02 314 -315 109 -110 111 -112 u=24 imp:n=1 TMP=2.5301E-08
C Na plate can
2310 20 7.87808E-02 313 -316 21 -22 23 -24 &
      (-109:110:-111:112:-314:315) u=24 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2311 23 6.951414E-02 317 -318 105 -106 107 -108 u=24 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2312 24 7.067127E-02 316 -319 21 -22 23 -24 &
      (-105:106:-107:108:-317:318) u=24 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2313 25 2.3191E-02 320 -321 109 -110 111 -112 u=24 imp:n=1 TMP=2.5301E-08
C Na plate can
2314 20 7.87808E-02 319 -322 21 -22 23 -24 &
      (-109:110:-111:112:-320:321) u=24 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2315 7 8.607216E-02 322 -323 21 -22 23 -24 u=24 imp:n=1 TMP=2.5301E-08
c
c
c UO2 plate
c UO2 core
2316 23 6.951414E-02 324 -325 105 -106 107 -108 u=24 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2317 24 7.067127E-02 323 -326 21 -22 23 -24 &
      (-105:106:-107:108:-324:325) u=24 imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2318 25 2.3191E-02 327 -328 109 -110 111 -112 u=24 imp:n=1 TMP=2.5301E-08
C Na plate can

```

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```

2319  20 7.87808E-02 326 -329 21 -22 23 -24 &
      (-109:110:-111:112:-327:328) u=24  imp:n=1 TMP=2.5301E-08
c
c
c Pu plate PUIV4
C Plate core
2320  31 6.4446E-02 330 -331 113 -114 115 -116 u=24  imp:n=1 TMP=2.5301E-08
C Pu canning
2321  32 7.3500E-02 329 -332 21 -22 23 -24 &
      (-113:114:-115:116:-330:331) u=24  imp:n=1 TMP=2.5301E-08
c
c
c Sodium Plate NASTDM4
c Na plate core
2322  25 2.3191E-02 333 -334 109 -110 111 -112 u=24  imp:n=1 TMP=2.5301E-08
C Na plate can
2323  20 7.87808E-02 332 -335 21 -22 23 -24 &
      (-109:110:-111:112:-333:334) u=24  imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2324  23 6.951414E-02 336 -337 105 -106 107 -108 u=24  imp:n=1 TMP=2.5301E-08
c UO2 plate can
2325  24 7.067127E-02 335 -338 21 -22 23 -24 &
      (-105:106:-107:108:-336:337) u=24  imp:n=1 TMP=2.5301E-08
c
c Sodium Plate NASTDM4
c Na plate core
2326  25 2.3191E-02 339 -340 109 -110 111 -112 u=24  imp:n=1 TMP=2.5301E-08
C Na plate can
2327  20 7.87808E-02 338 -341 21 -22 23 -24 &
      (-109:110:-111:112:-339:340) u=24  imp:n=1 TMP=2.5301E-08
c
c End of Inner Core Cell D
c
c                               End of Inner Core Cells
c
c MZB Outer Core Cell A.
c
c Na plate
c Na plate core
2401  5 2.3126E-02 202 -203 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2402  6 7.865043E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=25 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2403  3 6.867137E-02 205 -206 105 -106 107 -108 u=25 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2404  4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=25 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2405  5 2.3126E-02 208 -209 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2406  6 7.865043E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=25 imp:n=1 TMP=2.5301E-08
c
c Pu plate
C Plate core
2407  1 4.023746E-02 101 -102 103 -104 211 -212 u=25 imp:n=1 TMP=2.5301E-08
C Pu canning
2408  2 6.6033E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=25 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2409  7 8.607216E-02 213 -214 21 -22 23 -24 u=25 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2410  3 6.867137E-02 215 -216 105 -106 107 -108 u=25 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2411  4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=25 imp:n=1 TMP=2.5301E-08

```

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```

c
c Na plate
c Na plate core
2412   5 2.3126E-02 218 -219 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2413   6 7.865043E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=25 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2414   5 2.3126E-02 221 -222 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2415   6 7.865043E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=25 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2416   3 6.867137E-02 224 -225 105 -106 107 -108 u=25 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2417   4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=25 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2418  10 8.1484E-02 226 -227 21 -22 23 -24 u=25 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate V
C Plate core
2419   1 4.023746E-02 228 -229 101 -102 103 -104 u=25 imp:n=1 TMP=2.5301E-08
C Pu canning
2420   2 6.6033E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=25 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2421   5 2.3126E-02 231 -232 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2422   6 7.865043E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=25 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2423   3 6.867137E-02 234 -235 105 -106 107 -108 u=25 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2424   4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=25 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2425   5 2.3126E-02 237 -238 109 -110 111 -112 u=25 imp:n=1 TMP=2.5301E-08
C Na plate can
2426   6 7.865043E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=25 imp:n=1 TMP=2.5301E-08
c
c End of MZB Outer Core Cell A
c
c
c MZB Outer Core Cell B.
c
c Na plate
c Na plate core
2451  25 2.3191E-02 202 -203 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2452  26 7.872422E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=26 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2453   3 6.867137E-02 205 -206 105 -106 107 -108 u=26 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2454   4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=26 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core

```

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2455 25 2.3191E-02 208 -209 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2456 26 7.872422E-02 207 -210 21 -22 23 -24 &
(-109:110:-111:112:-208:209) u=26 imp:n=1 TMP=2.5301E-08
c
c Pu plate VI
C Plate core
2457 33 4.04903E-02 101 -102 103 -104 211 -212 u=26 imp:n=1 TMP=2.5301E-08
C Pu canning
2458 34 6.74722E-02 210 -213 21 -22 23 -24 &
(-101:102:-103:104:-211:212) u=26 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2459 7 8.607216E-02 213 -214 21 -22 23 -24 u=26 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2460 3 6.867137E-02 215 -216 105 -106 107 -108 u=26 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2461 4 6.5639E-02 214 -217 21 -22 23 -24 &
(-105:106:-107:108:-215:216) u=26 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2462 25 2.3191E-02 218 -219 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2463 26 7.872422E-02 217 -220 21 -22 23 -24 &
(-109:110:-111:112:-218:219) u=26 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2464 25 2.3191E-02 221 -222 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2465 26 7.872422E-02 220 -223 21 -22 23 -24 &
(-109:110:-111:112:-221:222) u=26 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2466 3 6.867137E-02 224 -225 105 -106 107 -108 u=26 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2467 4 6.5639E-02 223 -226 21 -22 23 -24 &
(-105:106:-107:108:-224:225) u=26 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2468 10 8.1484E-02 226 -227 21 -22 23 -24 u=26 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate VI
C Plate core
2469 33 4.04903E-02 228 -229 101 -102 103 -104 u=26 imp:n=1 TMP=2.5301E-08
C Pu canning
2470 34 6.74722E-02 227 -230 21 -22 23 -24 &
(-101:102:-103:104:-228:229) u=26 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2471 25 2.3191E-02 231 -232 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2472 26 7.872422E-02 230 -233 21 -22 23 -24 &
(-109:110:-111:112:-231:232) u=26 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2473 3 6.867137E-02 234 -235 105 -106 107 -108 u=26 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2474 4 6.5639E-02 233 -236 21 -22 23 -24 &
(-105:106:-107:108:-234:235) u=26 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2475 25 2.3191E-02 237 -238 109 -110 111 -112 u=26 imp:n=1 TMP=2.5301E-08
C Na plate can
2476 26 7.872422E-02 236 -239 21 -22 23 -24 &
(-109:110:-111:112:-237:238) u=26 imp:n=1 TMP=2.5301E-08
c

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```
c End of MZB Outer Core Cell B
c
c
c MZB Outer Core Cell C.
c
c Na plate
c Na plate core
2501 25 2.3191E-02 202 -203 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
c Na plate can
2502 26 7.872422E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=27 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2503 3 6.867137E-02 205 -206 105 -106 107 -108 u=27 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2504 4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=27 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2505 25 2.3191E-02 208 -209 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
c Na plate can
2506 26 7.872422E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=27 imp:n=1 TMP=2.5301E-08
c
c Pu plate VII
c Plate core
2507 35 3.99151E-02 101 -102 103 -104 211 -212 u=27 imp:n=1 TMP=2.5301E-08
c Pu canning
2508 36 6.72170E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=27 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2509 7 8.607216E-02 213 -214 21 -22 23 -24 u=27 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2510 3 6.867137E-02 215 -216 105 -106 107 -108 u=27 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2511 4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=27 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2512 25 2.3191E-02 218 -219 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
c Na plate can
2513 26 7.872422E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=27 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2514 25 2.3191E-02 221 -222 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
c Na plate can
2515 26 7.872422E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=27 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2516 3 6.867137E-02 224 -225 105 -106 107 -108 u=27 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2517 4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=27 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2518 10 8.1484E-02 226 -227 21 -22 23 -24 u=27 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate
c Plate core
2519 35 3.99151E-02 228 -229 101 -102 103 -104 u=27 imp:n=1 TMP=2.5301E-08
c Pu canning
2520 36 6.72170E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=27 imp:n=1 TMP=2.5301E-08
c
```

