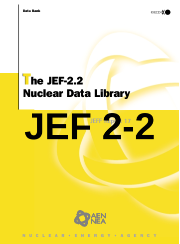

JEF/DOC-549

Description of DIMPLE S01A model developed with Monte Carlo computer code MCNP4A

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1 Brief description of DIMPLE [2]

DIMPLE is a versatile, water moderated reactor used to investigate performance, safety and safeguards issues relevant to the entire nuclear fuel cycle. The current DIMPLE programme includes lattice studies, reactivity and neutron source measurements with samples of irradiated fuel discharged from power reactors, criticality experiments relevant to fuel manufacturing, transport, storage and reprocessing issues and the development of sub-critical monitoring techniques.
Conventional assemblies consist of fuel pins supported and precisely located, between upper and lower lattice plates inside a large aluminium primary vessel (2.6 m diameter and 4 m high). Both simple geometry fuel pin benchmarks and more complex configurations, representative of operational or accident conditions, can be built. The ability to control the reactor by means of moderator level alone permits sub-critical and critical assemblies to be studied without the complicating perturbation of control rods. Shut-down is achieved by means of a fast dump system. When the reactor is operating, a 2 m diameter stainless stell bell-jar situated approximately 25 cm below the core sustains an air cavity. By venting the cavity through a pair of large valves, the water level can be dropped by 30 cm in about one second.
The reactor's low power operation of less than 200 W and ease of access provides for efficient configuration modifications or complete assembly changes.

2 Description of the S01A assembly [2]

To check predictions of critical moderator level and the water height reactivity coefficient ($d\rho/dH$) at various fuel loadings five S01 configurations were studied. This report covers only the S01A the description and modelling of S01A assembly, which was first built in 1983 following a refurbishment of the DIMPLE reactor. It comprised 1565 fuel pins arranged on a square pitch of 1.32 cm to provide a cylindrical, light water moderated core.The fuel pins comprised 3 % enriched uranium dioxide pellets, 1.013 cm diameter, wrapped in adhesive aluminium foil and stacked within stainless steel cans, 1.094 cm outer diameter, to a fuel height of approximately 69 cm. The 72 cm cans were sealed at each end using aluminium end plugs, with aluminium shims making up any apace between the top of the fuel and upper and plug.
The pins were supported, and precisely located, between aluminium lattice plates. A stainless steel dowel, fitted into the bottom end plug, retained each pin in the lower lattice plate. The lattice plates in DIMPLE are secured to aluminium fuel support beams, which in turn are supported by a tubular stainless steel chassis.

3 Description of DIMPLE S01A model developed with Monte Carlo computer code MCNP4A

3.1 Full reactor model

From the geometric and composition point of view, the full reactor model of DIMPLE S01A assembly developed using MCNP4A is exactly the same as proposed in Specification of the Benchmark Assemblies. Reactor core is a mesh of 54 x 54 unit cells and is divided into six segments (plates). Because of the mean deviation from the specified pin pitch of 1.3200 cm across the gaps at the extreme ends of the six top lattice and bottom lattice plates, dimensions of them were reduced exactly according to the values stated on Page 15 in the Specification. The upper and lower lattice plate have modeled all the Interstitial Drainage holes as specified on the Specifications Figure 8 .
The whole model (bottom to top) is 93 cm high, because of the fuel support plate and fuel beam base under the lower lattice plate, which are modeled exactly as stated on the Figure 9 of the Specification. Between fuel support and fuel beam base elements is water.
The critical moderator height is 49.26 cm as stated in Table 6 on Page 17 in the Specification (according to the temperature corrected to 20°C). It should be emphasized that cross-section data from the ENDF/B-V

and VI, used during the calculations were evaluated at the temperature of 300 K (27°C). This temperature difference of 7°C should be kept in mind when calculating the multiplication factor of the core.
A statement is written on the Page 2 of DIMPLE S01A Models paper [2], that 13 cm of water forms an effectively infinite reflector. All the features more than 13 cm from the edge of the outermost pin can be ignored, therefore the biological shield, the primary vessel, the beam support chassis and radial components of the fuel support beams are not needed to be modeled. A nominal axial and radial water/air filled surround is included to give a cylinder 100 cm in radius and 93 cm high, which definitely assures infinite reflector.
Pictures 1, 2, 3, 4 and Appendix A present the details of the 3D model and its MCNP input, respectively.

3.2 Pincell Model

The geometry and composition of the DIMPLE S01A pincell model, developed using MCNP4A is exactly the same as proposed in Specification of the Benchmark Assemblies [1]. But there is one major difference in transport calculation itself, comparing to Monte Carlo model developed with MONK5W code: in the case of MONK5W calculation, experimental bucklings were applied to transform the k_∞ model into a representative 1D reactor calculation giving k_{eff}.
MCNP4A is not capable of incorporating the buckling data into the definition of boundary conditions. Therefore the only feasible way in calculation of multiplication factor was the calculation of k_∞ using reflecting boundary conditions on the edges of the square pin with dimensions of 1.32 cm, and no axial leakage (infinite dimensions in the way of z-axis). The pincell geometric model is presented on picture 5 and MCNP pincell input is enclosed in Appendix B.

4 Calculation of k_{eff} and Reaction rates using MCNP4A

4.1 Evaluation of k_{eff} estimators [3]

The criticality eigenvalue k_{eff} and its standard deviation is automatically estimated in every criticality calculation performed with KCODE card of MCNP code. K_{eff} and various prompt neutron lifetimes are estimated for every active cycle, as well as averaged over all active cycles. K_{eff} is estimated in three different ways: using **collision estimator**, which estimates the mean number of fission neutrons produced per cycle, using **absorption estimator**, where only the nuclide involved in the collision is used for the estimation, rather than an average off all nuclides in the material (collision estimator) and **by track length estimator**, which is accumulated every time the neutron traverses a specified distance in a fissionable material cell.
These three estimates are combined using statistical correlations to provide the optimum estimate of k_{eff} and its standard deviation. The technique of combination of individual k_{eff} values is a generalization of the inverse weighting for uncorrelated estimators, and produces the maximum likelihood estimate for the three combined k_{eff} estimators. So it is the best final estimate from an MCNP calculation.

4.2 Evaluation of Reaction Rates [3]

In general, MCNP calculates Reaction Rates in the form of equation $C\cdot\int\varphi(E)\cdot R_m(E)\cdot dE$, where $\varphi(E)$ is the energy-dependent fluence (particles/cm^2) and R(E) is an operator of additive and/or multiplicative response functions from the MCNP cross-section libraries or specially designed quantities. The reaction cross sections are microscopic (with units of barns) and not macroscopic. Thus, if the constant C is the atomic density (in atoms per barn-cm), the result will include the normalization "per cm^3".

