BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: August 25, 1981

TO: John F. Carew

FROM: M. D. Zenter JC for M.D.Z.

SUBJECT: MESH - A Code for Determining the DOT Fixed Neutron Source

SUMMARY

MESH is a FORTRAN program designed to generate fixed source input to DOT-3.5.[1] Given fuel assembly boundaries and powers and the DOT 3.5 core model, MESH will assign a power value to each mesh point. Both X-Y and R-Θ constructions can be used for the reactor model.

I. INTRODUCTION

When the fixed source input option is chosen in DOT 3.5, a power density value must be provided for each mesh point for each neutron group. A typical (R,Θ) model of one octant of a reactor has 120 radial nodes, 20 angular nodes, and 16 neutron groups, requiring 38,400 input values. Since a power reactor core is heterogeneous, the problem of determining source terms becomes one of calculating each mesh block's location in the reactor. This is done by first overlaying the DOT R-Θ or X-Y geometry on the X-Y geometry of the core. Then, as will be explained below, a sector by sector mapping of the DOT model is performed. If the midpoint of a DOT mesh block is inside a fuel assembly, it is assigned that assembly's power density. After the mapping is complete, the result is multiplied by a 16-group ENDF/B-IV Watt fission spectrum, to provide the required source description.

II. METHODS

a. Reactor Model

MESH is designed to translate fuel assembly powers to DOT fixed source power data given fuel assembly coordinates. MESH, using an algorithm described below, determines which mesh blocks are in which fuel assembly. Thus, to model the reactor for input to MESH, it is necessary to provide the coordinates of the corners of each fuel assembly, using the reactor center as the origin. If it is necessary to describe a finer power structure than that given by a whole fuel assembly, then the fuel assemblies can be subdivided and the coordinates of the sub-assemblies given. Similarly, if large areas of constant power exist, a coarser model may be used, and the coordinates of the super-assembly input.

b. DOT Model

DOT 3.5 allows specification of a fixed radial and angular spatial mesh. As can be seen from Figure 1, the core material boundary may vary from sector to sector. For example, in Sector 2, mesh 68 is in the core while in Sector 9, mesh 68 is in the reflector. MESH will list each mesh point and its location. Using this data will expedite constructing the DOT model and will also ensure a one-to-one correspondence between DOT and MESH models.

Since outside the core region the reactor exhibits angular symmetry (Figure 1) and has no power source, usually it is only necessary to model the core and part of the reflector for MESH, which will automatically zero fill the source terms for the rest of the reactor.

c. Calculational Procedures

It is very important that there be a one-to-one correspondence between the output produced by MESH and that expected by DOT since DOT has no fixed source input error checking capability. Thus, it is recommended that the following procedure be used when preparing a model.

The reactor core is usually divided into two zones. In the first zone the radial mesh is relatively widely spaced; for example, two mesh blocks per fuel assembly. The radial mesh in the second zone must be much smaller, to account for fuel assembly edge effects. A recommended width is half the core shroud (typically $\sim$ 1 cm). The size of the two zones will have to be determined on a model by model basis, but the second zone should be as small as possible, since there will be a large number of mesh blocks in it. See Figure 1 for an example of how the zones are determined.

The angular or axial mesh must be determined by an iterative process. Any required spacing (for example, modeling a surveillance capsule or an instrument thimble) will have to be set up. Then, a preliminary angular or axial mesh will be chosen and a run made. The adequacy of the mesh can be determined by comparing the calculated and input fuel assembly areas. It is desirable to have the calculated and input core areas as close as possible, and a judicious selection of angular (or axial) and radial mesh spacing will accomplish this. Once an adequate core model has been achieved, it can then be used as the basis for the DOT 3.5 model.

d. Calculational Methods

First, sector boundaries are established, then the mesh calculations begin at the core center and step out towards the reactor outer boundary. For

