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DIMPLE S01A Models

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Summary

This paper contains details of the 3D and 1D models used to study the DIMPLE S01A core using Mote-Carlo and deterministic methods.

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CONTENTS

1. INTRODUCTION

At the December 1994 JEF Benchmark Working Group meeting (JEF/DOC-515) a detailed description of DIMPLES01 was presented (JEF/DOC-504). A. Knipe's paper specifies all components of the reactor subject to minimal validated homogenisation of minor components. It thus gives appropriate detail to set up complex three dimensional models. The paper also specifies experimental bucklings which enable the construction of pincell models. The JEF working group wished to use DIMPLES01 as a method benchmark to study the representation of leakage in different deterministic codes. (20% of neutrons leak from the core.) However it was noted that A. Knipe's paper did not include sample input for either a 3D or a pincell model. This follow up paper has thus been written to include both.

2. THE WIMS6 COMPUTER CODE

WIMS6 (1) includes deterministic and Monte Carlo methods for modelling reactors. The NOVICE sub-group treatment has been introduced and the MONK5W Monte Carlo code included as a module. Both methods use broad group cross sections (172 energy groups at most). However by incorporating MONK5W in WIMS6 we are able to run our 3D model of DIMPLE, and our PINCELL model with the same nuclear data and Monte Carlo method. Further within the same code we are able to perform a deterministic PINCELL calculation. Before performing this latter calculation we optimised the deterministic PINCELL route within WIMS6 after studying results from Monte Carlo solutions of the PWR PINCELL Benchmark (JEF/DOC-494). A further important feature of MONK5W is that the geometric input is very similar to that for the hyper-fine (12000) group Monte Carlo code MONK7 (2).

3. NUCLEAR DATA

The 1995 (JEF2.2 based) WIMS nuclear data library in 172 groups was used for all calculations quoted in this paper. Results are also available using other JEF2.2 and UKNDL based libraries but are not included here.

4. FULL REACTOR MODEL

Figure 1 shows a typical picture of a Dimple core. A very important validated feature of the cylindrical pin arrangement in the DIMPLES01 core is that 13 cm of water forms an effectively infinite reflector. Thus features more than 13 cm from the edge of the outermost pin can be ignored. There is no need to model: the biological shield, the primary vessel, the beam support chassis, and radial components of the fuel support beams. Core components in the model are shown in Figure 2. The moderator height is below the upper lattice plate and it is probable that this structure and detail at the top of the pins need not be modelled but this has not been proved so all were included. A nominal axial and radial water/air filled surround is included to give a cylinder 100cm in radius and 93 cm high. Temperature corrected critical moderator height is 49.26cm above the fuel base in an average pin.

Using dimensions and material compositions in A. Knipe's paper, the annotated input in Appendix 1 was set up. There are 13 materials used. The MONK geometry

data assembles the core by forming building blocks of specified shape called TYPEs. One TYPE can contain several others as components. The core is assembled in TYPE 19. We have annotated all TYPEs so by starting at TYPE 19 it should be possible to get some idea of the structure without a MONK data description. However TYPEs contain more complex shapes called HOLES. We have referenced figures in JEF/DOC -497 to help describe the HOLES but note that is not possible to understand the model fully without a MONK5W user guide(3). However an experienced Monte Carlo user will have some understanding.

All input data were checked by both authors against A. Knipe's paper. The VISAGE(4) code was used to generate 2D axial and radial colour pictures of the detailed structure.

The NOVICE option in the WHEAD module generates sub- group cross sections and weights for the MONK5W Monte Carlo calculation by fitting group dependent tables of resonance integrals tabulated against background cross section. The same sub-group cross sections and weights are used in the 1D calculation.

Three MONK5W calculations were run using different random number seeds. Results quoted below give average K values to higher accuracy than is obtained by running a single calculation for 3 times as long. This method also gives more confidence in results.

5. PINCELL MODELS

The reflected average pincell model is shown in Figure 3. Experimental bucklings are applied to transform the K_∞ model into a representative 1D reactor calculation giving K-effective. The 3% enriched UO2 fuel is clad in crimped and glued aluminium foil. The can is stainless steel and the moderator light water. Appendix 2 give the annotated MONK5W model and Appendix 3 that for the deterministic calculation.

The NOVICE option in the WHEAD module is again used for MONK5W but a different sub-group fitting is performed for the deterministic calculation. Here the WPRES module generates overall sub-group cross sections covering the resonance range. These are mixed and used in WPIJ to form collision probabilities. The module WRES firstly forms group dependent weights then uses these with the energy independent sub-group cross sections to form shielded group data for DIMPLES01 fuel.

Again, three MONK5W calculations are performed for the Monte Carlo PINCELL. The deterministic route uses the shielded cross sections to form collision probabilities in WPIJ and then uses these in WPIP to calculate fluxes and subsequently WCRITIC is used to apply the experimental bucklings and calculate K-effective.

6. UK RESULTS

Figure 4 gives the K values from the 3 calculations. A. Knipe quotes the overall experimental uncertainty of between +/- 0.001 to +/- 0.002 on reactivity. All our results with JEF2.2 are close to these. Three dimensional Monte Carlo broad group calculations indicate JEF2.2 may give very slightly high results but ironically the deterministic pincell calculation is closer to unity.

7. CONCLUSIONS

Three and one dimensional models of DIMPLES01 are presented.

The models have been used to calculate K-effective close to experimental accuracy using broad group JEF2.2 data.

We recommend DIMPLES01 be adopted as a method benchmark.

8. REFERENCES

1 M J Halsall et al.
An Introduction to WIMS6
American Nuclear Society 1994 Topical Meeting on Advances in Reactor Physics
Knoxville, Tennessee, April 1994

2 The ANSWERS Software Package MONK
A Monte Carlo Program for Nuclear Criticality Safety Analyses.
A User Guide for Version 7A
ANSWERS/MONK(94)3