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```

c Na plate
c Na plate core
2521 25 2.3191E-02 231 -232 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
C Na plate can
2522 26 7.872422E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=27 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2523 3 6.867137E-02 234 -235 105 -106 107 -108 u=27 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2524 4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=27 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2525 25 2.3191E-02 237 -238 109 -110 111 -112 u=27 imp:n=1 TMP=2.5301E-08
C Na plate can
2526 26 7.872422E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=27 imp:n=1 TMP=2.5301E-08
c
c End of MZB Outer Core Cell C
c
c
c MZB Outer Core Cell D.
c
c Na plate
c Na plate core
2551 25 2.3191E-02 202 -203 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08
C Na plate can
2552 26 7.872422E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=28 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2553 3 6.867137E-02 205 -206 105 -106 107 -108 u=28 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2554 4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=28 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2555 25 2.3191E-02 208 -209 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08
C Na plate can
2556 26 7.872422E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=28 imp:n=1 TMP=2.5301E-08
c
c Pu plate VIII
C Plate core
2557 37 4.01503E-02 101 -102 103 -104 211 -212 u=28 imp:n=1 TMP=2.5301E-08
C Pu canning
2558 38 6.71396E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=28 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2559 7 8.607216E-02 213 -214 21 -22 23 -24 u=28 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2560 3 6.867137E-02 215 -216 105 -106 107 -108 u=28 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2561 4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=28 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2562 25 2.3191E-02 218 -219 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08
C Na plate can
2563 26 7.872422E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=28 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2564 25 2.3191E-02 221 -222 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08
C Na plate can

```


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```

2565  26 7.872422E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=28 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2566  3 6.867137E-02 224 -225 105 -106 107 -108 u=28 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2567  4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=28 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2568  10 8.1484E-02 226 -227 21 -22 23 -24 u=28 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate VIII
C Plate core
2569  37 4.01503E-02 228 -229 101 -102 103 -104 u=28 imp:n=1 TMP=2.5301E-08
C Pu canning
2570  38 6.71396E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=28 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2571  25 2.3191E-02 231 -232 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08
C Na plate can
2572  26 7.872422E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=28 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2573  3 6.867137E-02 234 -235 105 -106 107 -108 u=28 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2574  4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=28 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2575  25 2.3191E-02 237 -238 109 -110 111 -112 u=28 imp:n=1 TMP=2.5301E-08
C Na plate can
2576  26 7.872422E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=28 imp:n=1 TMP=2.5301E-08
c
c End of MZA Core Cell D
c
c MZB Outer Core Cell G.
c
c Na plate
c Na plate core
2601  25 2.3191E-02 202 -203 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
C Na plate can
2602  20 7.87808E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=29 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2603  3 6.867137E-02 205 -206 105 -106 107 -108 u=29 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2604  4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=29 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2605  25 2.3191E-02 208 -209 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
C Na plate can
2606  20 7.87808E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=29 imp:n=1 TMP=2.5301E-08
c
c Pu plate XII
C Plate core
2607  43 4.02475E-02 101 -102 103 -104 211 -212 u=29 imp:n=1 TMP=2.5301E-08
C Pu canning
2608  44 6.55545E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=29 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2609  7 8.607216E-02 213 -214 21 -22 23 -24 u=29 imp:n=1 TMP=2.5301E-08

```

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```
c
c UO2 plate
c UO2 core
2610   3 6.867137E-02 215 -216 105 -106 107 -108 u=29 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2611   4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=29 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2612   25 2.3191E-02 218 -219 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
C Na plate can
2613   20 7.87808E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=29 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2614   25 2.3191E-02 221 -222 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
C Na plate can
2615   20 7.87808E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=29 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2616   3 6.867137E-02 224 -225 105 -106 107 -108 u=29 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2617   4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=29 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2618   10 8.1484E-02 226 -227 21 -22 23 -24 u=29 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate XII
C Plate core
2619   43 4.02475E-02 228 -229 101 -102 103 -104 u=29 imp:n=1 TMP=2.5301E-08
C Pu canning
2620   44 6.55545E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=29 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2621   25 2.3191E-02 231 -232 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
C Na plate can
2622   20 7.87808E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=29 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2623   3 6.867137E-02 234 -235 105 -106 107 -108 u=29 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2624   4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=29 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2625   25 2.3191E-02 237 -238 109 -110 111 -112 u=29 imp:n=1 TMP=2.5301E-08
C Na plate can
2626   20 7.87808E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=29 imp:n=1 TMP=2.5301E-08
c
c End of MZB Outer Core Cell G
c
c
c MZB Outer Core Cell BG.
c
c Na plate
c Na plate core
2651   25 2.3191E-02 202 -203 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
C Na plate can
2652   20 7.87808E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=30 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
```

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```

2653   3 6.867137E-02 205 -206 105 -106 107 -108 u=30 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2654   4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=30 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2655   25 2.3191E-02 208 -209 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
c Na plate can
2656   20 7.87808E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=30 imp:n=1 TMP=2.5301E-08
c
c Pu plate VI
c Plate core
2657   33 4.04903E-02 101 -102 103 -104 211 -212 u=30 imp:n=1 TMP=2.5301E-08
c Pu canning
2658   34 6.74722E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=30 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2659   7 8.607216E-02 213 -214 21 -22 23 -24 u=30 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2660   3 6.867137E-02 215 -216 105 -106 107 -108 u=30 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2661   4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=30 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2662   25 2.3191E-02 218 -219 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
c Na plate can
2663   20 7.87808E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=30 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2664   25 2.3191E-02 221 -222 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
c Na plate can
2665   20 7.87808E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=30 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2666   3 6.867137E-02 224 -225 105 -106 107 -108 u=30 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2667   4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=30 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2668   10 8.1484E-02 226 -227 21 -22 23 -24 u=30 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate
c Plate core
2669   33 4.04903E-02 228 -229 101 -102 103 -104 u=30 imp:n=1 TMP=2.5301E-08
c Pu canning
2670   34 6.74722E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=30 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2671   25 2.3191E-02 231 -232 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
c Na plate can
2672   20 7.87808E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=30 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2673   3 6.867137E-02 234 -235 105 -106 107 -108 u=30 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2674   4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=30 imp:n=1 TMP=2.5301E-08
c

```

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```

c Na plate
c Na plate core
2675 25 2.3191E-02 237 -238 109 -110 111 -112 u=30 imp:n=1 TMP=2.5301E-08
C Na plate can
2676 20 7.87808E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=30 imp:n=1 TMP=2.5301E-08
c
c End of MZB Outer Core Cell BG
c
c MZB Outer Core Cell DG
c
c Na plate
c Na plate core
2701 25 2.3191E-02 202 -203 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2702 20 7.87808E-02 201 -204 21 -22 23 -24 &
      (-109:110:-111:112:-202:203) u=31 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2703 3 6.867137E-02 205 -206 105 -106 107 -108 u=31 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2704 4 6.5639E-02 204 -207 21 -22 23 -24 &
      (-105:106:-107:108:-205:206) u=31 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2705 25 2.3191E-02 208 -209 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2706 20 7.87808E-02 207 -210 21 -22 23 -24 &
      (-109:110:-111:112:-208:209) u=31 imp:n=1 TMP=2.5301E-08
c
c Pu plate VIII
C Plate core
2707 37 4.01503E-02 101 -102 103 -104 211 -212 u=31 imp:n=1 TMP=2.5301E-08
C Pu canning
2708 38 6.71396E-02 210 -213 21 -22 23 -24 &
      (-101:102:-103:104:-211:212) u=31 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2709 7 8.607216E-02 213 -214 21 -22 23 -24 u=31 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2710 3 6.867137E-02 215 -216 105 -106 107 -108 u=31 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2711 4 6.5639E-02 214 -217 21 -22 23 -24 &
      (-105:106:-107:108:-215:216) u=31 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2712 25 2.3191E-02 218 -219 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2713 20 7.87808E-02 217 -220 21 -22 23 -24 &
      (-109:110:-111:112:-218:219) u=31 imp:n=1 TMP=2.5301E-08
c
c
c Na plate
c Na plate core
2714 25 2.3191E-02 221 -222 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2715 20 7.87808E-02 220 -223 21 -22 23 -24 &
      (-109:110:-111:112:-221:222) u=31 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2716 3 6.867137E-02 224 -225 105 -106 107 -108 u=31 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2717 4 6.5639E-02 223 -226 21 -22 23 -24 &
      (-105:106:-107:108:-224:225) u=31 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2718 10 8.1484E-02 226 -227 21 -22 23 -24 u=31 imp:n=1 TMP=2.5301E-08
c
c
c Pu plate

```

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```

C Plate core
2719 37 4.01503E-02 228 -229 101 -102 103 -104 u=31 imp:n=1 TMP=2.5301E-08
C Pu canning
2720 38 6.71396E-02 227 -230 21 -22 23 -24 &
      (-101:102:-103:104:-228:229) u=31 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2721 25 2.3191E-02 231 -232 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2722 20 7.87808E-02 230 -233 21 -22 23 -24 &
      (-109:110:-111:112:-231:232) u=31 imp:n=1 TMP=2.5301E-08
c
c UO2 plate
c UO2 core
2723 3 6.867137E-02 234 -235 105 -106 107 -108 u=31 imp:n=1 TMP=2.5301E-08
c UO2 plate can
2724 4 6.5639E-02 233 -236 21 -22 23 -24 &
      (-105:106:-107:108:-234:235) u=31 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2725 25 2.3191E-02 237 -238 109 -110 111 -112 u=31 imp:n=1 TMP=2.5301E-08
C Na plate can
2726 20 7.87808E-02 236 -239 21 -22 23 -24 &
      (-109:110:-111:112:-237:238) u=31 imp:n=1 TMP=2.5301E-08
c
c End of MZB Outer Core Cell DG
c
c
c
c End of MZB Core Cells
c
c
c Axial blanket cell B11-1
c
c Na plate
c Na plate core
2801 5 2.3126E-02 402 -403 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2802 6 7.865043E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=44 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2803 8 4.7208E-02 404 -405 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2804 10 8.1484E-02 405 -406 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2805 5 2.3126E-02 407 -408 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2806 6 7.865043E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=44 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2807 7 8.607216E-02 409 -410 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2808 8 4.7208E-02 410 -411 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2809 5 2.3126E-02 412 -413 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2810 6 7.865043E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=44 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2811 10 8.1484E-02 414 -415 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2812 5 2.3126E-02 416 -417 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08