For the calculation of the Reaction-Rate Ratios specified in Table 7 of [1], the number of total fissions in ^{235}U, ^{238}U, ^{239}Pu and total captures in ^{238}U isotopes, has to be obtained first. But in the ENDF/B-V library, the cross-section data for total fission reaction (No. 18), were evaluated only for ^{239}Pu, while in the ENDF/B-VI library they were evaluated for the ^{235}U isotope, also. According to [4], the number of total fission reactions can also be set up by summing the number of partial fission reactions: first, second, third and fourth chance fission, which are designated with reaction numbers 19, 20, 21 and 38, respectively (in both cross-section libraries we used). Unfortunately, the cross-section data for reaction No. 38, meaning fourth chance fission were not evaluated for ^{235}U isotope in ENDF/B-V library, thus for this isotope the number of fission reactions was obtained only by adding the number of first, second and third chance fissions. For ^{238}U isotope, the partial cross-section data for all kind of fission reactions mentioned above are present in the ENDF/B-V and VI evaluations, thus there were no problems for obtaining the number of total fission reactions easy by summing them.

Considering the calculation of the number of capture reactions in ^{238}U isotope, the following should be emphasized: the cross-section for total capture reaction is a sum of partial cross-sections for (n, γ), (n, p), (n, d), (n, t), (n, ^{3}He) and (n, α) reactions, which are labeled with reaction numbers 102, 103, 104, 105, 106 and 107, respectively. But in both, ENDF/B-V and VI[4] data libraries, acctually evaluated is only radiative capture - (n, γ) reaction with No. 102. Consquently the number of capture reactions calculated in ^{238}U isotope, consists only of (n, γ) reactions.

5 Cross-section data

Two different cross-section data libraries were used for performing the calculations: ENDF/B-V and ENDF/B-VI version (including Thermal S(α,β) Cross-Section data). All the details about libraries mentioned, can be found in:

a) B. L. Kirk, R. W. Roussin, T. Jordan: RSIC DATA LIBRARY COLLECTION, MCNPDAT, MCNP, Version 4, Standard Neutron Cross Section Data Library based in Part on ENDF/B-V, Contributed by LANL, New Mexico, USA.
b) J. S. Hendricks, S. C. Frankle, J. D. Court: ENDF/B-VI Data for MCNP, LANL, New Mexico, USA.
c) J. D. Court, J. S. Hendricks, S. C. Frankle: MCNP ENDF/B-VI Validation: Infinite Media Comparison of ENDF/B-VI and ENDF/B-V, LANL, New Mexico, USA.
d) J. D. Court, J. S. Hendricks: Benchmark Analysis of MCNP ENDF/B-VI Iron, LANL, New Mexico, USA.

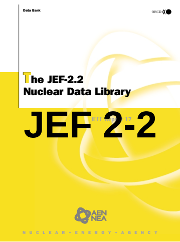
6 Results

Calculation of k_∞ and k_{eff}

	ENDF/B -V lib.	ENDF/B -VI lib.
Pincell Model (k_∞)	1.25947 ± 0.00019	1.26723 ± 0.00020
3D full Core Model (k_{eff})	0.99348 ± 0.00039	0.99657 ± 0.00021

Calculation of Reaction Rate Ratios

	ENDF/B -V lib.	ENDF/B -VI lib.	Experimental res. [2]
^{238}U fission / ^{235}U fission	$2.74 \cdot 10^{-3} \pm 0.8$ %	$2.73 \cdot 10^{-3} \pm 0.4$ %	$3.02 \cdot 10^{-3} \pm 3.4$ %
^{239}Pu fission / ^{235}U fission	2.16 ± 0.5 %	2.16 ± 0.4 %	2.189 ± 0.9 %
^{238}U capture / ^{235}U fission	$1.96 \cdot 10^{-2} \pm 0.4$ %	$1.96 \cdot 10^{-2} \pm 0.4$ %	$2.03 \cdot 10^{-2} \pm 0.5$ %



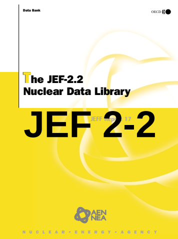
References

[1] A. D. Knipe: Specification of the DIMPLE S01 Benchmark Assemblies, AEA Technology, Technical Services Division, November 1994.

[2] R. J. Perry, C. J. Dean: DIMPLE S01A Models, AEA Technology, Technical Services Division, March 1995.

[3] J. F. Briesmeister, Ed.: MCNP - A General Monte Carlo N-Particle Transport Code, Version 4A, LANL, New Mexico, USA, November 1993.

[4] Rose, P. F. (Ed.): ENDF-201, ENDF/B-VI Summary Documentation, National Nuclear Data Center, BNL, USA, October 1991.