3 MONK5W - User Guide
AEEW-R2445
July 1991

4 VISAGE2 User Guide.
ANSWERS/VISAGE(93)3
June 1993

Figure 1. TYPICAL ARRANGEMENT OF ASSEMBLY WITHIN DIMPLE PRIMARY VESSEL

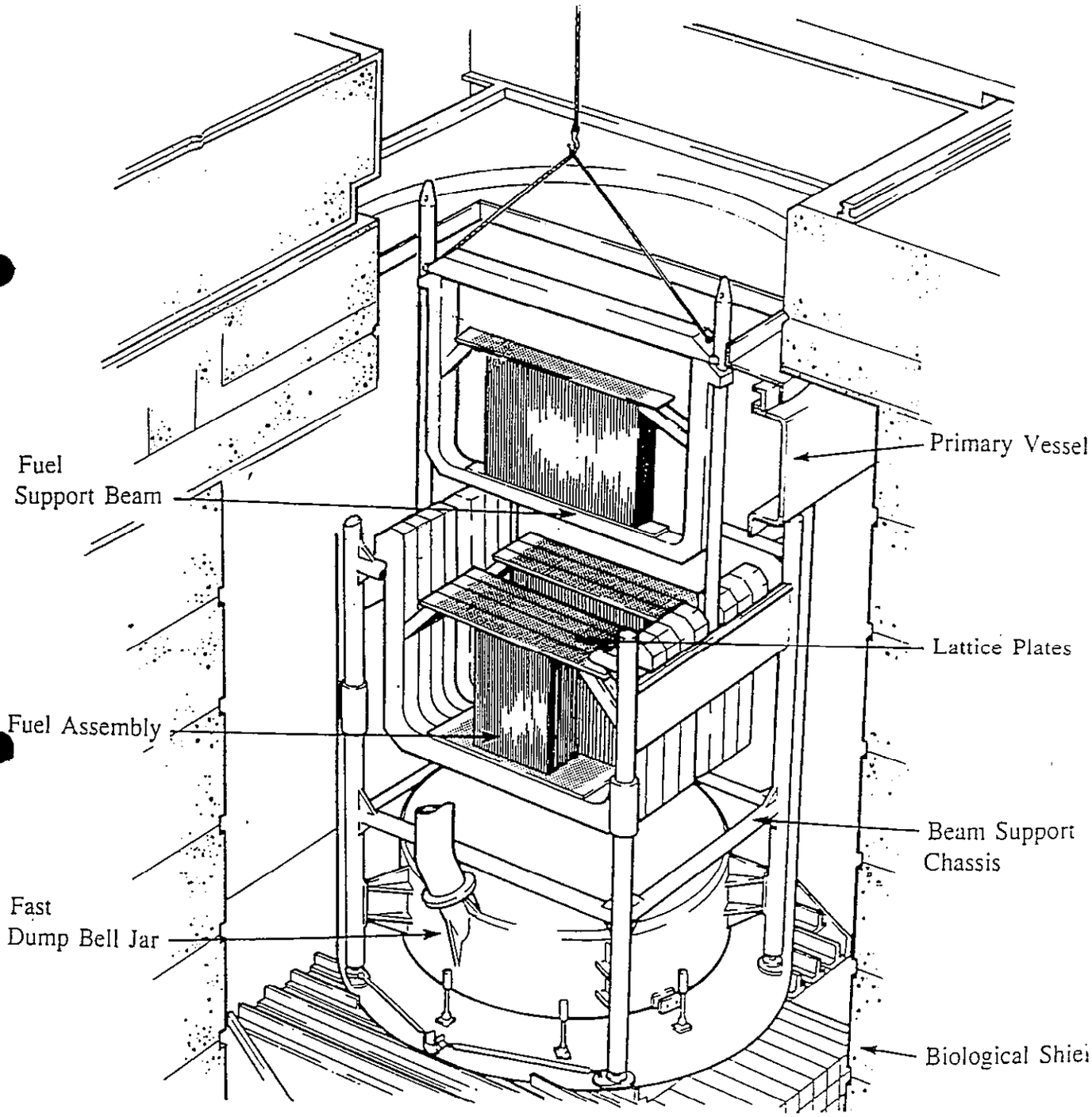

Figure 2. CORE COMPONENTS INCLUDED IN THE 3D MODEL

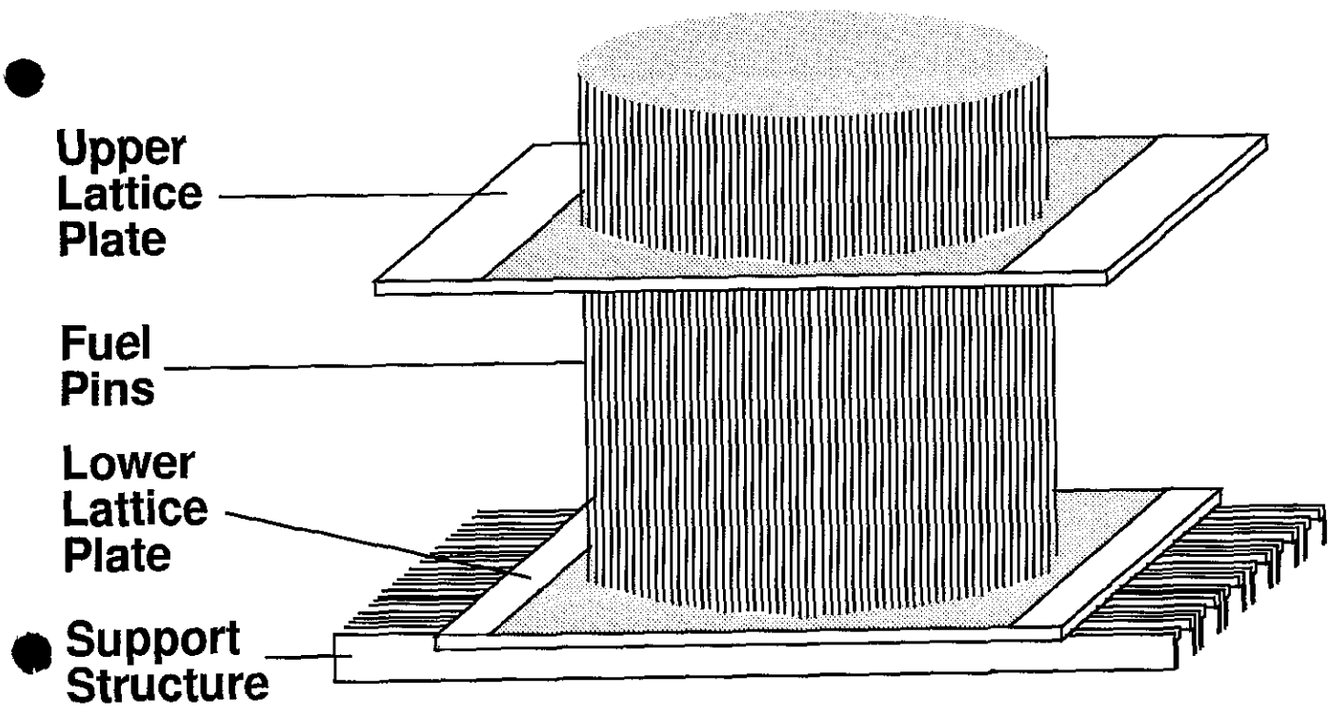