```

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```

C Na plate can
2813   6 7.865043E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=44 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2814   7 8.607216E-02 418 -419 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2815   8 4.7208E-02 419 -420 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2816   5 2.3126E-02 421 -422 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2817   6 7.865043E-02 420 -423 21 -22 23 -24 &
      (-109:110:-111:112:-421:422) u=44 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2818  10 8.1484E-02 423 -424 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2819   5 2.3126E-02 425 -426 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2820   6 7.865043E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=44 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2821   8 4.7208E-02 427 -428 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2822   7 8.607216E-02 428 -429 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2823   5 2.3126E-02 430 -431 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2824   6 7.865043E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=44 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2825   8 4.7208E-02 432 -433 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8
2826  10 8.1484E-02 433 -434 21 -22 23 -24 u=44 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2827   5 2.3126E-02 435 -436 109 -110 111 -112 u=44 imp:n=1 TMP=2.5301E-08
C Na plate can
2828   6 7.865043E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=44 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B11-1
c
c
c
c Axial blanket cell B11-1A
c
c Na plate
c Na plate core
2831  25 2.3191E-02 402 -403 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2832  26 7.872422E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=45 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2833   8 4.7208E-02 404 -405 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2834  10 8.1484E-02 405 -406 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08

```

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```

c
c Na plate
c Na plate core
2835 25 2.3191E-02 407 -408 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2836 26 7.872422E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=45 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2837 7 8.607216E-02 409 -410 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2838 8 4.7208E-02 410 -411 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2839 25 2.3191E-02 412 -413 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2840 26 7.872422E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=45 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2841 10 8.1484E-02 414 -415 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2842 25 2.3191E-02 416 -417 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2843 26 7.872422E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=45 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2844 7 8.607216E-02 418 -419 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2845 8 4.7208E-02 419 -420 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2846 25 2.3191E-02 421 -422 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2847 26 7.872422E-02 420 -423 21 -22 23 -24 &
      (-109:110:-111:112:-421:422) u=45 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2848 10 8.1484E-02 423 -424 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2849 25 2.3191E-02 425 -426 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2850 26 7.872422E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=45 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2851 8 4.7208E-02 427 -428 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2852 7 8.607216E-02 428 -429 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2853 25 2.3191E-02 430 -431 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2854 26 7.872422E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=45 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2855 8 4.7208E-02 432 -433 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8

```

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```

2856 10 8.1484E-02 433 -434 21 -22 23 -24 u=45 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2857 25 2.3191E-02 435 -436 109 -110 111 -112 u=45 imp:n=1 TMP=2.5301E-08
C Na plate can
2858 26 7.872422E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=45 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B11-1A
c
c
c Axial blanket cell B11-1AG
c
c Na plate
c Na plate core
2861 25 2.3191E-02 402 -403 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
C Na plate can
2862 20 7.87808E-02 401 -404 21 -22 23 -24 &
      (-109:110:-111:112:-402:403) u=46 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2863 8 4.7208E-02 404 -405 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2864 10 8.1484E-02 405 -406 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2865 25 2.3191E-02 407 -408 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
C Na plate can
2866 20 7.87808E-02 406 -409 21 -22 23 -24 &
      (-109:110:-111:112:-407:408) u=46 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2867 7 8.607216E-02 409 -410 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2868 8 4.7208E-02 410 -411 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2869 25 2.3191E-02 412 -413 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
C Na plate can
2870 20 7.87808E-02 411 -414 21 -22 23 -24 &
      (-109:110:-111:112:-412:413) u=46 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2871 10 8.1484E-02 414 -415 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2872 25 2.3191E-02 416 -417 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
C Na plate can
2873 20 7.87808E-02 415 -418 21 -22 23 -24 &
      (-109:110:-111:112:-416:417) u=46 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2874 7 8.607216E-02 418 -419 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2875 8 4.7208E-02 419 -420 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2876 25 2.3191E-02 421 -422 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
C Na plate can
2877 20 7.87808E-02 420 -423 21 -22 23 -24 &
      (-109:110:-111:112:-421:422) u=46 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GI8
2878 10 8.1484E-02 423 -424 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate

```


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```

c Na plate core
2879 25 2.3191E-02 425 -426 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
C Na plate can
2880 20 7.87808E-02 424 -427 21 -22 23 -24 &
      (-109:110:-111:112:-425:426) u=46 imp:n=1 TMP=2.5301E-08
c
c U8 plate
2881 8 4.7208E-02 427 -428 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c
c Steel plate
2882 7 8.607216E-02 428 -429 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2883 25 2.3191E-02 430 -431 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
C Na plate can
2884 20 7.87808E-02 429 -432 21 -22 23 -24 &
      (-109:110:-111:112:-430:431) u=46 imp:n=1 TMP=2.5301E-08
c
c
c U8 plate
2885 8 4.7208E-02 432 -433 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c
c Graphite plate GI8
2886 10 8.1484E-02 433 -434 21 -22 23 -24 u=46 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2887 25 2.3191E-02 435 -436 109 -110 111 -112 u=46 imp:n=1 TMP=2.5301E-08
C Na plate can
2888 20 7.87808E-02 434 -437 21 -22 23 -24 &
      (-109:110:-111:112:-435:436) u=46 imp:n=1 TMP=2.5301E-08
c
c End of Axial Blanket Cell B11-1AG
c
c Radial Blanket Central Range B11-3
c
c Graphite plate GII8
2901 11 8.5125E-02 501 -502 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2902 25 2.3191E-02 503 -504 109 -110 111 -112 u=51 imp:n=1 TMP=2.5301E-08
C Na plate can
2903 26 7.872422E-02 502 -505 21 -22 23 -24 &
      (-109:110:-111:112:-503:504) u=51 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2904 11 8.5125E-02 505 -506 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2905 7 8.607216E-02 506 -507 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c U2 plate
2906 9 4.7925E-02 507 -508 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2907 11 8.5125E-02 508 -509 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2908 25 2.3191E-02 510 -511 109 -110 111 -112 u=51 imp:n=1 TMP=2.5301E-08
C Na plate can
2909 26 7.872422E-02 509 -512 21 -22 23 -24 &
      (-109:110:-111:112:-510:511) u=51 imp:n=1 TMP=2.5301E-08
c
c MST8 plate
c
2910 27 8.4980E-02 512 -513 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2911 11 8.5125E-02 513 -514 21 -22 23 -24 u=51 imp:n=1 TMP=2.5301E-08
c
c Na plate

```

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```

c Na plate core
2912  25 2.3191E-02 515 -516 109 -110 111 -112 u=51 imp:n=1 TMP=2.5301E-08
C Na plate can
2913  26 7.872422E-02 514 -517 21 -22 23 -24 &
      (-109:110:-111:112:-515:516) u=51 imp:n=1 TMP=2.5301E-08

c
c
      End of Central Section of the Radial blanket B11-3
c
c
c Radial Blanket Central Range B11-3A
c
c Graphite plate GII8
2916  11 8.5125E-02 501 -502 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2917  25 2.3191E-02 503 -504 109 -110 111 -112 u=52 imp:n=1 TMP=2.5301E-08
C Na plate can
2918  26 7.872422E-02 502 -505 21 -22 23 -24 &
      (-109:110:-111:112:-503:504) u=52 imp:n=1 TMP=2.5301E-08

c
c Graphite plate GII8
2919  11 8.5125E-02 505 -506 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2920  7 8.607216E-02 506 -507 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c U2 plate
2921  9 4.7925E-02 507 -508 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2922  11 8.5125E-02 508 -509 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2923  25 2.3191E-02 510 -511 109 -110 111 -112 u=52 imp:n=1 TMP=2.5301E-08
C Na plate can
2924  26 7.872422E-02 509 -512 21 -22 23 -24 &
      (-109:110:-111:112:-510:511) u=52 imp:n=1 TMP=2.5301E-08

c
c MST8 plate
c
2925  27 8.4980E-02 512 -513 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2926  11 8.5125E-02 513 -514 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2927  25 2.3191E-02 515 -516 109 -110 111 -112 u=52 imp:n=1 TMP=2.5301E-08
C Na plate can
2928  26 7.872422E-02 514 -517 21 -22 23 -24 &
      (-109:110:-111:112:-515:516) u=52 imp:n=1 TMP=2.5301E-08

c
c
      End of Central Section of the Radial blanket B11-3A
c
c
c Radial Blanket Central Range B11-3G
c Includes the sodium plate NASTDM4 and graphite plate GIII8
c Graphite plate GIII8
2931  11 8.5125E-02 501 -502 21 -22 23 -24 u=52 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2932  25 2.3191E-02 503 -504 109 -110 111 -112 u=53 imp:n=1 TMP=2.5301E-08
C Na plate can
2933  26 7.872422E-02 502 -505 21 -22 23 -24 &
      (-109:110:-111:112:-503:504) u=53 imp:n=1 TMP=2.5301E-08

c
c Graphite plate GII8
2934  11 8.5125E-02 505 -506 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c
c Steel plate
2935  7 8.607216E-02 506 -507 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c
c U2 plate

```

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```

2936   9 4.7925E-02 507 -508 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2937   11 8.5125E-02 508 -509 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2938   25 2.3191E-02 510 -511 109 -110 111 -112 u=53 imp:n=1 TMP=2.5301E-08
c Na plate can
2939   26 7.872422E-02 509 -512 21 -22 23 -24 &
      (-109:110:-111:112:-510:511) u=53 imp:n=1 TMP=2.5301E-08
c
c MST8 plate
c
2940   27 8.4980E-02 512 -513 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c
c Graphite plate GII8
2941   11 8.5125E-02 513 -514 21 -22 23 -24 u=53 imp:n=1 TMP=2.5301E-08
c
c Na plate
c Na plate core
2942   25 2.3191E-02 515 -516 109 -110 111 -112 u=53 imp:n=1 TMP=2.5301E-08
c Na plate can
2943   26 7.872422E-02 514 -517 21 -22 23 -24 &
      (-109:110:-111:112:-515:516) u=53 imp:n=1 TMP=2.5301E-08
c
c
c           End of Central Section of the Radial blanket B11-3G
c
c           Upper and Lower Section of the radial Blanket
c
c ALG8
2951   29 2.6752E-02 601 -603 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c AL2O34
2952   30 1.106986E-01 603 -604 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c GII8
2953   11 8.5125E-02 604 -605 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c ALG8
2954   29 2.6752E-02 605 -606 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c U2 plate
2955   9 4.7925E-02 606 -607 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c ALG8
2956   29 2.6752E-02 607 -608 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c GII8
2957   11 8.5125E-02 608 -609 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c AL2O34
2958   30 1.106986E-01 609 -610 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c MST2 (MST8) plate
c
2959   27 8.4980E-02 610 -611 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2960   29 2.6752E-02 611 -612 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c GII8
2961   11 8.5125E-02 612 -613 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2962   29 2.6752E-02 613 -615 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c U2 plate
2963   9 4.7925E-02 615 -616 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c