R-Θ geometry, the mesh midpoint is determined by equations 1 and 2 and for X-Y geometry, by equations 3 and 4,

$$X_m = \frac{R_2+R_1}{2}\left(\cos\left(\frac{\theta_2+\theta_1}{2}\right)\right) \quad (1)$$

$$Y_m = \frac{R_2+R_1}{2}\left(\sin\left(\frac{\theta_2+\theta_1}{2}\right)\right) \quad (2)$$

$$X_m = \frac{R_2+R_1}{2} \quad (3)$$

$$Y_m = \frac{Z_2+Z_1}{2} \quad (4)$$

where

$$R_2 = R_1 + \Delta R_z \quad (5)$$

ΔR_z is the zonewise radial increment, θ_1 and θ_2 are the angular boundaries in an R-Θ model, and Z_2 and Z_1 are axial boundaries in an X-Y model.

Mesh areas are determined by equation 6 if an R-Θ model is used, and by equation 7 for an X-Y geometry.

$$A_m = \frac{\pi\left(\theta_2-\theta_1\right)}{360}\left(R_2^2 - R_1^2\right) \quad (6)$$

$$A_m = \left(Z_2-Z_1\right)\left(R_2-R_1\right) \quad (7)$$

The mesh block is determined to be inside a fuel assembly if:

$$FE_{xmin} \leq X_m \leq FE_{xmax}$$

and

$$FE_{ymin} \leq Ym \leq FE_{ymax}$$

where FE_{xmin}, FE_{ymin}, FE_{xmax}, FE_{ymax} are the fuel assembly boundaries.

e. INPUT

The first input field tells MESH whether an X-Y (XY) or R-Θ (RT) reactor model is to be used (MESH handles XY and RZ geometries in exactly the same way).

The second input field is a table of fuel assembly (or super, or sub-assembly) data, consisting of an identification number, left and right x-coordinates, and bottom and top y-coordinates for each assembly. The assemblies may be in any order in this table, but the fuel assembly powers, specified in the third input field, must be in the same order. Any number (up to a maximum of 220) of assemblies may be input. An end of record card must be located at the end of this table so MESH can count the number of fuel assemblies entered.

The third input field is the list of fuel assembly powers. There must be as many of these as there are fuel assemblies, and they must be in the same order as the fuel assembly base table.

The fourth and fifth input fields are the number of radial and angular (for an R-Θ model) or radial and vertical (for an X-Y model) mesh points respectively in the DOT model.

The sixth input field contains the DOT angular mesh boundaries, (in degrees) for an R-Θ model, or the vertical mesh boundaries for an X-Y model.

The seventh through ninth fields contain the number of radial zones in the MESH model, the radial increment in each, and the boundaries of each zone.

If an X-Y model is to be used, the tenth field is the axial power distribution, consisting of one value for each vertical mesh.

The last field is the 16-group ENDF/B-IV Watt fission spectrum.

Typical MESH sample input for both an XY and R-Θ model are given in Appendices A and B.

f. Output

The first output field is an "Echo" of all input data.

The second field is a set of data on each fuel assembly, in the order it was input. The area of the assembly, based on the input coordinates, will be listed, as will the area calculated by adding the areas of the mesh blocks determined to be inside that fuel assembly. The input power will also be listed. If the calculated area and the input area differ by more than ten percent, an error message is printed. This implies that the calculational model may be inadequate.

The next output field is a sector-by-sector listing of the following data. First, the sector number and boundary angles or vertical mesh are printed. Then, for each fuel assembly in that sector; the mesh blocks in that fuel assembly are listed including their power values, midpoints and areas.

Finally, at the end of each sector output, there is a table of mesh blocks and their associated fuel assemblies.

References

(1) "DOT-3.5, Two-Dimensional Discrete Ordinates Radiation Transport Code," Radiation Shielding Information Center Computer Code Collection CCC-276 (1976).