Appendix A: MCNP 3D whole lattice model input

14050517

```
DIMPLE BENCHMARK - K EFF - REAL 3D GEOMETRY OF A WHOLE LATTICE
c
c     *****************************************************************
c     * real geometry of a unit cell                                  *
c     * enrichment of uranium dioxide is 3%                           *
c     * water up to the critical height of 14.6175 cm                 *
c     * support assembly under the lower lattice plate                *
c     * the height of a whole sistem (bottom-up) is 93 cm             *
c     * upper and lower lattice plates containes pin holes            *
c     * the whole lattice is surrounded with water cylinder (r=100 cm) *
c     * lattice is divided into six parts (deviations from the spec. pitch *
c     * calculation of reaction rates in fuel isotopes                *
c     * cross-section data from ENDF/B-VI library are used            *
c     *****************************************************************
c
c     ***** DETAILED GEOMETRY OF A FUEL UNIT CELL *****
1     1  -10.42      -1 -8 9                    u=2       $uranium
2     2  -0.868      1 -2 -8 9                  u=2       $Al wrapper and gap
4     5  -1.644      -2 12 -9 #5                u=2       $part of a lower end plug
5     6  -6.072      -20 -14 15                 u=2       $pin dowel
7     7  -2.681      -12 41 42 43 44 #5         u=2       $l.l.p. without corners
8     4  -0.9982041  (-41:-42:-43:-44) -12      u=2       $corners of l.l.p. (water)
10    3  -7.806      2 -3 13 -10                u=2       $cladding
11    4  -0.9982041  2 12 -19 #10               u=2       $water up to the Hcrit
12    9  -1.600      -2 8                       u=2       $upper end plug
13    8  -2.669      3 18 -17 37 38 39 40       u=2       $u.l.p. without corners
14    0              (-37:-38:-39:-40) 18 -17 u=2         $corners of u.l.p. (air)
16    0              2 19 #13 #14 #10           u=2       $air above Hcrit
c
c     ***** NO-FUEL UNIT CELL - without any corner *****
18    0              19 #22 #23                 u=1       $air without u.l.p.
19    4  -0.9982041  12 -19                     u=1       $water up to the Hcrit
20    4  -0.9982041  -20 -12 15                 u=1       $water in the pin hole
21    7  -2.681      -12 #20 41 42 43 44        u=1       $l.l.p. without corners
22    8  -2.669      3 18 -17 37 38 39 40       u=1       $u.l.p. without corners
23    0              (-37:-38:-39:-40) 18 -17 u=1         $corners of u.l.p. (air)
24    4  -0.9982041  (-41:-42:-43:-44) -12      u=1       $corners of l.l.p. (water)
c
c     ***** NO-FUEL UNIT CELL - corner element: left up *****
25    0              19 #29 #30         u=5               $air without u.l.p.
26    4  -0.9982041  12 -19             u=5               $water up to the Hcrit
27    4  -0.9982041  -20 -12 15         u=5               $water in the pin hole
28    7  -2.681      -12 41 #27         u=5               $l.l.p. without corners
29    8  -2.669      3 18 -17 37        u=5               $u.l.p. without corners
30    0              -37 18 -17         u=5               $corners of u.l.p. (air)
31    4  -0.9982041  -41 -12            u=5               $corners of l.l.p. (water)
c
c     ***** NO-FUEL UNIT CELL - corner element: right up *****
32    0              19 #36 #37         u=6               $air without u.l.p.
33    4  -0.9982041  12 -19             u=6               $water up to the Hcrit
34    4  -0.9982041  -20 -12 15         u=6               $water in the pin hole
35    7  -2.681      -12 42 #34         u=6               $l.l.p. without corners
36    8  -2.669      3 18 -17 38        u=6               $u.l.p. without corners
37    0              -38 18 -17         u=6               $corners of u.l.p. (air)
38    4  -0.9982041  -42 -12            u=6               $corners of l.l.p. (water)
c
c     ***** NO-FUEL UNIT CELL - corner element: left down *****
39    0              19 #43 #44         u=7               $air without u.l.p.
40    4  -0.9982041  12 -19             u=7               $water up to the Hcrit
41    4  -0.9982041  -20 -12 15         u=7               $water in the pin hole
42    7  -2.681      -12 43 #41         u=7               $l.l.p. without corners
43    8  -2.669      3 18 -17 39        u=7               $u.l.p. without corners
44    0              -39 18 -17         u=7               $corners of u.l.p. (air)
45    4  -0.9982041  -43 -12            u=7               $corners of l.l.p. (water)
c
c     ***** NO-FUEL UNIT CELL - corner element: right down *****
46    0              19 #50 #51         u=8               $air without u.l.p.
47    4  -0.9982041  12 -19             u=8               $water up to the Hcrit