```

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```

c AL2O34
2964 30 1.106986E-01 616 -617 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2965 29 2.6752E-02 617 -618 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c GII8
2966 11 8.5125E-02 618 -619 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c MST8 plate
c
2967 27 8.4980E-02 619 -620 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c ALG8
2968 29 2.6752E-02 620 -621 21 -22 23 -24 u=55 imp:n=1 TMP=2.5301E-08
c
c
c End of upper and lower radial blanket sections
c
c c Lower Plenum Cell
c
c ALSC3 plate
2971 28 4.7627E-02 7 -33 21 -22 23 -24 u=71 imp:n=1 TMP=2.5301E-08
c
c MST1 plate
c
2972 27 8.4980E-02 33 -34 21 -22 23 -24 u=71 imp:n=1 TMP=2.5301E-08
c
c ALSC3 plate
2973 28 4.7627E-02 34 -35 21 -22 23 -24 u=71 imp:n=1 TMP=2.5301E-08
c
c MST3 plate
c
2974 27 8.4980E-02 35 -36 21 -22 23 -24 u=71 imp:n=1 TMP=2.5301E-08
c
c ALSC3 plate
c
2975 28 4.7627E-02 36 -37 21 -22 23 -24 u=71 imp:n=1 TMP=2.5301E-08
c
c Upper Plenum Cell
c
c ALSC3 plate
c
2981 28 4.7627E-02 7 -33 21 -22 23 -24 u=72 imp:n=1 TMP=2.5301E-08
c
c MST3 plate
c
2982 27 8.4980E-02 33 -38 21 -22 23 -24 u=72 imp:n=1 TMP=2.5301E-08
c
c ALSC3 plate
2983 28 4.7627E-02 38 -39 21 -22 23 -24 u=72 imp:n=1 TMP=2.5301E-08
c
c MST1 plate
c
2984 27 8.4980E-02 39 -36 21 -22 23 -24 u=72 imp:n=1 TMP=2.5301E-08
c
c ALSC3 plate
2985 28 4.7627E-02 36 -37 21 -22 23 -24 u=72 imp:n=1 TMP=2.5301E-08
c
c Cell data complete
c -----

c
c ----- SURFACE CARDS -----
c
c MZA Core and MZB Outer Core Element cell surfaces
1 px -2.7127
2 px 2.7127
3 py -2.7127
4 py 2.7127
7 pz 0.0 $ Assembly lower limit

```

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```

8      pz 30.0 $ End Lower Packing, Start Plenum
9      pz 63.0048 $ End Plenum, Start Lower Axial Blanket
10     pz 97.9512 $ End Lower Blanket, Start Core Fuel
11     pz 187.9008 $ End Core Fuel, Start Upper Axial Blanket
12     pz 222.8472 $ End Upper Blanket, Start Upper Plenum
13     pz 255.852 $ End Upper Plenum, Start Upper Packing
16     pz 285.0 $ Assembly upper axial limit
17     cz 132.9 $ Assembly outer radius
21     px -2.5335 $ Nominal half-width of plates
22     px 2.5335
23     py -2.5335
24     py 2.5335
28     px -2.54 $ Radial shield half-width
29     px 2.54
30     py -2.54
31     py 2.54
c
c
c axial heights in the lower plenum
33     pz 7.62 $ alsc3
34     pz 10.1585 $ mst1
35     pz 17.7785 $ alsc3
36     pz 25.3848 $ mst3
37     pz 33.0048 $ alsc3
c different axial heights in the upper plenum
38     pz 15.2263 $ mst3
39     pz 22.8463 $ alsc3 / mst1
c
c cell subdivisions in the axial blanket and core cells of MZA elements
c
c 9      pz 63.0048 $ End Plenum, Start Lower Axial Blanket
41     pz 71.7414
42     pz 80.478
43     pz 89.2146
c 10     pz 97.9512 $ lower axial blanket / core
44     pz 105.447
45     pz 112.9428
46     pz 120.4386
47     pz 127.9344
48     pz 135.4302
49     pz 142.926
50     pz 150.4218
51     pz 157.9176
52     pz 165.4134
53     pz 172.9092
54     pz 180.405
c 11     pz 187.9008 $ core / upper axial blanket
56     pz 196.6374
57     pz 205.374
58     pz 214.1106
c 12     pz 222.8472 $ axial blanket / plenum
c
c
c 62     px -2.551 $ sheath inner half-width
63     px 2.551
64     py -2.551
65     py 2.551
66     px -2.6272 $ sheath outer half-width
67     px 2.6272
68     py -2.6272
69     py 2.6272
c
c
c Grid plate heights
c
71     pz 62.3
72     pz 92.7
73     pz 193.1
74     pz 223.5
c
c coordinates of the elements in 5x5 arrays
81     px -8.05815
82     px 8.05815
83     py -8.05815
84     py 8.05815
85     px -13.43025

```

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```

86      px 13.43025
87      py -13.43025
88      py 13.43025
89      px -13.5635
90      px 13.5635
91      py -13.5635
92      py 13.5635
c
c
c  plate inner core widths
c
101     px -2.3355 $ Pu metal plate core width
102     px 2.3355
103     py -2.3355
104     py 2.3355
105     px -2.4255 $ UO2 plate core width
106     px 2.4255
107     py -2.4255
108     py 2.4255
109     px -2.4815 $ Na plate core width
110     px 2.4815
111     py -2.4815
112     py 2.4815
113     px -2.4765 $ MOX plate PUIV4
114     px 2.4765
115     py -2.4765
116     py 2.4765
c
c
c  MZA Core Cell  Axial heights
c
201     pz 0
202     pz 0.03683
203     pz 0.57917 $ Na
204     pz 0.616
205     pz 0.65283
206     pz 1.20707 $ UO2
207     pz 1.2439
208     pz 1.28073
209     pz 1.82307 $ Na
210     pz 1.8599
211     pz 1.90562
212     pz 2.14068 $ Pu
213     pz 2.1864
214     pz 2.5036 $ SS
215     pz 2.54043
216     pz 3.09467 $ UO2
217     pz 3.1315
218     pz 3.16833
219     pz 3.71067 $ Na
220     pz 3.7475
221     pz 3.78433
222     pz 4.32667 $ Na
223     pz 4.3635
224     pz 4.40033
225     pz 4.95457 $ UO2
226     pz 4.9914
227     pz 5.3094 $ GI8
228     pz 5.35512
229     pz 5.59018 $ Pu
230     pz 5.6359
231     pz 5.67273
232     pz 6.21507 $ Na
233     pz 6.2519
234     pz 6.28873
235     pz 6.84297 $ UO2
236     pz 6.8798
237     pz 6.91663
238     pz 7.45897 $ Na
239     pz 7.4958
c
c  MZB Inner core cell axial heights
c
301     pz 0
302     pz 0.03683
303     pz 0.57917 $ na

```

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

304	pz	0.616	
305	pz	0.65283	
306	pz	1.21047	\$ uo2
307	pz	1.2473	
308	pz	1.28413	
309	pz	1.82647	\$ na
310	pz	1.8633	
311	pz	1.90902	
312	pz	2.14408	\$ puix8
313	pz	2.1898	
314	pz	2.22663	
315	pz	2.76897	\$ na
316	pz	2.8058	
317	pz	2.84263	
318	pz	3.40027	\$ uo2
319	pz	3.4371	
320	pz	3.47393	
321	pz	4.01627	\$ na
322	pz	4.0531	
323	pz	4.3703	\$ ssbr8
324	pz	4.40713	
325	pz	4.96477	\$ uo2
326	pz	5.0016	
327	pz	5.03843	
328	pz	5.58077	\$ na
329	pz	5.6176	
330	pz	5.65494	
331	pz	6.20806	\$ puiv4
332	pz	6.2454	
333	pz	6.28223	
334	pz	6.82457	\$ na
335	pz	6.8614	
336	pz	6.89823	
337	pz	7.45587	\$ uo2
338	pz	7.4927	
339	pz	7.52953	
340	Pz	8.07187	\$ na
341	pz	8.1087	

c

c Axial blanket cells

c

401	pz	0	
402	pz	0.03683	
403	pz	0.57917	\$ na
404	pz	0.616	
405	pz	0.933	\$ u8
406	pz	1.251	\$ g
407	pz	1.28783	
408	pz	1.83017	\$ na
409	pz	1.867	
410	pz	2.1842	\$ ss
411	pz	2.5012	\$ u8
412	pz	2.53803	
413	pz	3.08037	\$ na
414	pz	3.1172	
415	pz	3.4352	\$ g
416	pz	3.47203	
417	pz	4.01437	\$ na
418	pz	4.0512	
419	pz	4.3684	\$ ss
420	pz	4.6854	\$ u8
421	pz	4.72223	
422	pz	5.26457	\$ na
423	pz	5.3014	
424	pz	5.6194	\$ g
425	pz	5.65623	
426	pz	6.19857	\$ na
427	pz	6.2354	
428	pz	6.5524	\$ u8
429	pz	6.8696	\$ ss
430	pz	6.90643	
431	pz	7.44877	\$ na
432	pz	7.4856	
433	pz	7.8036	\$ g
434	pz	8.1206	\$ u8
435	pz	8.15743	

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

436 pz 8.69977 $ na
437 pz 8.7366
c
c Inner (axially) radial blanket cells
c
501 pz 0
502 pz 0.31775 $ g
503 pz 0.35458
504 pz 0.89692 $ na
505 pz 0.93375
506 pz 1.2515 $ g
507 pz 1.5751 $ ss
508 pz 2.8474 $ u2
509 pz 3.16515 $ g
510 pz 3.20198
511 pz 3.74432 $ na
512 pz 3.78115
513 pz 4.09585 $ mst
514 pz 4.4136 $ g
515 pz 4.45043
516 pz 4.99277 $ na
517 pz 5.0296
c
c Upper and lower sections of the radial blanket
c
601 pz 0
c 602 pz 0.317 $ al
603 pz 0.634 $ al
604 pz 1.2657 $ al2o3
605 pz 1.58345 $ gii
606 pz 1.90045 $ al
607 pz 3.17275 $ u2
608 pz 3.48975 $ al
609 pz 3.8075 $ gii
610 pz 4.4392 $ al2o3
611 pz 5.711 $ mst2
612 pz 6.028 $ al
613 pz 6.34575 $ gii
c 614 pz 6.66275 $ al
615 pz 6.97975 $ al
616 pz 8.25205 $ u2
617 pz 8.88375 $ al2o3
618 pz 9.20075 $ al
619 pz 9.5185 $ gii
620 pz 9.8332 $ mst8
621 pz 10.1502 $ al
c
c heights of cells in the MZB inner core elements
c
701 pz 97.9512 $ First core cell lower boundary
702 pz 106.0599
703 pz 114.1686
704 pz 122.2773
705 pz 130.386
706 pz 138.4947
707 pz 146.6034
708 pz 154.7121
709 pz 162.8208
710 pz 170.9295
711 pz 179.0382
712 pz 187.1469 $ Core upper boundary
713 pz 195.8835
714 pz 204.6201
715 pz 213.3567
716 pz 222.0933 $ Axial blanket upper boundary
717 pz 255.0981
c
c Heights of cells in the radial blanket
c
801 pz 30.0 $ Packing
802 pz 63.0048 $ End Lower plenum/
803 pz 73.155
804 pz 83.3052
805 pz 93.4554 $ End Lower Blanket
806 pz 98.485
807 pz 103.5146