Figure 3. GEOMETRY OF DIMPLE S01A PINCELL MODEL

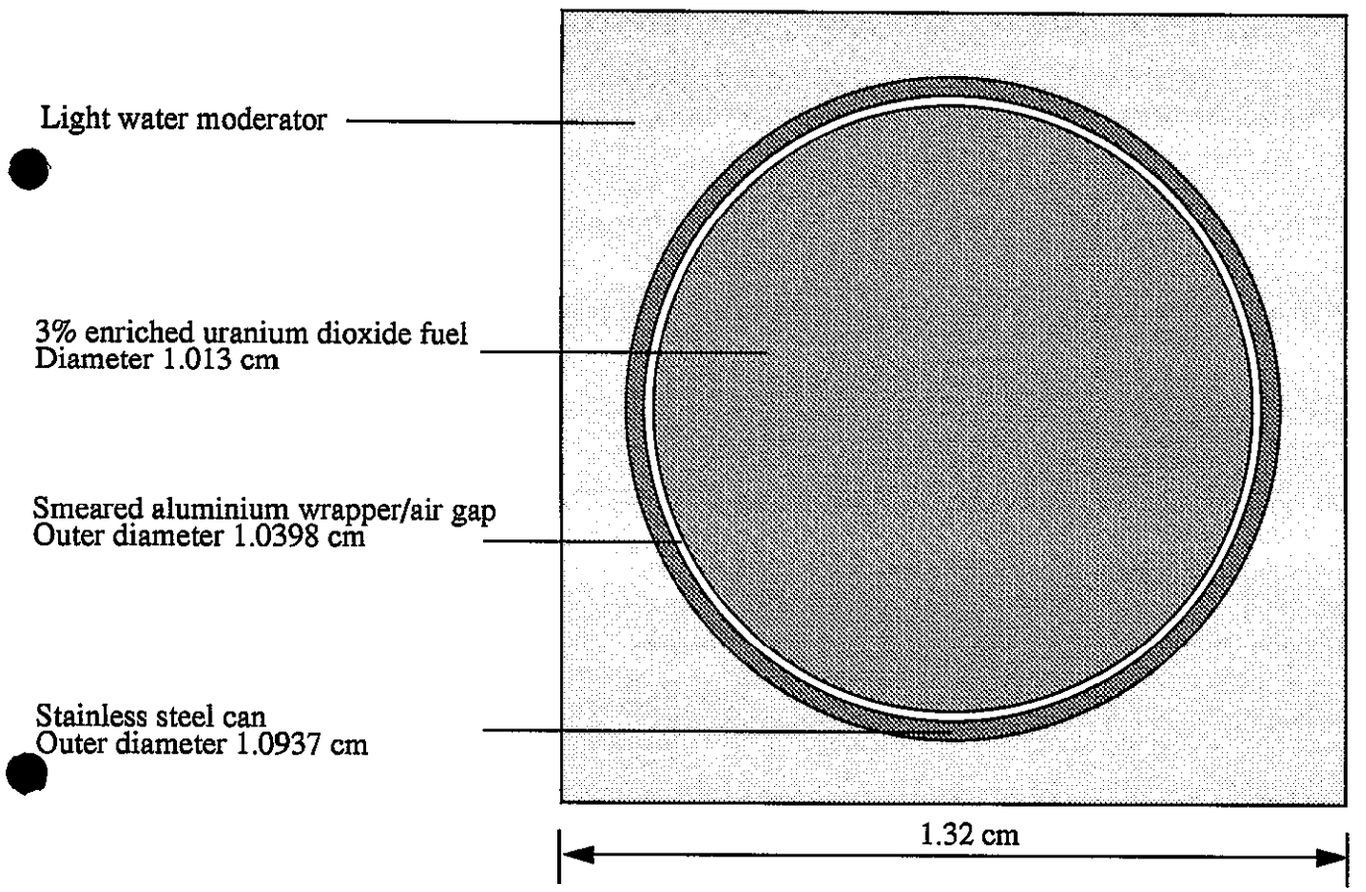

Figure 4. RESULTS FROM THE DIMPLE S01A BENCHMARK FOR THE 1995 WIMS LIBRARY IN 172 GROUPS

MODEL	K-EFFECTIVE
MONK5W 3D	1.0014 +/- 0.0008
MONK5W Pincell	1.0028 +/- 0.0006
Deterministic Pincell	1.00074