48    4  -0.9982041  -20 -12 15         u=8               $water in the pin hole
49    7  -2.681      -12 44 #48         u=8               $l.l.p. without corners
50    8  -2.669      3 18 -17 40        u=8               $u.l.p. without corners
51    0              -40 18 -17         u=8               $corners of u.l.p. (air)
52    4  -0.9982041  -44 -12            u=8               $corners of l.l.p. (water)
c
c     ***** NO-FUEL UNIT CELL - upper edge line *****
53    0              19 #57 #58         u=9               $air without u.l.p.
54    4  -0.9982041  12 -19             u=9               $water up to the Hcrit
55    4  -0.9982041  -20 -12 15         u=9               $water in the pin hole
56    7  -2.681      -12 41 42 #55      u=9               $l.l.p. without corners
57    8  -2.669      3 18 -17 37 38     u=9               $u.l.p. without corners
58    0              (-37:-38) 18 -17 u=9                 $corners of u.l.p. (air)
59    4  -0.9982041  (-41:-42) -12      u=9               $corners of l.l.p. (water)
c
c     ***** NO-FUEL UNIT CELL - bottom edge line *****
60    0              19 #64 #65         u=10              $air without u.l.p.
61    4  -0.9982041  12 -19             u=10              $water up to the Hcrit
62    4  -0.9982041  -20 -12 15         u=10              $water in the pin hole
63    7  -2.681      -12 43 44 #62      u=10              $l.l.p. without corners
64    8  -2.669      3 18 -17 39 40     u=10              $u.l.p. without corners
65    0              (-39:-40) 18 -17 u=10                $corners of u.l.p. (air)
66    4  -0.9982041  (-43:-44) -12      u=10              $corners of l.l.p. (water)
c
c     ***** NO-FUEL UNIT CELL - right edge line *****
67    0              19 #71 #72         u=11              $air without u.l.p.
68    4  -0.9982041  12 -19             u=11              $water up to the Hcrit
69    4  -0.9982041  -20 -12 15         u=11              $water in the pin hole
70    7  -2.681      -12 42 44 #69      u=11              $l.l.p. without corners
71    8  -2.669      3 18 -17 38 40     u=11              $u.l.p. without corners
72    0              (-38:-40) 18 -17 u=11                $corners of u.l.p. (air)
73    4  -0.9982041  (-42:-44) -12      u=11              $corners of l.l.p. (water)
c
c     ***** NO-FUEL UNIT CELL - left edge line *****
74    0              19 #78 #79         u=12              $air without u.l.p.
75    4  -0.9982041  12 -19             u=12              $water up to the Hcrit
76    4  -0.9982041  -20 -12 15         u=12              $water in the pin hole
77    7  -2.681      -12 41 43 #76      u=12              $l.l.p. without corners
78    8  -2.669      3 18 -17 37 39     u=12              $u.l.p. without corners
79    0              (-37:-39) 18 -17 u=12                $corners of u.l.p. (air)
80    4  -0.9982041  (-41:-43) -12      u=12              $corners of l.l.p. (water)
c
c     ***** LATTICE OF 9X54 ELEMENTS - #1 *****
81    0              -4 5 -6 7  u=21  lat=1  fill=-4:4 -26:27 0:0
                     7 10 7r
                     12 1 7r
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                     12 1 3r 2 3r
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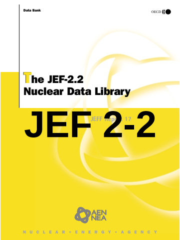


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                      5 9 7r
c    ***** BOX - #1 ******
82   0                105 -110 -25 26 -11 16  fill=21 trcl=1
c
c    ***** LATTICE OF 9X54 ELEMENTS - #2 *****
83   0                -4 5 -6 7  u=22  lat=1  fill=-4:4 -26:27 0:0
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c    ***** BOX - #2 ******
84   0                115 -120 -25 26 -11 16  fill=22 trcl=2
c
c    ***** LATTICE OF 9X54 ELEMENTS - #3 *****
85   0                -4 5 -6 7  u=23  lat=1  fill=-4:4 -26:27 0:0
                      10 8r
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                 9 8r
c    ***** BOX - #3 ******
86   0           125 -130 -25 25 -11 16  fill=23 trcl=3
c
c    ***** LATTICE OF 9X54 ELEMENTS - #4 *****
87   0           -4 5 -6 7  u=24  lat=1  fill=-4:4 -26:27 0:0
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c    ***** BOX - #4 ******
88   0           135 -140 -25 26 -11 16  fill=24 trcl=4
c
c    ***** LATTICE OF 9X54 ELEMENTS - #5 *****
89   0           -4 5 -6 7  u=25  lat=1  fill=-4:4 -26:27 0:0
                 10 8r
                 1 8r
                 1 8r
                 1 8r
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                 1 8r
                 2 2 1 6r
                 2 3r 1 4r
                 2 4r 1 3r
                 2 5r 1 2r
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                 2 6r 1 1
                 2 5r 1 2r
                 2 4r 1 3r
