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An Introduction to the New Features of MONK Version 8B

M J Armishaw

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Executive Summary

Version 8B is the latest release of the MONK Monte Carlo code. This new version incorporates a range of additional features, including the capability to perform first order sensitivity calculations. This report provides an introduction to the use of each of the additional features of the new code and is directed at existing MONK8A code users. Further information on all the features introduced here can be found in the MONK8 User Guide.

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1 Introduction

The development and subsequent release of MONK7A was the culmination of a major renewal programme for the MONK criticality codes. This comprised a comprehensive software re-engineering programme to bring MONK into line with the successful modular system employed for the shielding codes MCBEND and RANKERN. This has provided customer and custodian benefits in terms of shared facilities and developments and more cost-effective and efficient maintenance. Versions 7B [1] and 8A [2] were later released and included a range of extra features to extend the capabilities of the code.

Version 8B is now available from the ANSWERS Software Service and is the first version to provide the capability to perform first order sensitivity calculations. In addition several other features have been developed and are included in version 8B. This report provides an introduction to their use and is directed at existing MONK8A code users. Further information for all the features introduced here can be found in the MONK8 User Guide [3].

The new features of MONK8B (as described in section 2) comprise:

1. ICSBEP Format Output
2. Fission Spectrum Scoring
3. Outer Boundary Reflection Tallying
4. Albedo Material Tallying
5. Alphanumeric Part and Material Names
6. Buckling Option with DICE Data
7. Hole Tallying with DICE Data
8. Duplicate/Ambiguous ZONEMAT Data
9. Fissile Nuclide Concentration
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21. Part/Region Display for Action Tallies
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40. Parameters as functions of parameters
41. First order sensitivity
42. GHOLE option
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2 Guide to New Features

2.1 ICSBEP FORMAT OUTPUT

The option to print tables in ICSBEP (International Criticality Safety Benchmark Evaluation Project) format to the output file has been added to MONK8. The ICSBEP tables give:

- Tallies in the core materials (as defined by the user)
- Automatic identification of fuel in the core materials (i.e. fissile/fissionable isotopes)
- Tables of Flux, fission% and capture% in the ICSBEP 3 and 30-group schemes
- Balance of fissions and captures by isotope in the core
- $\nu^* \Sigma_f / \Sigma_a$ in the fuel isotopes

To activate this option three changes are required to a standard input:

- Enter into the CONTROL DATA input unit the keywords ICSBEP CORE MATERIALS followed by a list of one or more materials identifying to the code those materials which the user considers to be core materials. Core materials are usually the fissile or fissionable materials, although for some cases it may be desirable to exclude, for example, a depleted uranium reflector.
- Add into the ENERGY DATA input unit the keywords SCORING ICSBEP to select the ICSBEP 3- and 30-group boundaries in addition to the standard MONK 3-group boundaries for flux scoring.
- In the datasets file include the named channel ICSBEP and assign a file to it into which the ICSBEP data will be written.

An enhancement required to MONK for the ICSBEP format output was the option to score in multiple group schemes during a single MONK run. The current implementation causes the flux spectrum for each of the selected group schemes to be printed to the file on the named channel ICSBEP. A side effect is that the normal flux output written to named channel OUTPUT is in a single group scheme that has boundaries which are the result of merging all the group schemes. An example of the format of the input is:

```
BEGIN ENERGY DATA
SCORING SCHEMES 3          ! 3 schemes will entered
3 15.0 100.0E-3 0.625E-06 0.0 ! 3 groups followed by the 4 boundaries of the first scheme
1 15.0 0.0                ! 1 group followed by 2 boundaries for the second scheme
5 6.0 4.0 3.0 2.0 1.5 0.9 ! 5 groups followed by 6 boundaries
END
```

Note that when SCORING SCHEME is used the MONK 3-group boundaries will automatically be added by the code to the list of group schemes.

If there is sufficient interest in this option future work may enable the Action Tally results to be printed in each of the group schemes entered.

2.2 FISSION SPECTRUM SCORING

An enhancement to the Action Tallies for MONK8B is the option to tally the spectrum of the daughters from fission events to produce a case specific fission spectrum. The group scheme of the results will be that used for the calculation. To select the option the following changes are required to a standard input:

- Enter the keywords FISSION SPECTRUM into the ACTION TALLY input unit
- In the datasets file include the named channel FISPEC and assign a file to it into which the fission spectrum data will be written.
- Optionally use SCORING GROUPS in the ENERGY DATA input unit to set the energy group scheme required.