Appendix 1. INPUT FOR MONK5W 3D MODEL

```
* Dimple S01 3D MODEL
* WIMS6, 1995 Library, 172 groups
************************************************************************
*                                                                      *
*                        WIMS control data                             *
*      The HEAD module prepares material cross sections for 13         *
*      materials in 13 regions with P1 data.                           *
*                                                                      *
************************************************************************
WHEAD 1
* Prelude data
NMATER 13
NREGION 13
PONE
endp
* Main data
cent
*
*  DIMPLE CORE S01A from JEF/DOC-497
*
************************************************************************
*                     MATERIAL DATA                                    *
* Tables 1 - 3 of JEF/DOC-497                                          *
*                                                                      *
*   1) Pin Dowels  2) outer clad 3)3% enriched fuelUO2 4) moderator    *
*   5) fuel beam base 6) Lower end plugs                               *
*   7) UO2 ABOVE WATER LEVEL 8) fuel wrapper                           *
*   9) Upper End Plug and Shims 10)Upper Lattice Plate                 *
*   11) Lower Lattice Plate     12 Fuel Support Plate                  *
*   13) Air (as in dungeness)                                          *
*  Note                                                                *
* Zn64 used for Zn due to lack of evaluated data for natural zn       *
*                                                                      *
* Material specifications consist of the following data               *
* keyword 'MATE', material number, density (g/cc), temperature,       *
* resonance region number (1=fuel, 2 or 3 otherwise), a list of       *
* nuclide-abundance (mass %) pairs.                                    *
************************************************************************
MATE 1 6.072  293.16 2 CO 0.125 CR 16.85 CU 0.28 FE 70.515 MN 1.17
                       MO 0.425 NI 9.65 S32 0.066514 S33 5.25e-04
                       S34 2.947e-03 S36 1.4e-5 SI 0.425 TI 0.44
                       ZN64 0.05
MATE 2 7.806  293.16 2 FE 67.552 MN 1.66 MO .34 AL .246 CR 18.0 CO .102
                       CU .152 NI 11.18 TI 0.666 V 0.05 ZN64 0.052
MATE 3 10.42  293.16 1 FE 0.008 SI 0.0116 O 11.8919 U234 0.0169
                       U235 2.6465 U236 0.0363 U238 85.3603 AL .0285
MATE 4 0.9982041  293.16 3 H 11.19 O 88.81
MATE 5 2.844  293.16 2 AL 87.405 C 0.001 CO 0.003 CR 1.371 CU 0.016
                       FE 5.5 MG 0.508 MN 0.156 MO 0.006 NB 0.018
                       NI 0.774 P 0.0001 S32 9.502e-04 S33 7.5e-06
                       S34 4.21e-05 S36 2.0e-07 SI 4.071 SN 0.042
                       TI 0.126 ZN64 0.001
MATE 6 1.644  293.16 2 AL 97.5006 CU 0.0072 FE 0.22 MG 1.84 MN 0.265
                       NI 0.0085 SI 0.15 TI 0.0087
MATE 7 10.42  293.16 1 FE 0.008 SI 0.0116 O 11.8919 U234 0.0169
                       U235 2.6465 U236 0.0363 U238 85.3603 AL .0285
```

```
MATE 8 0.868  293.16 2 AL 84.7439 CR 0.0025 CU 0.015 FE 0.3 MG 0.0015
                       MN 0.006 NI 0.002 SI 0.025 C 12.76 H 2.13
                       CL 0.005 SN 0.009 SR84 5.6e-07 SR86 9.86e-06
                       SR87 7.0e-06 SR88 8.258e-05
MATE 9 1.6    293.16 2 AL 98.1891 CU 0.0047 FE 0.2719 MG 1.2032
                       MN 0.1733 NI 0.0056 SI 0.1465 TI 0.0057
MATE 10 2.669 293.16 2 AL 97.0 CU 0.01 FE 0.35 MG 2.08 MN 0.34 SI 0.2
                    Ti 0.01 ZN64 0.01
MATE 11 2.681 293.16 2 AL 97.07 CU 0.03 FE 0.3 MG 2.12 MN 0.36 SI 0.12
MATE 12 3.279 293.16 2 AL 71.36 C 0.01 CR 4.729 CU 0.015 FE 18.508
                       MG 1.498 MN 0.659 NB 0.105 NI 2.836 P 0.006
                       S32 2.8506e-03 S33 2.25e-05 S34 1.263e-04
                       S36 6.0e-07 SI 0.215 TI 0.049 ZN64 0.007
MATE 13    -1 293.16 3 C 7.511E-9 N 3.910E-5 O 1.051E-5
*********************************************************************
*                                                                   *
*    A dummy region (annulus) is defined for each of the 13 materials   *
*    WIMS requires that all materials be used in an annulus and that the   *
*    inner annulus contains a fuel material.                        *
*                                                                   *
*********************************************************************
annulus 1 1 3
annulus 2 2 7
annulus 3 3 1
annulus 4 4 2
annulus 5 5 5
annulus 6 6 6
annulus 7 7 8
annulus 8 8 9
annulus 9 9 10
annulus 10 10 11
annulus 11 11 12
annulus 12 12 4
annulus 13 13 13
*********************************************************************
*                                                                   *
*      The NOVICE sub-group treatment is requested                  *
*                                                                   *
*********************************************************************
NOVICE
beginc
*
*********************************************************************
*                                                                   *
*                   MONK5W control data                             *
*                                                                   *
*********************************************************************
WMONK 1
AMSTO 9000000 1210000
VWTS 0.5 1.5 0.167
NOVICE DATA
13 172 0
FLUX 172
PRINT FX BC AC GR MG
PONE 172
SUBGROUP 13 46 92
CM
19
```

```
*********************************************************************
*                     GEOMETRY DATA                                 *
*                                                                   *
*********************************************************************
*  Build components called TYPEs. Assemble into other TYPEs later.  *
*********************************************************************
*                                                                   *
*Type 1  Lower core support                                         *
*       Fuel support plate (regions 1-12) then Lattice support beams*
*  See figure 9 JEF/DOC-497                                         *
*  Note- overall radius of the enclosing cylinder is nominal (over  *
*       ~13 cm outside the fuel). This allows representation of the *
*       whole of the lattice plates and support beams.              *
*                                                                   *
*  The simple cuboidal geometry of the fuel support structures are  *
*  defined by specifying the overall dimensions, position and       *
*  material of each component.                                      *
*  One component is defined per line thus                           *
*  region number, region type, material number, +x +y +z -x -y -z   *
*                                                                   *
* E.g. CUBOID 1 is of material 12 has                               *
*      x planes from -64cm to +64cm                                 *
*      y planes from 32.148cm to 34.1635cm                          *
*      z planes from -4.126cm to -2.348cm                           *
*                                                                   *
*********************************************************************
*                                                                   *
*TYPE 1
CLUSTER 25
1  CUBOID 12  64.0  34.1635  -2.348 -64.0  32.148    -4.126
2  CUBOID 12  64.0  27.162   -2.348 -64.0  25.1465   -4.126
3  CUBOID 12  64.0  22.3015  -2.348 -64.0  20.286    -4.126
4  CUBOID 12  64.0  15.3     -2.348 -64.0  13.2845   -4.126
5  CUBOID 12  64.0  10.4395  -2.348 -64.0   8.424    -4.126
6  CUBOID 12  64.0   3.438   -2.348 -64.0   1.4225   -4.126
7  CUBOID 12  64.0  -1.4225  -2.348 -64.0  -3.438    -4.126
8  CUBOID 12  64.0  -8.424   -2.348 -64.0 -10.4395   -4.126
9  CUBOID 12  64.0 -13.2845  -2.348 -64.0 -15.3      -4.126
10 CUBOID 12  64.0 -20.286   -2.348 -64.0 -22.3015   -4.126
11 CUBOID 12  64.0 -25.1465  -2.348 -64.0 -27.162    -4.126
12 CUBOID 12  64.0 -32.148   -2.348 -64.0 -34.1635   -4.126
13 CUBOID  5  64.0  34.1635  -4.126 -64.0  32.6189  -16.826
14 CUBOID  5  64.0  26.6911  -4.126 -64.0  25.1465  -16.826
15 CUBOID  5  64.0  22.3015  -4.126 -64.0  20.7569  -16.826
16 CUBOID  5  64.0  14.8291  -4.126 -64.0  13.2845  -16.826
17 CUBOID  5  64.0  10.4395  -4.126 -64.0   8.8949  -16.826
18 CUBOID  5  64.0   2.9671  -4.126 -64.0   1.4225  -16.826
19 CUBOID  5  64.0  -1.4225  -4.126 -64.0  -2.9671  -16.826
20 CUBOID  5  64.0  -8.8949  -4.126 -64.0 -10.4395  -16.826