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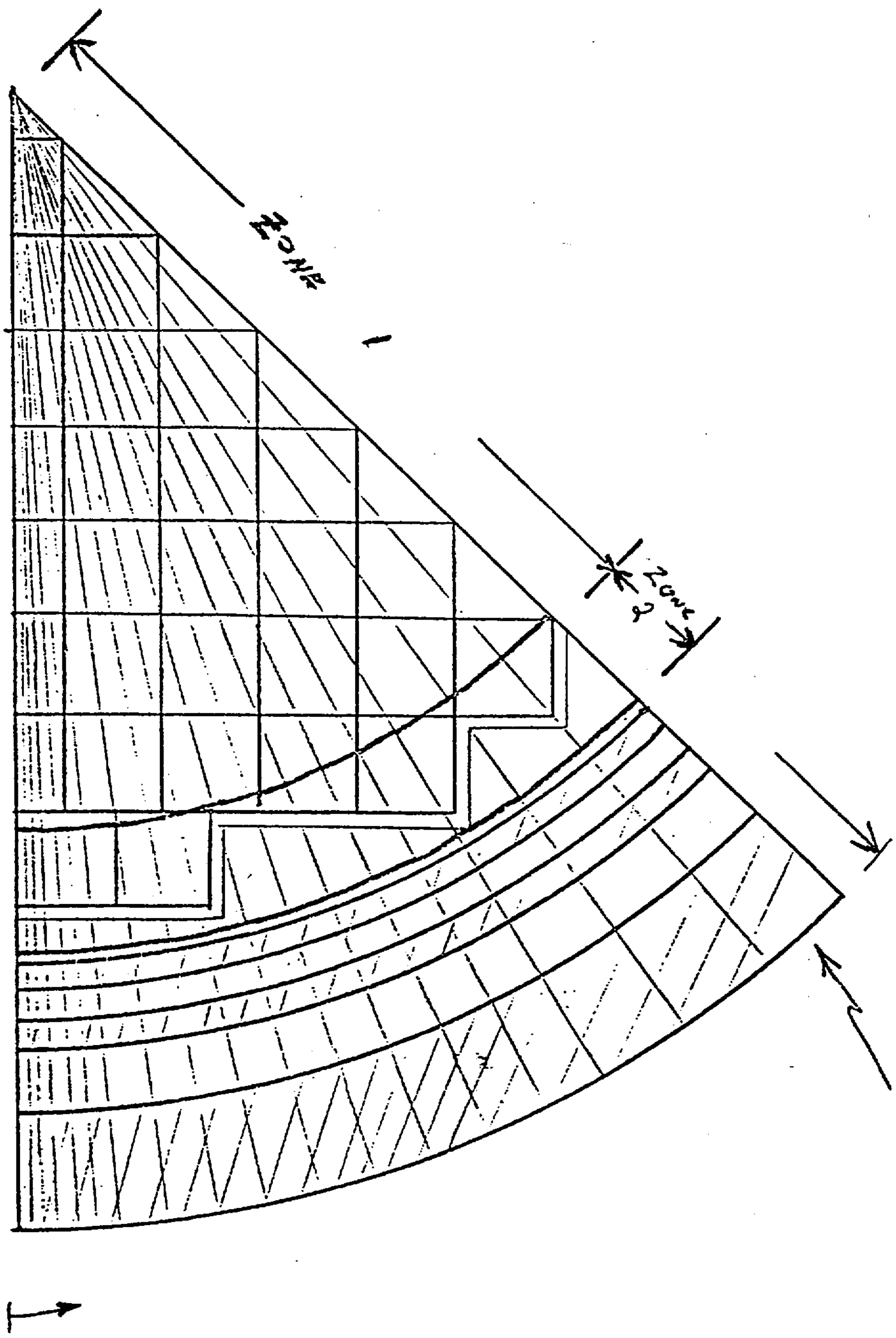

Figure 1

Appendix A Sample input data file for MESH R-θ model.