```


ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

808	pz	108.5442	
809	pz	113.5738	
810	pz	118.6034	
811	pz	123.633	
812	pz	128.6626	
813	pz	133.6922	
814	pz	138.7218	
815	pz	143.7514	
816	pz	148.781	
817	pz	153.8106	
818	pz	158.8402	
819	pz	163.8698	
820	pz	168.8994	
821	pz	173.929	
822	pz	178.9586	
823	pz	183.9882	
824	pz	189.0178	
825	pz	194.0474	\$ End Middle Blanket
826	pz	204.1976	
827	pz	214.3478	
828	pz	224.498	\$ End Upper Blanket
829	pz	257.5028	\$ End Upper plenum
830	pz	285.0	\$ Top of assembly

c

c

c -----

c

c

c

c ----- TALLY CARDS -----

c

c --- MATERIALS CARDS FOR JEFF-3.1 ---

c

c Region Compositions

C MATERIAL 1 Pu metal plate PUV8 core

c

ml	92238.31c	1.3318E-06
	94238.31c	2.9103E-05
	94239.31c	2.9328E-02
	94240.31c	6.7928E-03
	94241.31c	1.0119E-03
	94242.31c	1.6639E-04
	95241.31c	9.4236E-05
	1001.31c	1.7475E-04
	6000.31c	2.5027E-04
	7014.31c	1.3413E-05
	8016.31c	5.0640E-05
	13027.31c	2.1760E-05
	14028.31c	2.3831E-05
	25055.31c	1.0687E-06
	24050.31c	2.2568E-07
	24052.31c	4.3521E-06
	24053.31c	4.9349E-07
	24054.31c	1.2284E-07
	26054.31c	9.7085E-07
	26056.31c	1.5240E-05
	26057.31c	3.5197E-07
	26058.31c	4.6840E-08
	28058.31c	8.0358E-06
	28060.31c	3.0954E-06
	28061.31c	1.3455E-07
	28062.31c	4.2902E-07
	28064.31c	1.0926E-07
	31000.31c	2.2424E-03
	42092.31c	2.9375E-07
	42094.31c	1.9583E-07
	42095.31c	2.9375E-07
	42096.31c	2.9375E-07
	42097.31c	1.9583E-07
	42098.31c	4.8958E-07
	42100.31c	1.9583E-07

c total 4.023746E-02

c MATERIAL 2 PuV8 plate canning

c

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-*BUCK*-SPEC-REAC-RRATE

```

m2      1001.31c    1.3404E-05
        6000.31c    9.2801E-05
        14028.31c   4.1625E-04
        15031.31c   1.8432E-05
        16032.31c   9.3252E-06
        25055.31c   7.5220E-04
        24050.31c   4.0213E-04
        24052.31c   7.7546E-03
        24053.31c   8.7931E-04
        24054.31c   2.1888E-04
        26054.31c   2.0054E-03
        26056.31c   3.1481E-02
        26057.31c   7.2703E-04
        26058.31c   9.6754E-05
        28058.31c   3.0905E-03
        28060.31c   1.1905E-03
        28061.31c   5.1748E-05
        28062.31c   1.6500E-04
        28064.31c   4.2019E-05
        29063.31c   1.1638E-02
        29065.31c   4.9880E-03
c total 6.6033E-02
C MATERIAL 3 UO2 plate UO24R4 core
c
m3      1001.31c    2.4503E-05
        6000.31c    3.0842E-05
        8016.31c    4.5733E-02
        13027.31c   3.3911E-06
        14028.31c   1.3190E-05
        26054.31c   3.8771E-07
        26056.31c   6.0862E-06
        26057.31c   1.4056E-07
        26058.31c   1.8706E-08
        92234.31c   1.1871E-06
        92235.31c   1.6462E-04
        92238.31c   2.2694E-02
c total 6.867137E-02
C MATERIAL 4 UO2 plate UO24R4 canning
c
m4      1001.31c    1.7335E-05
        6000.31c    1.4546E-04
        14028.31c    6.0964E-04
        15031.31c    2.2563E-05
        16032.31c    2.1792E-05
        25055.31c    9.7951E-04
        24050.31c    5.3726E-04
        24052.31c    1.0361E-02
        24053.31c    1.1748E-03
        24054.31c    2.9243E-04
        26054.31c    2.5374E-03
        26056.31c    3.9831E-02
        26057.31c    9.1988E-04
        26058.31c    1.2242E-04
        28058.31c    4.0937E-03
        28060.31c    1.5769E-03
        28061.31c    6.8547E-05
        28062.31c    2.1856E-04
        28064.31c    5.5660E-05
        29063.31c    5.7122E-04
        29065.31c    2.4481E-04
        47107.31c    6.3840E-04
        47109.31c    5.9840E-04
c total 6.5639E-02
C MATERIAL 5 sodium plate NASTBR4 core
c
m5      1001.31c    2.1098E-06
        3006.31c    2.8720E-08
        3007.31c    3.5424E-07
        5010.31c    2.9500E-08
        5011.31c    1.1802E-07
        8016.31c    1.9937E-06
        11023.31c   2.3119E-02
        19039.31c   4.6230E-07
        20040.31c    1.7244E-06
        26054.31c    2.2256E-09
        26056.31c    3.4937E-08

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ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

26057.31c 8.0685E-10
26058.31c 1.0738E-10
c total 2.3126E-02
c MATERIAL 6 Sodium plate NASTBR4 canning

c
m6 1001.31c 2.1496E-05
6000.31c 2.1646E-04
14028.31c 6.0171E-04
15031.31c 2.7979E-05
16032.31c 2.7023E-05
25055.31c 1.0806E-03
24050.31c 6.5175E-04
24052.31c 1.2568E-02
24053.31c 1.4252E-03
24054.31c 3.5475E-04
26054.31c 3.1596E-03
26056.31c 4.9599E-02
26057.31c 1.1454E-03
26058.31c 1.5244E-04
28058.31c 4.9357E-03
28060.31c 1.9012E-03
28061.31c 8.2645E-05
28062.31c 2.6351E-04
28064.31c 6.7108E-05
28064.31c 6.5701E-05
41093.31c 3.0316E-04

c total 7.865043E-02
C MATERIAL 7 STSTBR8 steel plate

c
m7 1001.31c 2.3265E-05
6000.31c 7.8091E-04
13027.31c 1.7381E-04
14028.31c 1.3358E-03
22048.31c 2.9384E-04
25055.31c 9.3901E-04
24050.31c 7.0932E-04
24052.31c 1.3679E-02
24053.31c 1.5510E-03
24054.31c 3.8609E-04
26054.31c 3.4063E-03
26056.31c 5.3472E-02
26057.31c 1.2349E-03
26058.31c 1.6434E-04
28058.31c 5.2766E-03
28060.31c 2.0326E-03
28061.31c 8.8354E-05
28062.31c 2.8171E-04
28064.31c 7.1743E-05
29063.31c 5.1661E-05
29065.31c 2.2140E-05
42092.31c 1.4665E-05
42094.31c 9.7764E-06
42095.31c 1.4665E-05
42096.31c 1.4665E-05
42097.31c 9.7764E-06
42098.31c 2.4441E-05
42100.31c 9.7764E-06

c total 8.607216E-02

c
C MATERIAL 8 U8 metal plate

m8 1001.31c 4.4048E-05
6000.31c 4.9283E-04
14028.31c 2.1076E-04
26054.31c 6.1951E-06
26056.31c 9.7250E-05
26057.31c 2.2459E-06
26058.31c 2.9889E-08
92235.31c 3.3369E-04
92238.31c 4.6021E-02

c total 4.7208E-02

C MATERIAL 9 U2 metal plate

m9 1001.31c 4.3899E-05
6000.31c 4.6047E-04
14028.31c 1.9692E-04
26054.31c 5.7884E-06
26056.31c 9.0866E-05

ZEBRA-LMFR-EXP-002
LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

26057.31c  2.0985E-06
26058.31c  2.7927E-08
92235.31c  3.3962E-04
92238.31c  4.6785E-02
c total 4.7925E-02
c MATERIAL 10 Graphite plate GI8
m10  1001.31c  4.8551E-05
      6000.31c  8.1417E-02
      16032.31c  1.2207E-05
      26054.31c  3.5851E-07
      26056.31c  5.6278E-06
      26057.31c  1.2997E-07
      26058.31c  1.7297E-08
c Total 8.1484E-02
c MATERIAL 11 Graphite plate GII8
m11  1001.31c  2.0286E-05
      6000.31c  8.5101E-02
      16032.31c  1.2751E-06
      26054.31c  1.0700E-07
      26056.31c  1.6796E-06
      26057.31c  3.8790E-08
      26058.31c  5.1623E-09
c total 8.5125E-02
c Steel radial shield
m12  1001.31c  4.6306E-05
      6000.31c  6.8972E-04
      14028.31c  3.1158E-04
      15031.31c  4.2944E-05
      16032.31c  3.7110E-05
      25055.31c  7.1275E-04
      26054.31c  4.9065E-03
      26056.31c  7.4517E-02
      26057.31c  1.7491E-03
      26058.31c  2.5903E-04
c total 8.32720E-02
c
c radial shield void surround low density
m13  1001.31c  4.6306E-08
      6000.31c  6.8972E-07
      14028.31c  3.1158E-07
      15031.31c  4.2944E-08
      16032.31c  3.7110E-08
      25055.31c  7.1275E-07
      26054.31c  4.9065E-06
      26056.31c  7.4517E-05
      26057.31c  1.7491E-06
      26058.31c  2.5903E-07
c total 8.32720E-05
c
c Axial shield
m14  1001.31c  2.5700E-05
      6000.31c  5.1066E-04
      13027.31c  1.3989E-04
      22048.31c  3.9416E-05
      24050.31c  1.2213E-06
      24052.31c  2.2823E-05
      24053.31c  2.5531E-06
      24054.31c  6.2449E-07
      25055.31c  3.2634E-04
      26054.31c  5.0496E-03
      26056.31c  7.6690E-02
      26057.31c  1.8001E-03
      26058.31c  2.6658E-04
      28058.31c  1.2564E-06
      28060.31c  4.6968E-07
      28061.31c  2.2000E-08
      28062.31c  6.2769E-08
      28064.31c  1.6774E-08
      29063.31c  3.1184E-05
      29065.31c  1.3364E-05
      42092.31c  1.4753E-06
      42094.31c  9.8355E-07
      42095.31c  1.4753E-06
      42096.31c  1.4753E-06
      42097.31c  9.8355E-07
      42098.31c  2.4589E-06

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

      42100.31c 9.8355E-07
c total 8.4932E-02
c
c Assembly Axial Padding at bottom and top of elements
m16      1001.31c 3.1777E-05
      6000.31c 9.9996E-05
      13027.31c 8.3095E-06
      24050.31c 6.9087E-08
      24052.31c 1.2911E-06
      24053.31c 1.4442E-07
      24054.31c 3.5326E-08
      25055.31c 1.0785E-04
      26054.31c 1.9605E-03
      26056.31c 2.9775E-02
      26057.31c 6.9890E-04
      26058.31c 1.0350E-04
      28058.31c 1.5636E-07
      28060.31c 5.8452E-08
      28061.31c 2.7378E-09
      28062.31c 7.8115E-09
      28064.31c 2.0875E-09
      29063.31c 6.5270E-06
      29065.31c 2.7973E-06
c Total 3.279692E-02
c
c
c Smeared stainless steel wrapper material
c
m17      1001.31c 9.7398E-06
      6000.31c 3.2692E-04
      13027.31c 1.4553E-04
      14028.31c 4.1943E-04
      22048.31c 1.2302E-04
      23000.31c 3.8541E-05
      25055.31c 5.0032E-04
      24050.31c 2.9367E-04
      24052.31c 5.6632E-03
      24053.31c 6.4216E-04
      24054.31c 1.5985E-04
      26054.31c 1.3891E-03
      26056.31c 2.1805E-02
      26057.31c 5.0358E-04
      26058.31c 6.7017E-05
      28058.31c 2.5734E-03
      28060.31c 9.9126E-04
      28061.31c 4.3089E-05
      28062.31c 1.3739E-04
      28064.31c 3.4989E-05
      29063.31c 3.1184E-05
      29065.31c 1.3364E-05
      42092.31c 1.4753E-06
      42094.31c 9.8355E-07
      42095.31c 1.4753E-06
      42096.31c 1.4753E-06
      42097.31c 9.8355E-07
      42098.31c 2.4589E-06
      42100.31c 9.8355E-07
c Total 3.595949E-02
c
c
c mild steel wrapper material
m18      1001.31c 7.5725E-05
      6000.31c 2.3828E-04
      13027.31c 1.9802E-05
      24050.31c 1.6463E-07
      24052.31c 3.0767E-06
      24053.31c 3.4414E-07
      24054.31c 8.4182E-08
      25055.31c 2.5701E-04
      26054.31c 4.6718E-03
      26056.31c 7.0954E-02
      26057.31c 1.6655E-03
      26058.31c 2.4664E-04
      28058.31c 3.7260E-07
      28060.31c 1.3929E-07
      28061.31c 6.5242E-09

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LIQUID METAL FAST REACTOR - LMFR
CRIT-BUCK-SPEC-REAC-RRATE