21 CUBOID  5  64.0 -13.2845  -4.126 -64.0 -14.8291  -16.826
22 CUBOID  5  64.0 -20.7569  -4.126 -64.0 -22.3015  -16.826
23 CUBOID  5  64.0 -25.1465  -4.126 -64.0 -26.6911  -16.826
24 CUBOID  5  64.0 -32.6189  -4.126 -64.0 -34.1635  -16.826
25 CYLINDER 4 100.0 -2.348 -17
*********************************************************************
*                                                                   *
*   Type 2            FUEL CELL                                     *
*  Hole 11 is the fuel pin containing fuel-wrapper-can              *
```

```
*  Hole 12 is the square boundary of the pin                          *
*                                                                     *
*  This type defines the basic fuel cell with the cylindrical pin     *
*  contained in a cuboidal outer region. The detailed radial and      *
*  axial structures of the two regions are defined in the HOLE data.  *
*                                                                     *
***********************************************************************
*TYPE 2
NEST 2
1 ZCYL HOLE11 0.54685 70.748 -2.348
2 CUBOID HOLE14 0.66 0.66 70.748 -0.66 -0.66 -2.348
***********************************************************************
*                                                                     *
* Types 3 - 16  FUEL ARRAYS                                          *
*                                                                     *
* A number of arrays of fuel cells are defined. These will be used to*
* form the cylindrical fuelled region of the core.                    *
*                                                                     *
* E.g. TYPE 3 defines a 45 by 7 by 1 array of TYPE 2 components       *
*                                                                     *
***********************************************************************
*TYPE 3
ARRAY 45 7 1
(2)*45
(2)*45
(2)*45
(2)*45
(2)*45
(2)*45
(2)*45
*TYPE 4
ARRAY 43 4 1
(2)*43
(2)*43
(2)*43
(2)*43
*TYPE 5
ARRAY 41 2 1
(2)*41
(2)*41
*TYPE 6
ARRAY 39 2 1
(2)*39
(2)*39
*TYPE 7
ARRAY 37 2 1
(2)*37
(2)*37
*TYPE 8
ARRAY 35 1 1
(2)*35
*TYPE 9
ARRAY 33 1 1
(2)*33
*TYPE 10
ARRAY 31 1 1
(2)*31
*TYPE 11
```

```
ARRAY 29 1 1
(2)*29
*TYPE 12
ARRAY 27 1 1
(2)*27
*TYPE 13
ARRAY 23 1 1
(2)*23
*TYPE 14
ARRAY 19 1 1
(2)*19
*TYPE 15
ARRAY 15 1 1
(2)*15
*TYPE 16
ARRAY 7 1 1
(2)*7
*************************************************************************
*                                                                       *
*   Type 17    CORE CONFIGURATION                                       *
*                                                                       *
*  The cylindrical fuelled region of the core is defined using the      *
*  arrays of fuel cell defined above by specifying the spatial          *
*  coordinates of the volume that each array is to occupy.              *
*                                                                       *
*  The final region defines a cuboid which contains the whole           *
*  structure.                                                           *
*                                                                       *
*************************************************************************
*TYPE 17
CLUSTER 28
1  CUBOID TYPE16   3.96  30.36 70.748 -5.28   29.04 -2.348
2  CUBOID TYPE15   9.24  29.04 70.748 -10.56  27.72 -2.348
3  CUBOID TYPE14  11.88  27.72 70.748 -13.2   26.4  -2.348
4  CUBOID TYPE13  14.52  26.4  70.748 -15.84  25.08 -2.348
5  CUBOID TYPE12  17.16  25.08 70.748 -18.48  23.76 -2.348
6  CUBOID TYPE11  18.48  23.76 70.748 -19.8   22.44 -2.348
7  CUBOID TYPE10  19.8   22.44 70.748 -21.12  21.12 -2.348
8  CUBOID TYPE9   21.12  21.12 70.748 -22.44  19.8  -2.348
9  CUBOID TYPE8   22.44  19.8  70.748 -23.76  18.48 -2.348
10 CUBOID TYPE7   23.76  18.48 70.748 -25.08  15.84 -2.348
11 CUBOID TYPE6   25.08  15.84 70.748 -26.4   13.2  -2.348
12 CUBOID TYPE5   26.4   13.2  70.748 -27.72  10.56 -2.348
13 CUBOID TYPE4   27.72  10.56 70.748 -29.04   5.28 -2.348
14 CUBOID TYPE3   29.04   5.28 70.748 -30.36  -3.96 -2.348
15 CUBOID TYPE4   27.72  -3.96 70.748 -29.04  -9.24 -2.348
16 CUBOID TYPE5   26.4   -9.24 70.748 -27.72 -11.88 -2.348
17 CUBOID TYPE6   25.08 -11.88 70.748 -26.4  -14.52 -2.348
18 CUBOID TYPE7   23.76 -14.52 70.748 -25.08 -17.16 -2.348
19 CUBOID TYPE8   22.44 -17.16 70.748 -23.76 -18.48 -2.348
20 CUBOID TYPE9   21.12 -18.48 70.748 -22.44 -19.8  -2.348
21 CUBOID TYPE10  19.8  -19.8  70.748 -21.12 -21.12 -2.348
22 CUBOID TYPE11  18.48 -21.12 70.748 -19.8  -22.44 -2.348
23 CUBOID TYPE12  17.16 -22.44 70.748 -18.48 -23.76 -2.348
24 CUBOID TYPE13  14.52 -23.76 70.748 -15.84 -25.08 -2.348
25 CUBOID TYPE14  11.88 -25.08 70.748 -13.2  -26.4  -2.348
26 CUBOID TYPE15   9.24 -26.4  70.748 -10.56 -27.72 -2.348
27 CUBOID TYPE16   3.96 -27.72 70.748  -5.28 -29.04 -2.348
```

```
28 CUBOID HOLE1   29.04  30.36 70.748 -30.36 -29.04 -2.348
**********************************************************************
*                                                                    *
*   Type 18            CORE MADE UP OF NESTED HOLES                  *
*  Type 17 is the fuelled cuboid within the cylindrical reactor model *
*  Hole 1 is the radial region outside of the fuel                   *
*                                                                    *
*  The cuboidal fuelled region defined in TYPE 17 is surrounded by   *
*  a cylindrical region defining the outer limit of the model.       *
*                                                                    *
**********************************************************************
*TYPE 18
NEST 2
1 CUBOID TYPE 17 29.04 30.36 70.748 -30.36 -29.04 -2.348
2 CYLINDER HOLE 1 100.0 76.0 -2.348
**********************************************************************
*                                                                    *
*   Type 19 joins    CORE on top of  SUPPORTS                        *
*                                                                    *
*   TYPE 18 is the core region                                       *
*   TYPE 1  is the support structure                                 *
*                                                                    *
*  The fuelled core region and the fuel support structures (TYPE 1)  *
*  are positioned at the correct coordinates relative to each other. *
*                                                                    *
*  A final cylindrical region is defined to contain the entire model *
*                                                                    *
**********************************************************************
*TYPE 19
CLUSTER 3
1 CYLINDER TYPE 18 100.0 76.0 -2.348
2 CYLINDER TYPE 1 100.0 -2.348 -17
3 CYLINDER 13 100.0 76.0 -17
*
**********************************************************************
*                                                                    *
*  The reflective boundaries of the model ar defined a black         *
*                                                                    *
**********************************************************************
ALBEDO 0 0 0
*
**********************************************************************
*                                                                    *
*  The following HOLE data defines the detailed structure of the     *
*  TYPEs used above.                                                 *
*                                                                    *
*  Each shape (PLATE, SQUARE, GLOBE etc.) is followed by 13 materials*
*  then 1 2 ... 13 so that all materials can be used in the hole and *
*  in any subsidiary holes.                                          *
*  Detailed information about the geometric HOLEs requires reference *
* to the MONK5W user guide.                                          *
*                                                                    *
**********************************************************************
**********************************************************************
*                                                                    *
*   Hole 1 is the Axial regions of non fuelled core                  *
*  Positions and defines upper and lower lattice plates              *
*  Also defines water height above fuel                              *
```

```
*  See figure 7 JEF/DOC-497                                              *
*                                                                        *
**************************************************************************
*hole1
PLATE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