2.3 OUTER BOUNDARY REFLECTION TALLYING

In MONK8A the tallying of the distribution of neutrons at the outer boundary of the system was limited to escapes. In MONK8B these tallies now include reflection events. This combination allows the code to determine the effective albedo at each external surface of the system.

These additional results are produced when the Boundary Crossing tallies are requested and do not require any additional input from the user. In MONK8B the Action Tally default is to produce these data (as it was in MONK8A).

2.4 ALBEDO MATERIAL TALLYING

The option has been added into MONK to tally events at boundaries with Albedo Materials. This additional tally includes those samples entering, emerging from, or captured by the albedo material. To activate this option:

- Enter into the ACTION TALLY input unit the keywords ALBEDO MATERIALS

2.5 ALPHANUMERIC PART AND MATERIAL NAMES

MONK8B will accept alphanumeric part and material names in the MATERIAL GEOMETRY, MATERIAL SPECIFICATION and MATERIAL DATA input units. The restrictions on the names are:

- Alphanumeric names must be an unbroken string of up to 20 characters.
- The first character must not be a digit, @ , (, [or <.
- Can mix named and numbered parts, but not named and numbered materials

e.g. in MATERIAL GEOMETRY
PART 2

could become :

PART FUELEMENT

e.g. in MATERIAL DATA

MATERIALS 4

1

could become :

MATERIALS 4

NAME Moderator

To reference named parts and materials :

BOX P6

ZROD M1 ...

could become

BOX P FUELEMENT

ZROD M Moderator

Note the mandatory space between both the P and the M and their respective names

2.6 BUCKLING OPTION WITH DICE DATA

The buckling option which was only available for WIMS data calculations in MONK8A has been extended in MONK8B to include DICE data calculations. Also the use of the BUCKLING keywords in the CONTROL DATA input unit is now deprecated and the instructions below must be followed. To activate the option:

- In the ACTION TALLY input unit enter the keywords BUCKLING COSINE followed by Bx^2 , By^2 and Bz^2 .
- Optional input following the above data are the keywords BUCKLING LIMIT followed by a distance. This distance is the maximum length a sample can travel before it is killed off by the code. This is for use in those exceptional circumstances where streaming occurs and the sample must be gratuitously excised from the system.

2.7 HOLE TALLYING WITH DICE DATA

Hole tallying was coded into MONK8A for use in WIMS data calculations. In MONK8B the option has been extended to work with DICE data calculations. To activate the option for both types of calculations:

- In the ACTION TALLY input unit enter the keyword HOLACT

2.8 DUPLICATE/AMBIGUOUS ZONEMAT DATA

In previous versions of MONK it was necessary to ensure the ZONEMAT specifications were unambiguous and identified only a single zone within the system. If this zone were repeated (through repeated part use) then each occurrence would need to be explicitly entered. An enhancement in MONK8B allows an ambiguous ZONEMAT specification to be entered. The code will resolve all instances of the entered specification to generate the corresponding ZONEMAT entries. The ZONEMAT table printed to the output by the code will list all these additional entries as well as those the user has specified. This process is done automatically by the code so no additional keywords need to be entered by the user. To summarise:

- MONK8A ZONEMAT specification had to refer to a unique zone
- New MONK8B ZONEMAT can have ambiguous specifications and refer to several zones
- ZONEMAT specification will be applied to all occurrences of the zone
- Each occurrence has a separate entry listed in the ZONEMAT table written to the output file
- No additional data required from the user to use ambiguous specification

2.9 FISSILE NUCLIDE CONCENTRATION

An option has been added to allow the display of certain fissile nuclide concentrations, poison nuclide concentrations, total U and Pu and the H:fissile atom ratio. To activate this option:

- In the CONTROL DATA input unit enter the keywords FISSILE CONCS

Note that the values printed are based upon the atom densities supplied by the user in the composition data for individual materials and are not based on the results of any tracking. For example in a fuel pin lattice arrangement it is not possible to get the overall H:Fissile ratio for the arrangement.