                 2 3r 1 4r
                 2 2 1 6r
                 1 8r
                 1 8r
```
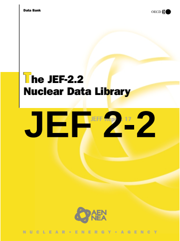
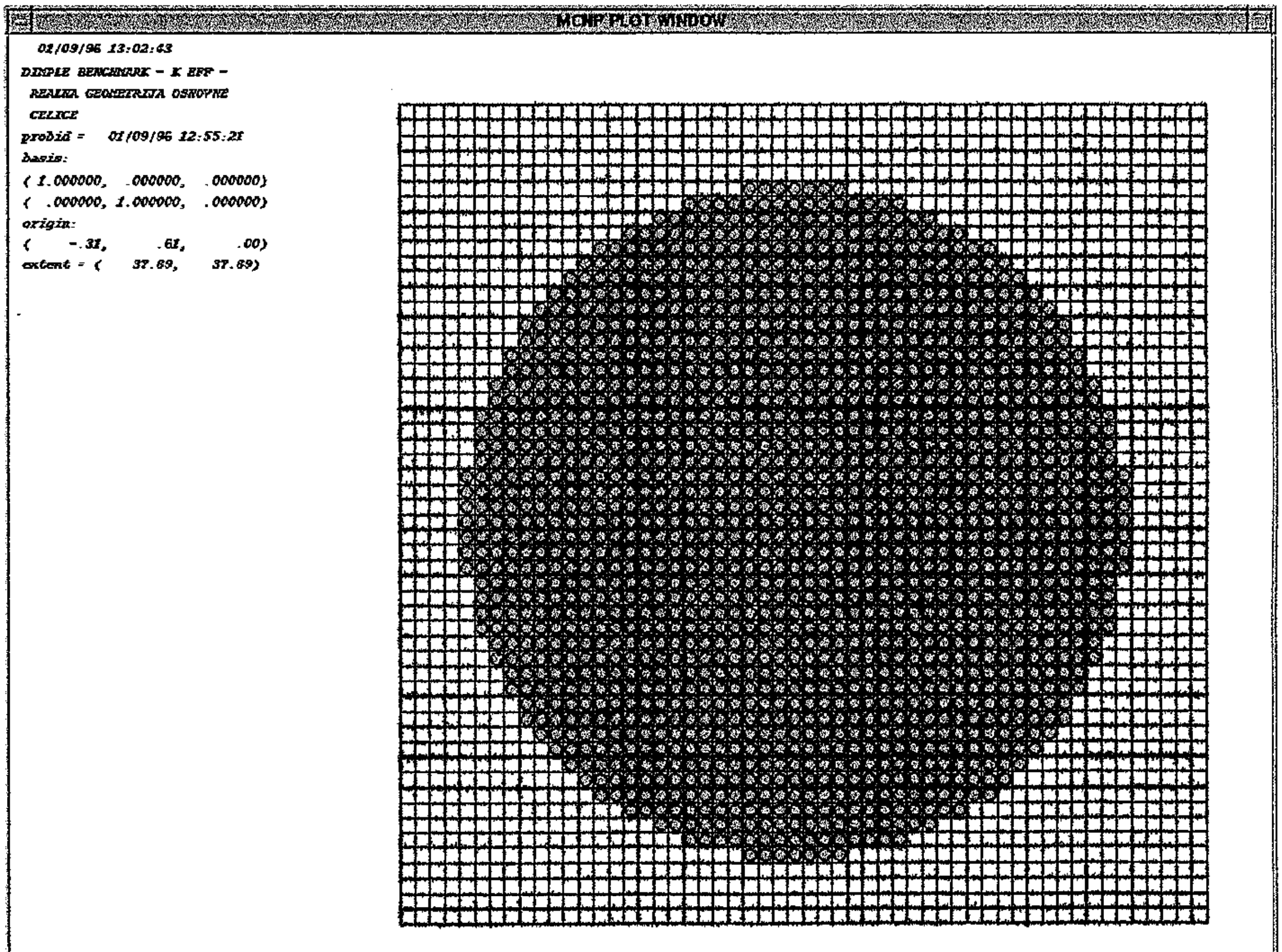

```
                     1 8r
                     1 8r
                     1 8r
                     1 8r
                     1 8r
                     9 8r
c      ***** BOX - #5 ******
90     0             145 -150 -25 26 -11 16  fill=25 trcl=5
c
c      ***** LATTICE OF 9X54 ELEMENTS - #6 *****
91     0             -4 5 -6 7  u=26  lat=1  fill=-4:4 -26:27 0:0
                     10 7r 8
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     2 1 6r 11
                     2 1 6r 11
                     2 2 1 5r 11
                     2 2 1 5r 11
                     2 2r 1 4r 11
                     2 2r 1 4r 11
                     2 2r 1 4r 11
                     2 2r 1 4r 11
                     2 3r 1 3r 11
                     2 3r 1 3r 11
                     2 3r 1 3r 11
                     2 3r 1 3r 11
                     2 3r 1 3r 11
                     2 3r 1 3r 11
                     2 3r 1 3r 11
                     2 2r 1 4r 11
                     2 2r 1 4r 11
                     2 2r 1 4r 11
                     2 2r 1 4r 11
                     2 2 1 5r 11
                     2 2 1 5r 11
                     2 1 6r 11
                     2 1 6r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     1 7r 11
                     9 7r 6
c      ***** BOX - #6 ******
92     0             155 -160 -25 26 -11 16  fill=26 trcl=6
c
c      ***** FUEL SUPPORT ASSEMBLY - basic element ******
93     10 -3.279     29 -33 35            u=4           $fuel support plate
94     10 -3.279     34 -30 35            u=4           $fuel support plate
95     11 -2.844     29 -31 -35 36        u=4           $fuel beam base
96     11 -2.844     32 -30 -35 36        u=4           $fuel beam base
97     4  -0.9982041 #93 #94 #95 #96      u=4           $water
98     0             24 -28 -25 26 -16 21  fill=4       $outer box of basic element
c
c      ***** FUEL SUPPORT ASSEMBLY - repetition of basic elements (7) *****
99     like 98 but trcl=12
100    like 98 but trcl=13
101    like 98 but trcl=14
102    like 98 but trcl=15
103    like 98 but trcl=16
104    like 98 but trcl=17
c
c      ***** CYLINDER SURROUNDING THE WHOLE SYSTEM *****
105    0             19 -11 -50 #82 #84 #86 #88 #90 #92
106    4   -0.9982041 -19 16 -50 #82 #84 #86 #88 #90 #92
107    4   -0.9982041 -16 21 -50 #98 #99 #100 #101 #102 #103 #104
c
c      ***** OUTSIDE *****
108    0             50:11:-21

1       cz 0.5065                              $uranium
2       cz 0.5199                              $wrapper and gap
3       cz 0.54685                             $cladding
4       px 0.66                                $water - pitch
5       px -0.66
6       py 0.66
7       py -0.66
8       pz 34.6425                             $uranium - up
9       pz -34.6425                            $uranium - bottom
10      pz 36.0575                             $cladding - up
11      pz 36.1055                             $upper end plug - up
12      pz -35.7205                            $l.l.p. - up
13      pz -35.6725                            $cladding - bottom
14      pz -35.3205                            $pin dowel - up
15      pz -35.7205                            $pin dowel - bottom
16      pz -36.9905                            $l.l.p. - bottom
17      pz 24.6195                             $u.l.p. - up
18      pz 23.9795                             $u.l.p. - bottom
19      pz 14.6175                             $Hcrit
20      cz 0.315                               $pin dowel radius
21      pz -56.8945                            $height of the system is 93 cm
24      px -35.543499999                       $left edge of the system
25      py 36.299999
26      py -34.9799999                         $f.s.a. basic element - outer dim.
28      px -25.3883
29      px -34.974                             $inner dimensions - x axis
30      px -25.9578
31      px -33.4294
32      px -27.5024
33      px -32.9585
34      px -27.9733
35      pz -38.7685                            $inner dimensions - z axis
36      pz -51.4685
37      c/z 0.66 -0.66 0.2                     $u.l.p. corner - left up
38      c/z -0.66 -0.66 0.2                    $u.l.p. corner - right up
39      c/z 0.66 0.66 0.2                      $u.l.p. corner - left down
40      c/z -0.66 0.66 0.2                     $u.l.p. corner - right down
41      c/z 0.66 -0.66 0.32                    $l.l.p. corner - left up
42      c/z -0.66 -0.66 0.32                   $l.l.p. corner - right up
43      c/z 0.66 0.66 0.32                     $l.l.p. corner - left down
```