0 0 1
5
59.262 13 58.622 -3 49.26 13 -1.078 4 -2.348 -4 4
**************************************************************************
*                                                                        *
*   Hole 2 is clad  (Axial dimensions)                                   *
*  See figure 7 JEF/DOC-497                                              *
*                                                                        *
**************************************************************************
*hole2
PLATE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
0 0 1
4
70.7 13 -1.03 2 -1.078 4 -2.348 -4 4
**************************************************************************
*                                                                        *
* Hole 3 is upper lattice plate (Radial dimensions)                      *
*  See figure 8 JEF/DOC-497                                              *
*                                                                        *
**************************************************************************
*hole3
SQUARE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
1.32 -0.66 0.66 0.5555 0.5555
WRAP 54 54 35.586 60.96 35.586 35.586
13 13 -9 10 13
**************************************************************************
*                                                                        *
* Hole 4 is lower lattice plate (Radial dimensions)                      *
*  dowels inserted                                                       *
*  See figure 8 JEF/DOC-497                                              *
*                                                                        *
**************************************************************************
*hole4
SQUARE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
1.32 -0.66 0.66 0.32 0.32
WRAP 54 54 35.586 43.18 35.586 35.586
4 4 -10 11 4
**************************************************************************
*                                                                        *
* Hole 5 is the dowel. Used in the lower lattice plate.                  *
*  See figure 7 JEF/DOC-497                                              *
*                                                                        *
**************************************************************************
*hole5
SQUARE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
1.32 0.0 0.0 0.315 0.32
1 4 11
**************************************************************************
*                                                                        *
* Hole 6 is the fuel pin  (axial dimensions)                             *
*  It includes all regions above and below the fuel but above the        *
* bottom of the lower lattice plate                                      *
*  See figure 7 JEF/DOC-497                                              *
```

```
*                                                                      *
************************************************************************
*hole6
PLATE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
0 0 1
8
70.748 13 69.285 9 49.26 7 0.0 3 -0.678 6 -1.078 -8
-2.078 -5 -2.348 -4 4
************************************************************************
*                                                                      *
* hole 7 is the wrapper (axial dimensions)                             *
*  See figure 7 JEF/DOC-497                                            *
*                                                                      *
************************************************************************
*hole7
PLATE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
0 0 1
5
70.748 13 69.285 9 0.0 8 -1.078 6 -2.348 -4 4
************************************************************************
*                                                                      *
* hole 8 is the dowel insertion into the lower end plug                *
*  See figure 7 JEF/DOC-497                                            *
*                                                                      *
************************************************************************
*hole8
SQUARE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
1.32 0.0 0.0 0.315 0.315
1 1 6
************************************************************************
*                                                                      *
* hole 9 defines the interstitial drainage holes in the upper          *
* lattice.                                                             *
* Note - the WRAP option is used to fix the number of drainage holes   *
* at 53.                                                               *
*  See figure 8 JEF/DOC-497                                            *
*                                                                      *
************************************************************************
*hole9
SQUARE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
1.32 0.0 0.0 0.2 0.2
WRAP 53 53 35.586 35.586 35.586 35.586
13 13 10 10 13
************************************************************************
*                                                                      *
* hole 10 defines the interstitial drainage holes in the lower         *
* lattice.                                                             *
*  See figure 8 JEF/DOC-497                                            *
*                                                                      *
************************************************************************
*hole10
SQUARE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
1.32 0.0 0.0 0.32 0.32
WRAP 53 53 35.586 35.586 35.586 35.586
4 4 11 11 4
************************************************************************
*                                                                      *
* hole 11 defines the fuel pin in the fuel cell                        *
```

```
*  See figure 6 JEF/DOC-497                                              *
*                                                                        *
**************************************************************************
*hole11
GLOBE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
4
0.5555 -15
0.54685 -2
0.5199 -7
0.5065 -6
-1
**************************************************************************
*                                                                        *
* holes 12, 13 & 14 define the structure of the fuel cell outside       *
* the pin thus :                                                         *
* hole 12 - radial structure in upper lattice plate                      *
* hole 13 - radial structure in lower lattice plate                      *
* hole 14 - axial structure                                              *
* Note - the outer radii of 1.5cm, in HOLEs 12 & 13 are nominal as       *
* the actual outer dimensions are defined by TYPE 2.                     *
*                                                                        *
**************************************************************************
*hole12
GLOBE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
2
1.5 B 4 0 0.933381 13 13 13  0.2 0.2 0.2
0.5555 -11
10
*hole13
GLOBE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
2
1.5 B 4 0 0.933381 4 4 4  0.32 0.32 0.32
0.5555 -11
11
*hole 14
PLATE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
0 0 1
5
59.262 13 58.622 -12 49.26 13 -1.078 4 -2.348 -13 4
**************************************************************************
*                                                                        *
* hole 15 is the axial structure of the air gap between the pin and      *
* the upper  lattice plate.                                              *
*                                                                        *
**************************************************************************
*hole 15
PLATE 13 1 2 3 4 5 6 7 8 9 10 11 12 13
0 0 1
1
49.26 13
-1

**************************************************************************
*                                                                        *
*              MONK5W CONTROL DATA                                       *
*                                                                        *
*                                                                        *
**************************************************************************
```

```
RANDOM 832537877
-10 1000 250 -1 5
AUTO 5
MIGRATION AREA
VOLUME ZCYL 45.0 49.0 0.0
REGION 1 IN TYPE 19 /
SOURCE 1 1
DISC LA
EDIT ALL PARTITION 172 BY ZONE AND MATERIAL
ABSORPTION FISSION
END
*
STOP
```