```

28062.31c 1.8615E-08
28064.31c 4.9746E-09
29063.31c 1.5554E-05
29065.31c 6.6660E-06
29063.31c 2.2220E-05
c Total 18 7.81552E-02
c
c MATERIAL 20 Sodium plate NASTDM4 canning
m20 1001.31c 2.1522E-05
6000.31c 2.1672E-04
14028.31c 7.8781E-04
15031.31c 3.2216E-05
16032.31c 1.6234E-05
25055.31c 1.2635E-03
24050.31c 6.9316E-04
24052.31c 1.3367E-02
24053.31c 1.5157E-03
24054.31c 3.7729E-04
26054.31c 3.0543E-03
26056.31c 4.7945E-02
26057.31c 1.1073E-03
26058.31c 1.4735E-04
28058.31c 5.3745E-03
28060.31c 2.0703E-03
28061.31c 8.9992E-05
28062.31c 2.8694E-04
28064.31c 7.3074E-05
41093.31c 3.4089E-04
c total 20 7.87808E-02
C MATERIAL 21 Pu metal plate PUIX8 core
c
m21 92238.31c 5.2779E-06
94238.31c 3.5515E-05
94239.31c 2.8995E-02
94240.31c 6.9474E-03
94241.31c 1.1413E-03
94242.31c 1.8046E-04
95241.31c 5.9252E-05
1001.31c 1.5145E-04
6000.31c 2.8155E-04
7014.31c 9.2216E-06
8016.31c 5.7245E-05
13027.31c 2.3065E-05
14028.31c 2.8430E-05
25055.31c 1.7099E-06
24050.31c 2.6493E-07
24052.31c 5.1090E-06
24053.31c 5.7931E-07
24054.31c 1.4420E-07
26054.31c 7.6195E-07
26056.31c 1.1961E-05
26057.31c 2.7623E-07
26058.31c 3.6762E-08
28058.31c 1.8251E-05
28060.31c 7.0304E-06
28061.31c 3.0561E-07
28062.31c 9.7441E-07
28064.31c 2.4815E-07
31000.31c 2.1190E-03
c total 4.0082E-02
c MATERIAL 22 Pu plate PUIX8 canning
c
m22 1001.31c 1.3771E-05
6000.31c 1.1312E-04
14028.31c 3.6529E-04
15031.31c 1.3425E-05
25055.31c 8.5801E-04
24050.31c 4.0780E-04
24052.31c 7.8640E-03
24053.31c 8.9172E-04
24054.31c 2.2197E-04
26054.31c 2.0740E-03
26056.31c 3.2557E-02
26057.31c 7.5188E-04
26058.31c 1.0006E-04
28058.31c 2.8303E-03

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LIQUID METAL FAST REACTOR - LMFR
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28060.31c	1.0902E-03
28061.31c	4.7391E-05
28062.31c	1.5110E-04
28064.31c	3.8482E-05
29063.31c	1.1638E-02
29065.31c	4.9880E-03
c total 6.7015E-02	
C MATERIAL 23 UO2 plate UO23R4 core	
m23	1001.31c 3.1012E-05
6000.31c	1.1970E-05
8016.31c	4.6295E-02
13027.31c	3.4753E-06
14028.31c	2.3148E-05
25055.31c	1.1378E-07
26054.31c	7.8510E-08
26056.31c	1.2324E-06
26057.31c	2.8462E-08
26058.31c	3.7878E-09
28058.31c	8.7016E-07
28060.31c	3.3518E-07
28061.31c	1.4570E-08
28062.31c	4.6456E-08
28064.31c	1.1831E-08
42092.31c	4.8869E-08
42094.31c	3.2579E-08
42095.31c	4.8869E-08
42096.31c	4.8869E-08
42097.31c	3.2579E-08
42098.31c	8.1448E-08
42100.31c	3.2579E-08
92235.31c	1.6647E-04
92238.31c	2.2980E-02
c total 6.951414E-02	
c MATERIAL 24 UO2 plate UO23R4 canning	
m24	1001.31c 1.9269E-05
6000.31c	1.2483E-04
14028.31c	6.2774E-04
15031.31c	3.4147E-04
16032.31c	3.5123E-05
25055.31c	8.3300E-04
24050.31c	5.8462E-04
24052.31c	1.1274E-02
24053.31c	1.2784E-03
24054.31c	3.1821E-04
26054.31c	2.7490E-03
26056.31c	4.3153E-02
26057.31c	9.9659E-04
26058.31c	1.3263E-04
28058.31c	5.5846E-03
28060.31c	2.1512E-03
28061.31c	9.3509E-05
28062.31c	2.9815E-04
28064.31c	7.5930E-05
c total 7.067127E-02	
C MATERIAL 25 sodium plate NASTDL4 and NASTDM4 core	
m25	1001.31c 1.3418E-05
8016.31c	5.6353E-06
11023.31c	2.3168E-02
20040.31c	3.5994E-06
26054.31c	9.4595E-09
26056.31c	1.4849E-07
26057.31c	3.4294E-09
26058.31c	4.5639E-11
c total 2.3191E-02	
c MATERIAL 26 Sodium plate NASTDL4 canning (see m20 for the DM can)	
m26	1001.31c 2.4319E-05
6000.31c	2.8978E-04
14028.31c	6.0218E-04
15031.31c	3.2445E-05
16032.31c	3.2865E-05
25055.31c	1.3425E-03
24050.31c	6.3446E-04
24052.31c	1.2235E-02
24053.31c	1.3873E-03
24054.31c	3.4534E-04
26054.31c	3.1836E-03