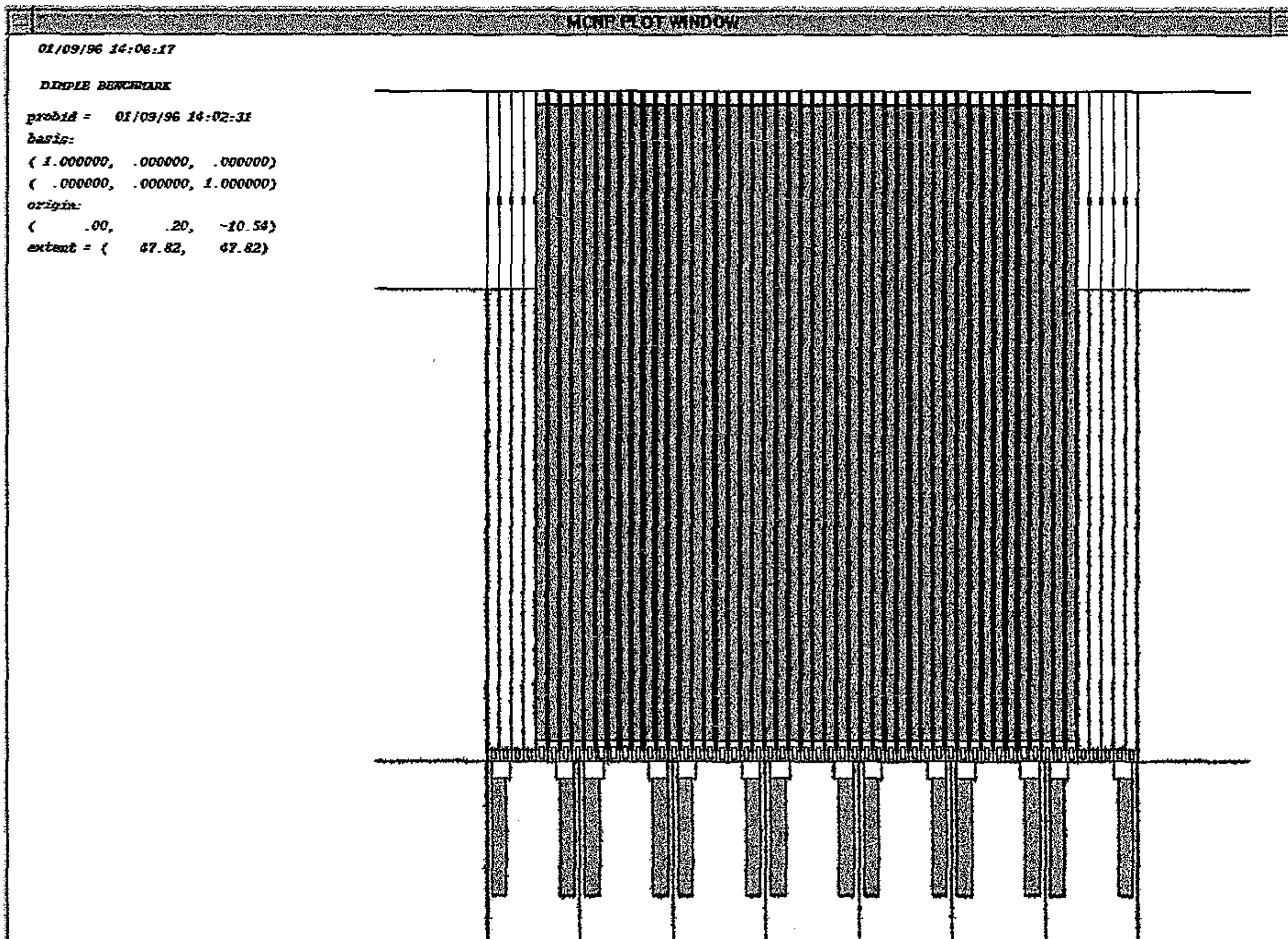
```
44     c/z -0.66 0.66 0.32                         $l.l.p. corner - right down
50     cz 100                                      $outer cylinder (r=100 cm)
c
c      Dimensions of the new universes
105    px -5.9399999                               $universe 21
110    px 5.9055
115    px -5.9055                                  $universe 22
120    px 5.9325
125    px -5.9325                                  $universe 23
130    px 5.9275
135    px -5.9275                                  $universe 24
140    px 5.9285
145    px -5.9285                                  $universe 25
150    px 5.9095
155    px -5.9095                                  $universe 26
160    px 5.9399999

mode  n
imp:n 1 101r 0
c
c      ***** Transformations of the lattice elements (#) *****
tr1    -29.6035 0 0
tr2    -17.7925 0 0
tr3    -5.9275 0 0
tr4    5.9275 0 0
tr5    17.7845 0 0
tr6    29.6035 0 0
c
c      ***** Transformations of the support assembly basic element *****
tr12   10.15528571 0 0
tr13   20.31057142 0 0
tr14   30.46585713 0 0
tr15   40.62114284 0 0
tr16   50.77642855 0 0
tr17   60.93171426 0 0
c
c      ***** Materials *****
m1     92234.60c -0.000169                   $uranium
       92235.60c -0.026465
       92236.60c -0.000363
       92238.60c -0.853603
       13027.60c -0.000285
       26056.60c -0.00008
        8016.60c -0.118919
       14000.60c -0.000116
m2     13027.60c -0.84744                    $wrapper and gap
        6000.60c -0.1276
       17000.60c -0.00005
       24052.60c -0.000025
       29063.60c -0.00015
       26056.60c -0.003
        1001.60c -0.0213
       12000.60c -0.000015
       25055.60c -0.00006
       28058.60c -0.00002
       14000.60c -0.00025
       50000.35c -0.00009
m3     13027.60c -0.00246                    $cladding
       27059.60c -0.00102
       24052.60c -0.18
       29063.60c -0.00152
       26056.60c -0.67604
       25055.60c -0.0166
       42000.60c -0.0034
       28058.60c -0.1118
       22000.60c -0.00666
       23000.60c -0.0005
m4      1001.60c -0.1119                     $water
        8016.60c -0.8881
m5     13027.60c -0.975006                   $bottom end plug
       29063.60c -0.000072
       26056.60c -0.0022
       12000.60c -0.0184
       25055.60c -0.00265
       28058.60c -0.000085
       14000.60c -0.0015
       22000.60c -0.000087
m6     27059.60c -0.00125                    $pin dowel
       24052.60c -0.1685
       29063.60c -0.0028
       26056.60c -0.70565
       25055.60c -0.0117
       42000.60c -0.00425
       28058.60c -0.0965
       16032.60c -0.0007
       14000.60c -0.00425
       22000.60c -0.0044
m7     13027.60c -0.9707                     $lower lattice plate
       29063.60c -0.0003
       26056.60c -0.003
       12000.60c -0.0212
       25055.60c -0.0036
       14000.60c -0.0012
m8     13027.60c -0.9701                     $upper lattice plate
       29063.60c -0.0001
       26056.60c -0.0035
       12000.60c -0.0208
       25055.60c -0.0034
       14000.60c -0.002
       22000.60c -0.0001
m9     13027.60c -0.981891                   $upper end plug
       29063.60c -0.000047
       26056.60c -0.002719
       12000.60c -0.012032
       25055.60c -0.001733
       28058.60c -0.000056
       14000.60c -0.001465
       22000.60c -0.000057
m10    13027.60c -0.71367                    $fuel support plate
        6000.60c -0.0001
       24052.60c -0.04729
       29063.60c -0.00015
       26056.60c -0.18508
       12000.60c -0.01498
       25055.60c -0.00659
       41093.60c -0.00105
       28058.60c -0.02836
       15031.60c -0.00006
       16032.60c -0.00003
       14000.60c -0.00215
       22000.60c -0.00049
m11    13027.60c -0.87406                    $fuel beam base
        6000.60c -0.00001
       27059.60c -0.00003
       24052.60c -0.01371
       29063.60c -0.00016
       26056.60c -0.055
       12000.60c -0.00508
       25055.60c -0.00156
       42000.60c -0.00006
       41093.60c -0.00018
       28058.60c -0.00774
```

```
       15031.60c -0.00001
       16032.60c -0.00001
       14000.60c -0.04071
       50000.35c -0.00042
       22000.60c -0.00126
m15    92235.60c -1.0
m16    92238.60c -1.0
m17    94239.60c -1.0
mt4    lwtr.01t                           $water S(alfa,beta)
c
c      ***** CALCULATION OF REACTION RATES IN FUEL ISOTOPES *****
c
f4:n  1
fm4    -1 15 18       $calculation of total fission reactions U-235
c
f14:n  1
fm14    -1 16 19      $calculation of first chance fission reactions in U-238
c
f24:n  1
fm24    -1 16 20      $calculation of second chance fission reactions in U-238
c
f34:n  1
fm34    -1 16 21      $calculation of third chance fission reactions in U-238
c
f44:n  1
fm44    -1 16 38      $calculation of fourth chance fission reactions in U-238
c
f54:n 1
fm54   -1 17 18       $calculation of total fission reactions in Pu-239
c
f64:n 1
fm64   -1   16 102    $calculation of radiative capture reactions in U-238
c
c      ****************
kcode 3000 1.0 50 4000
ksrc  -25.66 2.61 0
prdmp 2j -1
print
```