Appendix 2. INPUT FOR MONK5W PINCELL MODEL

```
PRINT 0
*  DIMPLE S01, Pincell Model
*  WIMS6, 1995 Library, 172 groups
************************************************************************
*                                                                      *
*                        WIMS control data                             *
*      The HEAD module prepares material cross sections for 4          *
*     materials in 6 regions with P1 data.                             *
*                                                                      *
************************************************************************
WHEAD 1
* Prelude data
NMATER 4
NREGION 6
PONE
NMESH 10
endp
* Main data
cent
************************************************************************
*                     MATERIAL DATA                                    *
* Tables 1 - 3 of JEF/DOC-497                                          *
*                                                                      *
*   1) moderator 2) outer clad 3)3% enriched fuelUO2                   *
*   4) fuel wrapper                                                    *
*  Note                                                                *
* Zn64 used for Zn due to lack of evaluated data for natural zn        *
*                                                                      *
* Material specifications consist of the following data                *
* keyword 'MATE', material number, density (g/cc), temperature,        *
* resonance region number (1=fuel, 2 or 3 otherwise), a list of        *
* nuclide-abundance (mass %) pairs.                                    *
************************************************************************
MATE 1 0.9982041  293.16 3 H 11.19 O 88.81
MATE 2 7.806  293.16 2 FE 67.552 MN 1.66 MO .34 AL .246 CR 18.0 CO .102
                       CU .152 NI 11.18 TI 0.666 V 0.05 ZN64 0.052
MATE 3 10.42  293.16 1 FE 0.008 SI 0.0116 O 11.8919 U234 0.0169
                       U235 2.6465 U236 0.0363 U238 85.3603 AL .0285
MATE 4 0.868  293.16 2 AL 84.7439 CR 0.0025 CU 0.015 FE 0.3 MG 0.0015
                       MN 0.006 NI 0.002 SI 0.025 C 12.76 H 2.13
                       CL 0.005 SN 0.009 SR84 5.6e-07 SR86 9.86e-06
                       SR87 7.0e-06 SR88 8.258e-05
************************************************************************
*
*                                                                      *
*    Dummy WIMS geometry data. A dummy region (annulus) is defined for *
*    each of the 4 materials.                                          *
*    WIMS requires that all materials be used in an annulus and that the *
*    inner annulus contains a fuel material.                           *
*                                                                      *
************************************************************************
*
annulus 1 0.25 3
annulus 2 0.5065 3
annulus 3 0.5199 4
annulus 4 0.54685 2
```

```
annulus 5 0.65 1
annulus 6 0.74473 1
square 1
mesh 1 1 1 1 2 4
*****************************************************************************
*
*                                                                            *
*      The NOVICE sub-group treatment is requested                           *
*                                                                           *
*****************************************************************************
*
NOVICE
BEGINC
*
*****************************************************************************
*
*                                                                            *
*                    MONK5W control data                                     *
*                                                                           *
*****************************************************************************
*
WMONK 1
AMSTO 9000000 1210000
VWTS 0.5 1.5 0.167 NOVICE DATA
4  172.000000  1
FLUX 172
PRINT GR
PONE  172.000000
SUBGROUP 4 46 92
CM
1
*************************************************************************
*                     GEOMETRY DATA                                     *
*                                                                       *
* TYPE 1 defines a nominal box (10 pitches by 10 pitches and 50 cm      *
* high) containing an array of pins cells defined by HOLE 2.            *
*                                                                       *
* HOLE 1 defines the fuel pin comprising fuel, wrapper and can.         *
* HOLE 2 defines the square bounary of the pin cell containing          *
*        moderator and the fuel pin defined in HOLE 1.                  *
*                                                                       *
* The ALBEDO keyword specifies a reflective outer boundary.             *
*                                                                       *
*************************************************************************
*TYPE 1
NEST 1 1 CUBOID H2 13.2 13.2 50.0 -13.2 -13.2 0.0
ALBEDO 1 1 1 1 1 1
*HOLE 1
GLOBE 4 1 2 3 4 3 0.54685 2 0.51990 4 0.5065 3 1
*HOLE 2
SQUARE 4 1 2 3 4 1.32 0.66 0.66 0.6 0.6 -1 -1 1
*************************************************************************
*                                                                       *
*              MONK5W CONTROL DATA                                      *
*                                                                       *
* For the pin cell model the control data includes the experimental     *
* buckling values.                                                      *
*                                                                       *
```

```
**************************************************************************
RANDOM 832537877
-10 1000 250 -1 5
AUTO 5
MIGRATION AREA
BUCKLING BESSEL 0.004150 0.002410
VOLUME CUBOID 13.2 13.2 49 -13.2 -13.2 0.0
REGION 1 IN TYPE 1 /
SOURCE 0 0 0
DISC LA
EDIT ALL PARTITION 172 BY ZONE AND MATERIAL
ABSORPTION FISSION CHILDREN
END
```