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26056.31c  4.9976E-02
26057.31c  1.1542E-03
26058.31c  1.5360E-04
28058.31c  4.7807E-03
28060.31c  1.8415E-03
28061.31c  8.0049E-05
28062.31c  2.5523E-04
28064.31c  6.5000E-05
41093.31c  3.0815E-04
c   total   7.872422E-02
c
c M27 Mild Steel MST3
m27  1001.31c  2.8087E-05
      6000.31c  5.1066E-04
      13027.31c  1.3989E-04
      22048.31c  3.9416E-05
      25055.31c  3.2634E-04
      24050.31c  1.1828E-06
      24052.31c  2.2809E-05
      24053.31c  2.5864E-06
      24054.31c  6.4380E-07
      26054.31c  4.8985E-03
      26056.31c  7.6895E-02
      26057.31c  1.7758E-03
      26058.31c  2.3633E-04
      28058.31c  3.2836E-05
      28060.31c  1.2648E-05
      28061.31c  5.4982E-07
      28062.31c  1.7531E-06
      28064.31c  4.4645E-07
      29063.31c  3.1184E-05
      29065.31c  1.3364E-05
      42092.31c  1.4753E-06
      42094.31c  9.8355E-07
      42095.31c  1.4753E-06
      42096.31c  1.4753E-06
      42097.31c  9.8355E-07
      42098.31c  2.4589E-06
      42100.31c  9.8355E-07
c Total atoms 8.4980E-02
c
c M28 Aluminium plate ALSC3
m28
      13027.31c  4.7590E-02
      14028.31c  4.5790E-06
      25055.31c  9.3634E-07
      26054.31c  1.7498E-06
      26056.31c  2.7467E-05
      26057.31c  6.3434E-07
      26058.31c  8.4420E-08
      29063.31c  1.2750E-06
      29065.31c  5.4640E-07
c Total 4.7627E-02
c
c M29 Aluminium plate ALG8
m29  13027.31c  2.6704E-02
      14028.31c  1.0296E-05
      25055.31c  6.5793E-07
      26054.31c  2.1261E-06
      26056.31c  3.3375E-05
      26057.31c  7.7077E-07
      26058.31c  1.0257E-07
      29063.31c  3.1854E-07
      29065.31c  1.3651E-07
c Total 2.6752E-02
c
c MATERIAL 30 AL2O34
m30  1001.31c  5.1483E-05
      5010.31c  4.5063E-06
      5011.31c  1.6599E-05
      8016.31c  6.6386E-02
      13027.31c  4.4240E-02
c Total 1.106986E-01
c
c Material 31 the UPuO2 plate PUIV4 core
c

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m31    6000.31c    6.2771E-05
        8016.31c    4.2860E-02
        13027.31c   2.7943E-05
        14028.31c   2.6845E-05
        26054.31c   7.8908E-07
        26056.31c   1.2387E-05
        26057.31c   2.8607E-07
        26058.31c   3.8070E-08
        28058.31c   8.7452E-06
        28060.31c   3.3686E-06
        28061.31c   1.4643E-07
        28062.31c   4.6689E-07
        28064.31c   1.1890E-07
        92234.31c   7.4340E-07
        92235.31c   1.1548E-04
        92238.31c   1.5938E-02
        93237.31c   2.4466E-07
        94239.31c   4.7730E-03
        94240.31c   5.3344E-04
        94241.31c   5.0303E-05
        94242.31c   4.7919E-06
        95241.31c   2.6204E-05

c
c Total 6.4446E-02
c material 32 The UPuO2 plate PUIV4 canning
m32    1001.31c    2.0111E-05
        6000.31c    1.6876E-04
        14028.31c   5.9180E-04
        15031.31c   2.6177E-05
        16032.31c    2.5282E-05
        25055.31c   1.0995E-03
        24050.31c   6.0639E-04
        24052.31c   1.1694E-02
        24053.31c   1.3260E-03
        24054.31c   3.3006E-04
        26054.31c   2.9475E-03
        26056.31c   4.6270E-02
        26057.31c   1.0686E-03
        26058.31c   1.4221E-04
        28058.31c   4.6976E-03
        28060.31c   1.8095E-03
        28061.31c   7.8659E-05
        28062.31c   2.5080E-04
        28064.31c   6.3871E-05
        29063.31c   1.9854E-04
        29065.31c   8.5090E-05

c
c Total 7.3500E-02
c
c
c MATERIAL 33 Pu metal plate PUVI8 core
c
m33    92238.31c   2.4663E-07
        94238.31c   3.6995E-05
        94239.31c   2.8972E-02
        94240.31c   7.3421E-03
        94241.31c   1.1537E-03
        94242.31c   2.0132E-04
        95241.31c   8.6769E-05
        1001.31c    1.0485E-04
        6000.31c    2.2876E-04
        7014.31c    2.4312E-05
        8016.31c    3.5962E-05
        13027.31c   1.7408E-05
        25055.31c   1.0687E-06
        24050.31c   1.3737E-07
        24052.31c   2.6491E-06
        24053.31c   3.0038E-07
        24054.31c   7.4772E-08
        26054.31c   1.1307E-06
        26056.31c   1.7749E-05
        26057.31c   4.0990E-07
        26058.31c   5.4549E-08
        28058.31c   4.6308E-06
        28060.31c   1.7838E-06
        28061.31c   7.7540E-08

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28062.31c 2.4723E-07
28064.31c 6.2963E-08
31000.31c 2.2555E-03
c total 33 4.04903E-02
c MATERIAL 34 PuVI8 plate canning
c
m34 1001.31c 1.3955E-05
    6000.31c 1.1413E-04
    14028.31c 3.6853E-04
    15031.31c 1.3545E-05
    16032.31c 9.3252E-06
    25055.31c 8.6563E-04
    24050.31c 4.1142E-04
    24052.31c 7.9338E-03
    24053.31c 8.9963E-04
    24054.31c 2.2394E-04
    26054.31c 2.0924E-03
    26056.31c 3.2846E-02
    26057.31c 7.5855E-04
    26058.31c 1.0095E-04
    28058.31c 2.8554E-03
    28060.31c 1.0999E-03
    28061.31c 4.7812E-05
    28062.31c 1.5245E-04
    28064.31c 3.8823E-05
    29063.31c 1.1638E-02
    29065.31c 4.9880E-03
c total 34 6.74722E-02
c
C MATERIAL 35 Pu metal plate PUVII8 core
c
m35 92238.31c 9.3720E-07
    94238.31c 3.1569E-05
    94239.31c 2.9028E-02
    94240.31c 6.9606E-03
    94241.31c 1.1476E-03
    94242.31c 1.8725E-04
    95241.31c 5.3467E-05
    1001.31c 1.3980E-04
    6000.31c 2.0335E-04
    7014.31c 6.7066E-06
    8016.31c 5.4310E-05
    13027.31c 1.6973E-05
    14028.31c 1.0870E-05
    25055.31c 8.5494E-07
    24050.31c 1.7662E-07
    24052.31c 3.4059E-06
    24053.31c 3.8621E-07
    24054.31c 9.6135E-08
    26054.31c 6.1449E-07
    26056.31c 9.6461E-06
    26057.31c 2.2277E-07
    26058.31c 2.9646E-08
    28058.31c 6.1291E-06
    28060.31c 2.3609E-06
    28061.31c 1.0263E-07
    28062.31c 3.2722E-07
    28064.31c 8.3333E-08
    31000.31c 2.0492E-03
c total 35 3.99151E-02
c MATERIAL 36 PuVII8 plate canning
c
m36 1001.31c 1.3771E-05
    6000.31c 1.1357E-04
    14028.31c 3.6675E-04
    15031.31c 1.3479E-05
    25055.31c 8.6145E-04
    24050.31c 4.0943E-04
    24052.31c 7.8955E-03
    24053.31c 8.9529E-04
    24054.31c 2.2286E-04
    26054.31c 2.0823E-03
    26056.31c 3.2687E-02
    26057.31c 7.5489E-04
    26058.31c 1.0046E-04
    28058.31c 2.8417E-03

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28060.31c 1.0946E-03
28061.31c 4.7581E-05
28062.31c 1.5171E-04
28064.31c 3.8636E-05
29063.31c 1.1638E-02
29065.31c 4.9880E-03
c total 36 6.72170E-02
c
C MATERIAL 37 Pu metal plate PUVIII8 core
c
m37 92238.31c 6.9057E-07
    94238.31c 3.0583E-05
    94239.31c 2.9035E-02
    94240.31c 6.9371E-03
    94241.31c 1.1574E-03
    94242.31c 1.8773E-04
    95241.31c 4.4181E-05
    1001.31c 1.2815E-04
    6000.31c 4.2429E-04
    7014.31c 2.4312E-05
    8016.31c 8.8804E-05
    13027.31c 2.3065E-05
    14028.31c 1.4215E-05
    25055.31c 1.4962E-06
    24050.31c 1.5700E-07
    24052.31c 3.0275E-06
    24053.31c 3.4330E-07
    24054.31c 8.5455E-08
    26054.31c 9.5858E-07
    26056.31c 1.5048E-05
    26057.31c 3.4751E-07
    26058.31c 4.6247E-08
    28058.31c 5.8567E-06
    28060.31c 2.2560E-06
    28061.31c 9.8066E-08
    28062.31c 3.1268E-07
    28064.31c 7.9630E-08
    31000.31c 2.0247E-03
c total 37 4.01503E-02
c MATERIAL 38 PuVIII8 plate canning
c CR 9.4087E-03 FE 3.5570E-02 NI 4.1678E-03
m38 1001.31c 1.3771E-05
    6000.31c 1.1340E-04
    14028.31c 3.6619E-04
    15031.31c 1.3461E-05
    25055.31c 8.6013E-04
    24050.31c 4.0881E-04
    24052.31c 7.8835E-03
    24053.31c 8.9392E-04
    24054.31c 2.2252E-04
    26054.31c 2.0791E-03
    26056.31c 3.2637E-02
    26057.31c 7.5372E-04
    26058.31c 1.0031E-04
    28058.31c 2.8373E-03
    28060.31c 1.0929E-03
    28061.31c 4.7509E-05
    28062.31c 1.5148E-04
    28064.31c 3.8577E-05
    29063.31c 1.1638E-02
    29065.31c 4.9880E-03
c total 38 6.71396E-02
c
c MATERIAL 39 PUX8 Plutonium metal plate core
m39 92238.31c 1.4305E-06
    94238.31c 3.4035E-05
    94239.31c 2.9107E-02
    94240.31c 6.9117E-03
    94241.31c 1.1359E-03
    94242.31c 1.8531E-04
    95241.31c 3.3658E-05
    1001.31c 1.0485E-04
    6000.31c 2.9524E-04
    7014.31c 1.0060E-05
    8016.31c 4.5503E-05
    13027.31c 2.1760E-05