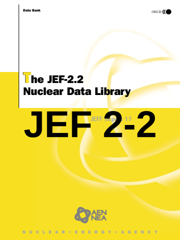


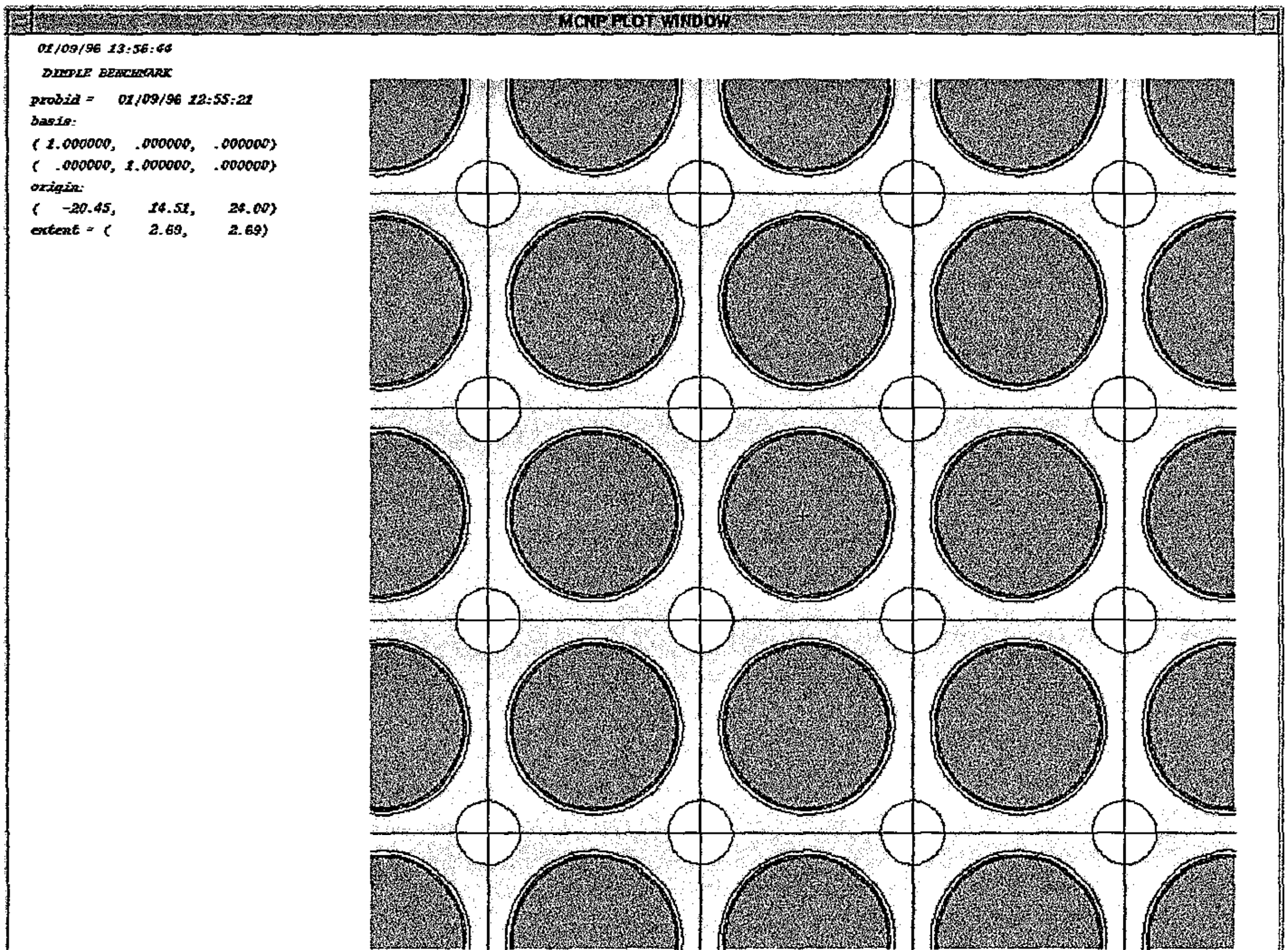


Picture 1: DIMPLE 3D whole lattice model - view from the top

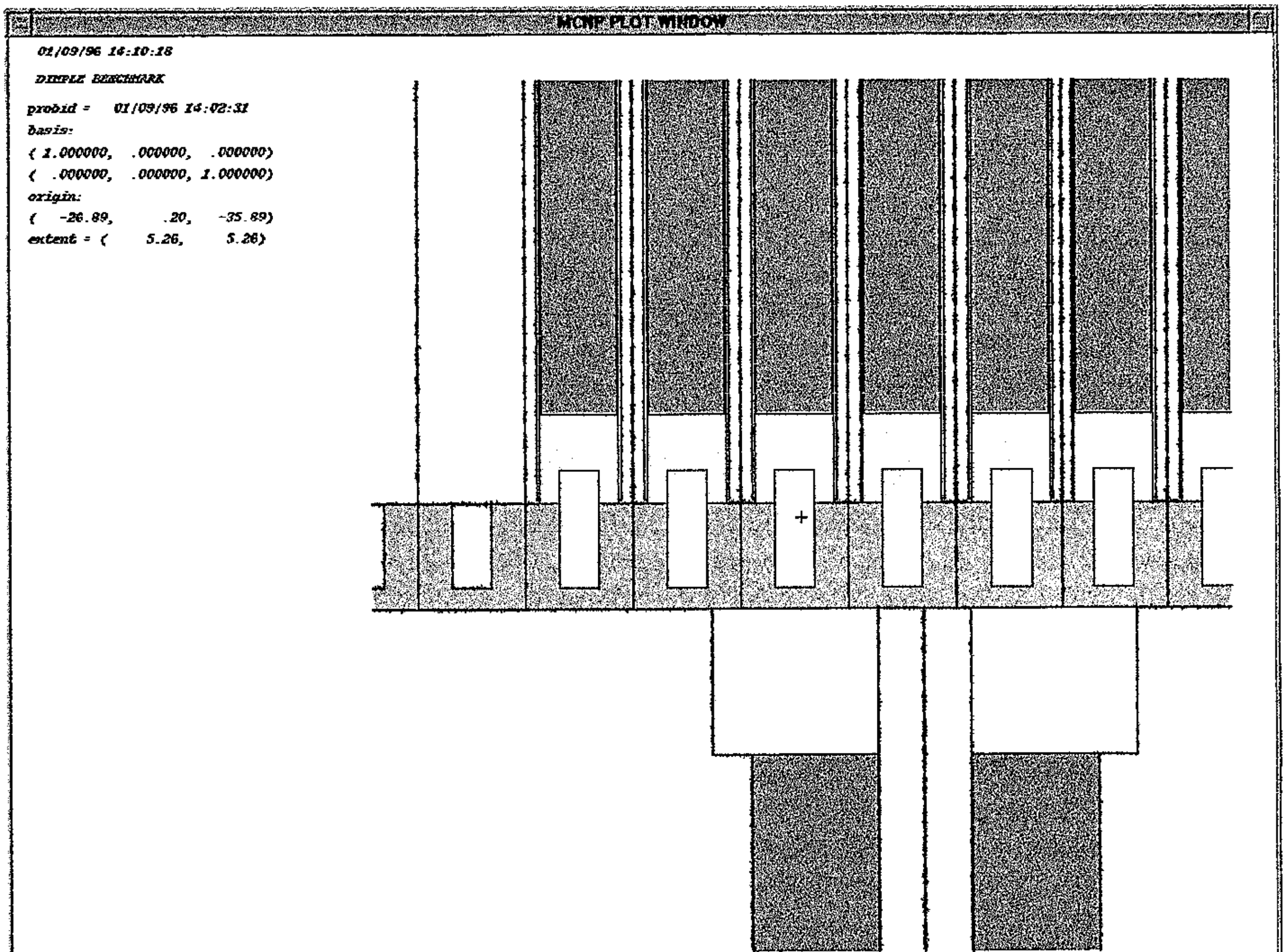


Picture 2: DIMPLE 3D whole lattice model - view from the side

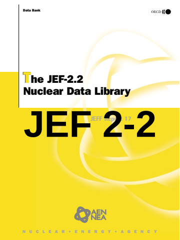




Picture 3: DIMPLE 3D model - intersection of the upper lattice plate

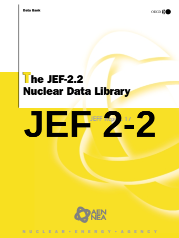


Picture 4: DIMPLE 3D model - detail of the lower lattice plate



Appendix B: MCNP pincell input

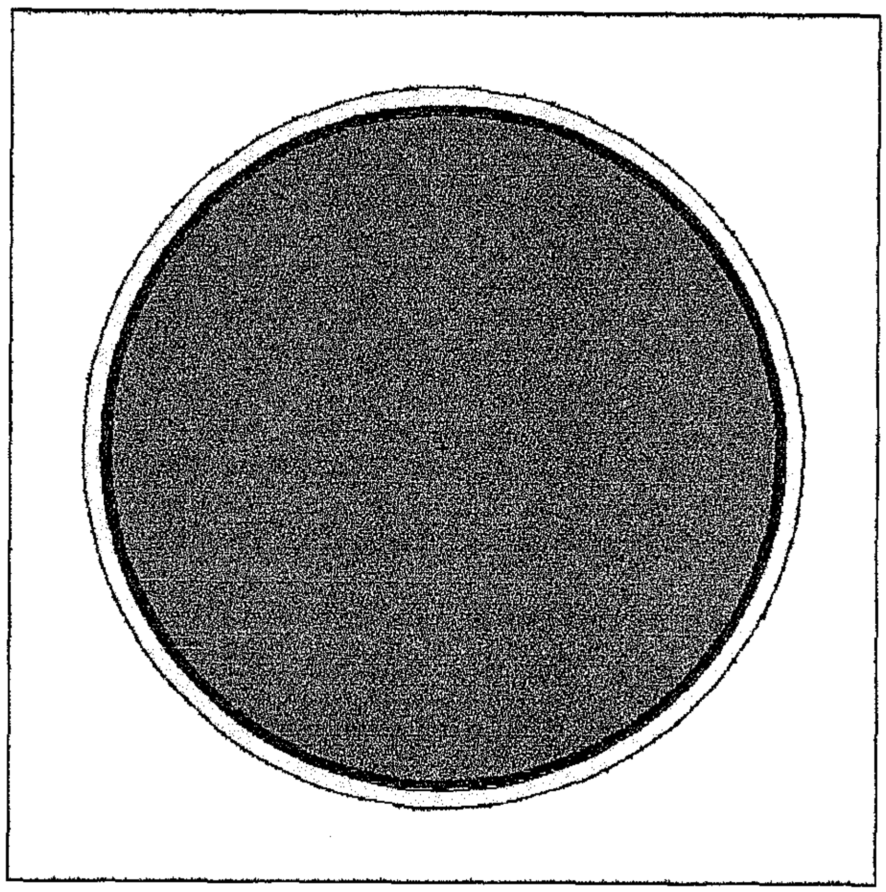
```
DIMPLE BENCHMARK K INF - simplified geometry of the pin cell
c    ******************************************************************
c    * Cross-section data from ENDF/B-VI library are used             *
c    * calculating of Kinf - reflecting boundaries, axialy no leakage  *
c    ******************************************************************
1      1  -10.42       -1                      $uranium
2      2  -0.868       1 -2                    $Al wrapper and gap
3      3  -7.806       2 -3                    $cladding
4      4  -0.9982041   3 -4 5 -6 7             $water up to the Hcrit
5      0               4:-5:6:-7               $surround

1      cz 0.5065                               $uranium
2      cz 0.5199                               $wrapper and gap
3      cz 0.54685                              $cladding
*4     px 0.66                                 $water - pitch
*5     px -0.66
*6     py 0.66