Appendix 3. INPUT FOR DETERMINISTIC PINCELL MODEL

```
PRINT 0
*
* WIMS Library Validation : DIMPLE
*  s01/1a latest KNIPE data
* Reference AEA TSD 0375, JEF/DOC-497
* Template created by Les Hutton
*
* 1995 LIBRARY - 172 groups
*              IDENTIFIERS 2235
*                          2238
*                          4239
*                GROUPS    69
*                THERMAL   45
* benoist used
* WIMS Library Validation : DIMPLE
************************************************************************
*                                                                      *
*                       WIMS control data                              *
*      The HEAD module prepares material sigmas for 4 materials        *
*      in 6 regions and 10 meshes with P1 data.                        *
*                                                                      *
************************************************************************
WHEAD 1
* Prelude data
NMATER 4
NREGION 6
PONE
NMESH 10
endp
* Main data
cent
*
*  DIMPLE CORE S01A from JEF/DOC-497
*
************************************************************************
*                     MATERIAL DATA                                    *
* Tables 1 - 3 of JEF/DOC-497                                          *
*                                                                      *
*   1) moderator 2) outer clad 3)3%   enriched fuelUO2                 *
*   4) fuel wrapper                                                    *
*  Note                                                                *
* Zn64 used for Zn due to lack of evaluated data for natural zn        *
*                                                                      *
* Material specifications consist of the following data                *
* keyword 'MATE', material number, density (g/cc), temperature,        *
* resonance region number (1=fuel, 2 or 3 otherwise), a list of        *
* nuclide-abundance (mass %) pairs.                                    *
*                                                                      *
************************************************************************
MATE 1 0.9982041  293.16 3 H 11.19 O 88.81
MATE 2 7.806  293.16 2 FE 67.552 MN 1.66 MO .34 AL .246 CR 18.0 CO .102
                       CU .152 NI 11.18 TI 0.666 V 0.05
*                      ZN64 0.052 removed for 86 library
MATE 3 10.42  293.16 1 FE 0.008 SI 0.0116 O 11.8919 U234 0.0169
                       U235 2.6465 U236 0.0363 U238 85.3603 AL .0285
MATE 4 0.868  293.16 2 AL 84.7439 CR 0.0025 CU 0.015 FE 0.3 MG 0.0015
```

```
                      MN 0.006 NI 0.002 SI 0.025 C 12.76 H 2.13
*                     CL 0.005 SN 0.009 SR84 5.6e-07 SR86 9.86e-06
*                     SR87 7.0e-06 SR88 8.258e-05  removed for 86 lib
trace 55  4239
*********************************************************************
*                                                                   *
* The geomety of the pincell is defined by a number of concentric   *
* annuli with the fuel at the centre surrounded by wrapper, can and *
* moderator regions. The outer moderator region is specifyed as an  *
* annulus of equivalent area to a 1.32cm square. The fuel and       *
* moderator are each split into two regions.                        *
*                                                                   *
* The SQUARE option is specified to adjust the Dancoff factors to   *
* account for the square lattice.                                   *
*                                                                   *
* A number of spacial meshes are defined. Two in the fuel, one each *
* in the wrapper and can and six in the moderator.                  *
*                                                                   *
*********************************************************************
annulus 1 0.25 3
annulus 2 0.506 3
annulus 3 0.51955 4
annulus 4 0.54625 2
annulus 5 0.65  1
annulus 6 0.74473 1
square 1
mesh 1 1 1 1 2 4
BEGINC
*
*********************************************************************
*                                                                   *
*  WPRES prepares subgroup cross-sections for use by a collision    *
*  probability package.                                             *
*                                                                   *
*********************************************************************
WPRES 1 2
GROUPS 46 92
NUCLIDE 2235
293
NUCLIDE 2238
293
BEGIN
*
*********************************************************************
*                                                                   *
*  WPIJ is used to calculate collision probabilities for a cell with *
*  a square outer boundary.                                         *
*                                                                   *
*********************************************************************
WPIJ 2
NSYM 1 1 4
NREG 6
NANNULI 1 1
NRODS 1 1 5 1
NTRACK 50 11
ENDP
RODSUB 1 1 0.25 3
RODSUB 1 2 0.5065 3
```

```
RODSUB 1 3 0.5199 4
RODSUB 1 4 0.54685 2
RODSUB 1 5 0.60 1
ARRAY 1 1 1 0 0
SQUARE 1 0.66 1
LINES 50
TRUNCATE 8
REFLECT 5
BEGIN
*
**************************************************************************
*                                                                        *
*  WRES calculates group averaged resonance cross-sections using the     *
*  subgroup method.                                                      *
*                                                                        *
**************************************************************************
WRES 2 3
GROUPS 46 92
NUCLIDE 2235
293
NUCLIDE 2238
293
BEGINC
*
**************************************************************************
*                                                                        *
*  WPIJ is used to calculate collision probabilities for a cell with     *
*  a square outer boundary.                                              *
*                                                                        *
**************************************************************************
WPIJ 3
NSYM 1 1 4
NREG 10
NANNULI 5 1
NRODS 1 1 5 1
NTRACK 50 11
ENDP
RODSUB 1 1 0.25 3
RODSUB 1 2 0.5065 3
RODSUB 1 3 0.5199 4
RODSUB 1 4 0.54685 2
RODSUB 1 5 0.60 1
ARRAY 1 1 1 0 0
ANNULUS 1 0.665 1
ANNULUS 2 0.73 1
ANNULUS 3 0.785 1
ANNULUS 4 0.86 1
SQUARE 5 0.66 1
LINES 30 5 5 5 5
TRUNCATE 8
REFLECT 5
BEGIN
*
**************************************************************************
*                                                                        *
*  WPIP calculates fluxes and evaluates k-infinity                       *
*                                                                        *
**************************************************************************
```

```
WPIP 3
omega 1.25
BEGIN
*
**************************************************************************
*                                                                        *
*  WINTER is used to copy interface 3 to interface 1                     *
*                                                                        *
**************************************************************************
WINTER 3 1
COPY
BEGINC
*
**************************************************************************
*                                                                        *
*  WSMEAR is used here to generate transport cross-sections to be        *
*  used with the B1 option of WCRITIC.                                   *
*                                                                        *
**************************************************************************
WSMEAR 1 2
mate 1
meshes 1
momt 2
endp
newmat 1 2 3 4 5 6 1 7 8 9 10
benoist 2 3
mcode 1
beginc
*
sface 2
*
**************************************************************************
*                                                                        *
*  WCRITIC applies the input buckling to the flux solution and           *
*  and evaluates k-effective.                                            *
*                                                                        *
**************************************************************************
WCRITIC 1 3
subs
bn 1
trans 2 3 4
cent
buckling 172
0.004150 0.002410 0.0 0.0
begin
*
BEGIN
```