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LIQUID METAL FAST REACTOR - LMFR
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14028.31c	1.5887E-05
25055.31c	1.0687E-06
24050.31c	1.8643E-07
24052.31c	3.5952E-06
24053.31c	4.0767E-07
24054.31c	1.0148E-07
26054.31c	8.7254E-07
26056.31c	1.3697E-05
26057.31c	3.1632E-07
26058.31c	4.2096E-08
28058.31c	1.1032E-05
28060.31c	4.2498E-06
28061.31c	1.8473E-07
28062.31c	5.8901E-07
28064.31c	1.5000E-07
31000.31c	2.2417E-03
C TOTAL 39 4.01805E-02	
C	
c MATERIAL 40 PUX8 Plutonium metal plate can	
c	
m40	1001.31c 1.3587E-05
6000.31c	1.2050E-04
14028.31c	5.2025E-04
15031.31c	2.6701E-05
16032.31c	1.5471E-05
22048.31c	5.7590E-06
25055.31c	8.5308E-04
24050.31c	4.3310E-04
24052.31c	8.3520E-03
24053.31c	9.4705E-04
24054.31c	2.3574E-04
26054.31c	1.9782E-03
26056.31c	3.1053E-02
26057.31c	7.1715E-04
26058.31c	9.5439E-05
28058.31c	3.2937E-03
28060.31c	1.2688E-03
28061.31c	5.5152E-05
28062.31c	1.7585E-04
28064.31c	4.4783E-05
29063.31c	1.1808E-02
29065.31c	5.0600E-03
c total 40 6.70733E-02	
c	
C MATERIAL 41 PUXI8 Plutonium metal plate core	
c	
m41	92238.31c 6.9057E-07
94238.31c	3.7488E-05
94239.31c	2.8990E-02
94240.31c	6.9709E-03
94241.31c	1.1546E-03
94242.31c	1.8482E-04
95241.31c	3.0855E-05
1001.31c	1.7475E-04
6000.31c	2.2876E-04
7014.31c	1.1737E-05
8016.31c	4.1833E-05
13027.31c	1.8713E-05
14028.31c	1.8396E-05
25055.31c	1.0687E-06
24050.31c	2.6493E-07
24052.31c	5.1090E-06
24053.31c	5.7931E-07
24054.31c	1.4420E-07
26054.31c	1.3027E-06
26056.31c	2.0449E-05
26057.31c	4.7226E-07
26058.31c	6.2849E-08
28058.31c	1.1986E-05
28060.31c	4.6169E-06
28061.31c	2.0069E-07
28062.31c	6.3989E-07
28064.31c	1.6296E-07
31000.31c	2.2490E-03
c total 41 4.01596E-02	
c	

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c Material 42 PUXI8 can
m42      1001.31c  1.3404E-05
          6000.31c  1.1825E-04
          14028.31c 5.1057E-04
          15031.31c 2.6205E-05
          16032.31c 1.5188E-05
          22048.31c 5.6508E-06
          25055.31c 8.3722E-04
          24050.31c 4.2505E-04
          24052.31c 8.1967E-03
          24053.31c 9.2943E-04
          24054.31c 2.3136E-04
          26054.31c 1.9414E-03
          26056.31c 3.0476E-02
          26057.31c 7.0382E-04
          26058.31c 9.3665E-05
          28058.31c 3.2325E-03
          28060.31c 1.2452E-03
          28061.31c 5.4126E-05
          28062.31c 1.7258E-04
          28064.31c 4.3950E-05
          29063.31c 1.1808E-02
          29065.31c 5.0600E-03
C total 42 6.61403E-02
c
c C MATERIAL 43 PUXII8 Plutonium metal plate core
c
m43      92238.31c 1.6771E-06
          94238.31c 3.6995E-05
          94239.31c 2.9064E-02
          94240.31c 6.8990E-03
          94241.31c 1.1606E-03
          94242.31c 1.7997E-04
          95241.31c 2.7359E-05
          1001.31c 1.7475E-04
          6000.31c 2.6298E-04
          7014.31c 6.7066E-06
          8016.31c 4.1833E-05
          13027.31c 1.7408E-05
          14028.31c 2.2159E-05
          25055.31c 8.5494E-07
          24050.31c 4.0230E-07
          24052.31c 7.7580E-06
          24053.31c 8.7970E-07
          24054.31c 2.1898E-07
          26054.31c 8.7254E-07
          26056.31c 1.3697E-05
          26057.31c 3.1632E-07
          26058.31c 4.2096E-08
          28058.31c 1.6208E-05
          28060.31c 6.2435E-06
          28061.31c 2.7140E-07
          28062.31c 8.6534E-07
          28064.31c 2.2038E-07
          31000.31c 2.3032E-03
c total 43 4.02475E-02
c
c Material 44 PUXII8 can
c
m44      1001.31c 1.3220E-05
          6000.31c 1.1685E-04
          14028.31c 5.0450E-04
          15031.31c 2.5895E-05
          16032.31c 1.5004E-05
          22048.31c 5.5851E-06
          25055.31c 8.2726E-04
          24050.31c 4.1999E-04
          24052.31c 8.0991E-03
          24053.31c 9.1838E-04
          24054.31c 2.2860E-04
          26054.31c 1.9183E-03
          26056.31c 3.0114E-02
          26057.31c 6.9545E-04
          26058.31c 9.2551E-05
          28058.31c 3.1940E-03
          28060.31c 1.2304E-03

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28061.31c 5.3482E-05
28062.31c 1.7052E-04
28064.31c 4.3427E-05
29063.31c 1.1808E-02
29065.31c 5.0600E-03
c Total 44 6.55545E-02
c
c
c --- MODE CARDS ---
c
c
mode n
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ksrc 0.0 0.0 100.0 0.0 0.0 112.0 0.0 0.0 124.3 0.0 0.0 136.3
      0.0 0.0 148.6 0.0 0.0 160.6 0.0 0.0 173.0 0.0 0.0 185.0
      27.0 0.0 100.0 27.0 0.0 112.0 27.0 0.0 124.3 27.0 0.0 136.3
      27.0 0.0 148.6 27.0 0.0 160.6 27.0 0.0 173.0 27.0 0.0 185.0
      -27.0 0.0 100.0 -27.0 0.0 112.0 -27.0 0.0 124.3 -27.0 0.0 136.3
      -27.0 0.0 148.6 -27.0 0.0 160.6 -27.0 0.0 173.0 -27.0 0.0 185.0
      0.0 27.0 100.0 0.0 27.0 112.0 0.0 27.0 124.3 0.0 27.0 136.3
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      0.0 -27.0 100.0 0.0 -27.0 112.0 0.0 -27.0 124.3 0.0 -27.0 136.3
      0.0 -27.0 148.6 0.0 -27.0 160.6 0.0 -27.0 173.0 0.0 -27.0 185.0
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      27.0 27.0 148.6 27.0 27.0 160.6 27.0 27.0 173.0 27.0 27.0 185.0
      -27.0 27.0 100.0 -27.0 27.0 112.0 -27.0 27.0 124.3 -27.0 27.0 136.3
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      27.0 -27.0 100.0 27.0 -27.0 112.0 27.0 -27.0 124.3 27.0 -27.0 136.3
      27.0 -27.0 148.6 27.0 -27.0 160.6 27.0 -27.0 173.0 27.0 -27.0 185.0
      -27.0 -27.0 100.0 -27.0 -27.0 112.0 -27.0 -27.0 124.3 -27.0 -27.0 136.3
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      8.1 8.1 100.0 8.1 8.1 112.0 8.1 8.1 124.3 8.1 8.1 136.3
      8.1 8.1 148.6 8.1 8.1 160.6 8.1 8.1 173.0 8.1 8.1 185.0
      -8.1 8.1 100.0 -8.1 8.1 112.0 -8.1 8.1 124.3 -8.1 8.1 136.3
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      -8.1 -8.1 148.6 -8.1 -8.1 160.6 -8.1 -8.1 173.0 -8.1 -8.1 185.0
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      -70.5 0.0 152.5 -70.5 0.0 163.5 -70.5 0.0 175.0 -70.5 0.0 186.0
      0.0 70.5 107.5 0.0 70.5 118.5 0.0 70.5 130.0 0.0 70.5 141.0
      0.0 70.5 152.5 0.0 70.5 163.5 0.0 70.5 175.0 0.0 70.5 186.0
      0.0 -70.5 107.5 0.0 -70.5 118.5 0.0 -70.5 130.0 0.0 -70.5 141.0
      0.0 -70.5 152.5 0.0 -70.5 163.5 0.0 -70.5 175.0 0.0 -70.5 186.0
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      70.5 70.5 152.5 70.5 70.5 163.5 70.5 70.5 175.0 70.5 70.5 186.0
      -70.5 70.5 107.5 -70.5 70.5 118.5 -70.5 70.5 130.0 -70.5 70.5 141.0
      -70.5 70.5 152.5 -70.5 70.5 163.5 -70.5 70.5 175.0 -70.5 70.5 186.0
      70.5 -70.5 107.5 70.5 -70.5 118.5 70.5 -70.5 130.0 70.5 -70.5 141.0
      70.5 -70.5 152.5 70.5 -70.5 163.5 70.5 -70.5 175.0 70.5 -70.5 186.0
      -70.5 -70.5 107.5 -70.5 -70.5 118.5 -70.5 -70.5 130.0 -70.5 -70.5 141.0
      -70.5 -70.5 152.5 -70.5 -70.5 163.5 -70.5 -70.5 175.0 -70.5 -70.5 186.0
      48.8 48.8 107.5 48.8 48.8 118.5 48.8 48.8 130.0 48.8 48.8 141.0
      48.8 48.8 152.5 48.8 48.8 163.5 48.8 48.8 175.0 48.8 48.8 186.0
      -48.8 48.8 107.5 -48.8 48.8 118.5 -48.8 48.8 130.0 -48.8 48.8 141.0
      -48.8 48.8 152.5 -48.8 48.8 163.5 -48.8 48.8 175.0 -48.8 48.8 186.0
      48.8 -48.8 107.5 48.8 -48.8 118.5 48.8 -48.8 130.0 48.8 -48.8 141.0
      48.8 -48.8 152.5 48.8 -48.8 163.5 48.8 -48.8 175.0 48.8 -48.8 186.0
      -48.8 -48.8 107.5 -48.8 -48.8 118.5 -48.8 -48.8 130.0 -48.8 -48.8 141.0
      -48.8 -48.8 152.5 -48.8 -48.8 163.5 -48.8 -48.8 175.0 -48.8 -48.8 186.0
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