*7     py -0.66

mode n
imp:n  1 3r 0
m1     92234.60c -0.000169                  $uranium
       92235.60c -0.026465
       92236.60c -0.000363
       92238.60c -0.853603
       13027.60c -0.000285
       26056.60c -0.00008
        8016.60c -0.118919
       14000.60c -0.000116
m2     13027.60c -0.84744                   $wrapper and gap
        6000.60c -0.1276
       17000.60c -0.00005
       24052.60c -0.000025
       29063.60c -0.00015
       26056.60c -0.003
        1001.60c -0.0213
       12000.60c -0.000015
       25055.60c -0.00006
       28058.60c -0.00002
       14000.60c -0.00025
       50000.35c -0.00009
m3     13027.60c -0.00246                   $cladding
       27059.60c -0.00102
       24052.60c -0.18
       29063.60c -0.00152
       26056.60c -0.67604
       25055.60c -0.0166
       42000.60c -0.0034
       28058.60c -0.1118
       22000.60c -0.00666
       23000.60c -0.0005
m4      1001.60c -0.1119                    $water
        8016.60c -0.8881
mt4    lwtr.01t                             $water - S(alfa,beta)
kcode  3000 1.2 50 2500
ksrc   0 0 0
prdmp  2j -1
print
```



MCNP PLOT WINDOW

01/09/96 14:15:01
DIMPLE BENCHMARK

probid = 01/09/96 14:13:59
basis:
(1.000000, .000000, .000000)
(.000000, 1.000000, .000000)
origin:
(.00, .00, .00)
extent = (.70, .70)



Legend:

- 3% enriched uranium dioxide fuel
- aluminium wrapper/air gap
- stainless steel can
- light water moderator

Picture 5: DIMPLE Pincell Model - view from the top