1. Geometry Indicator: RT

2. Fuel Assembly Table

1	00.00	10.39	00.00	10.39
2	10.39	31.17	00.00	10.39
3	31.17	51.94	00.00	10.39
4	51.94	72.72	00.00	10.39
5	72.72	93.50	00.00	10.39
6	93.50	114.27	00.00	10.39
7	114.27	135.05	00.00	10.39
8	10.39	31.17	10.39	31.17
9	31.17	51.94	10.39	31.17
10	51.94	72.72	10.39	31.17
11	72.72	93.50	10.39	31.17
12	93.50	114.27	10.39	31.17
13	114.27	135.05	10.39	31.17
14	31.17	51.94	31.17	51.94
15	51.94	72.72	31.17	51.94
16	72.72	93.50	31.17	51.94
17	93.50	114.27	31.17	51.94
18	114.27	135.05	31.17	51.94
19	51.94	72.72	51.94	72.72
20	72.72	93.50	51.94	72.72
21	93.50	114.27	51.94	72.72
22	114.27	135.05	51.94	72.72
23	72.72	93.50	72.72	93.50
24	93.50	114.27	72.72	93.50
25	114.27	135.05	72.72	93.50
26	93.50	114.27	93.50	114.27

End of Record: *EOR

3. Assembly Powers

.96 .91 .87 .83 .78 .96 .91 .87 .83 .78
.96 .91 .87 .83 .78
.73 .66 .59 .51 .44 .73 .66 .59 .51 .44
.73

4. Number of Radial Mesh: 120
5. Number of Angular Mesh: 21
6. Angular Mesh Boundaries: 0.0 .38 .759 1.0 1.5 2.0 3.0 4.0 5.0 7.5 10.0 12.5 15.0 18.0 21.0 24.0 27.0 30.0 35.0 40.0 45.0
7. Number of Radial Mesh Zones: 2
8. Zone Increments: 6.0 .715
9. Zone Boundaries: 0.0 150.0 185.0
10. ENDF/B-IV Watt Fission Spectrum

.57379E-01 .15021E+00 .84797E-01 .45207E-01
.92253E-01 .21265E+00 .19935E+00 .14074E+00
.17313E-01 .88947E-04 .64519E-05 .42670E-06
.74647E-07 .20547E-08 .31137E-09 **0.0**

Appendix B Sample input data file for MESH XY model.

1. Geometry Indicator

XY

2. Fuel Assembly Table

1	00.00	10.39	61.00	366.0
2	10.39	31.17	61.00	366.0
3	31.17	51.94	61.00	366.0
4	51.94	72.72	61.00	366.0
5	72.72	93.50	61.00	366.0
6	93.50	114.27	61.00	366.0
7	114.27	135.05	61.00	366.0
8	135.05	155.83	61.00	366.0
9	155.83	176.60	61.00	366.0
10	000.0	176.6	000.0	30.5
11	000.0	176.6	30.5	61.0
12	000.0	176.6	366.0	396.5
13	000.0	176.6	396.5	427.0

End of Record

*EOR

3. Assembly Powers	7*1.148 .87 .586 4*1.0
4. Number of Radial Meshes	120
5. Number of Axial Meshes	6
6. Axial Mesh Boundaries	0.0 30.5 61.0 88.73 116.45 144.18 171.91 199.64 227.36 255.89 282.82 310.55 338.27 366.0 396.5 427.0
7. Number of Radial Mesh Zones	2
8. Zone Increments	6.0 .715
9. Zone Boundaries	0.0 150.0 185.0
10. Axial Power Shape	0.0 0.0 .25 .90 1.3 1.47 1.5 1.44 1.25 1.0 .65 .25 .1 0.0 0.0

11. ENDF/B-IV Watt Fission Spectrum

.57379E-01	.15021E+00	.84797E-01	.45207E-01
.92253E-01	.21265E+00	.19935E+00	.14074E+00
.17313E-01	.88947E-04	.64519E-05	.42670E-06
.74647E-07	.20547E-08	.31137E-09	0.0