To summarise:

- Fissile/Fissionable isotope concentrations of Uranium (233, 234, 235, 236, 237, 238 and 239) and Plutonium (238, 239, 240, 241 and 242)
- Total Uranium, Plutonium
- The proportion of the poison nuclides Boron, Gadolinium and Hafnium in grams per litre
- Hydrogen atom : Fissile atom ratio (U235, PU239, PU241)

2.10 ROOTE FISSION SPECTRUM SAMPLING

In previous versions of MONK small discrepancies (of the order of 0.1% in k-effective) have occurred between the calculated and expected values of k-effective for fast energy systems. This has been traced to discrepancies in the shape of the low energy tail in the system. This new option modifies the low energy tail to improve the results. However, to maintain the consistency of the results with MONK8A, and due to the small size of the effect, the improved

treatment has been introduced in MONK8B as an option rather than as the default. To activate this option:

- In the CONTROL DATA input unit enter the keywords ROOTE FISSION SAMPLING

2.11 SIMPLE HOLE ROTATION

In line with the development in MONK8A of the simple rotation option in the MATERIAL GEOMETRY input unit (FG), this has now been extended for use in the HOLE DATA input unit (HG). The format and rotation sense is identical to that in FG and provides a simple alternative to ROTATE and DCOSINES in HG. To summarise:

- XROT, YROT or ZROT followed by angle in degrees
- Sense same as in Fractal Geometry
- Simple alternative to ROTATE and DCOSINES

The input is of the form:

```

PLATE                ! hole name
ORIGIN 1.0 2.0 5.0   ! optional ORIGIN data, always put before ZROT if used
ZROT 23.5            ! optional rotation data, here by 23.5 degrees around the Z axis
<remaining plate hole data>

```

2.12 GLOBE HOLE – DIFFERENT SUB-UNIT MATERIALS

The GLOBE hole has been modified to enable the user to specify a different material or subsidiary hole in each sub-unit. Refer to Appendix 1 for the GLOBE hole flowchart, specifically the new PINS option.

2.13 GLOBE HOLE – SUB-UNIT ORIENTATION IN DEGREES

The GLOBE hole has been modified to enable the user to enter the angle of rotation of the sub-unit ring in degrees as an alternative to S-values. Referring to the GLOBE flowchart in Appendix 1, the reader is directed to 'note 4' where the new keyword DSUB instructs the code to expect the 'orientation' to be in degrees instead of S-units adjacent to 'note 5'.

2.14 GLOBE HOLE – RADII IN INCREASING ORDER

For consistency with other holes the GLOBE hole has been modified to enable the user to specify the ring radii in increasing order. The code will still accept the old decreasing order, but the two cannot be mixed!

Referring to the GLOBE flowchart in Appendix 1, the reader is directed to 'note 2', 'note 5' and 'note 9'. At each of the places in the flowchart the input can now be in increasing value instead of the original decreasing value.

2.15 HOLE NUMBERING

The HOLE DATA input unit has been modified to allow the user to precede each hole name by HOLE nn, where nn is the hole number which must be in sequence and starting at 1. For example:

```
HOLE 1  
PLATE 0 0 1 ....
```

```
HOLE 2  
GLOBE ...
```

2.16 LATTICE HOLE – USER DEFINED NUMBER OF RADII

The LATTICE hole has been modified to enable the user to specify more than two radii for each pin should additional detail be required. This change removes the need for a GLOBE subsidiary hole in many cases. To summarise:

- Default to 2 radii for rod and clad
- MORE keyword to select additional radii
- Additional materials specified for each annulus
- Subsidiary holes allowed in annuli

Referring to the flowchart in Appendix 2 the keyword MORE can be used to set values of <NRAD> greater than 2, after which it is necessary to enter the required number of radii and materials.

2.17 PLATE HOLE – PLATE BOUNDARIES IN INCREASING ORDER

To provide consistency with other holes the PLATE hole has been modified to accept the plate boundaries in increasing order. The existing flowchart continues to be applicable. The code will continue to accept boundaries in decreasing order, but the two cannot be mixed!

2.18 RTZMESH HOLE

The RTZMESH hole is a new hole in MONK8B and enables the user to specify zero or more radial, azimuthal and/or z-mesh elements. The azimuthal breakdown allows for entities such a simple treatment for Y-joints in pipes. Refer to Appendix 3 for the flowchart and notes.

2.19 SQUARE HOLE – USER DEFINED NUMBER OF RADII

The SQUARE hole has been modified to enable the user to specify more than two radii for each pin should additional detail be required. This change removes the need for a GLOBE subsidiary hole in many cases. Refer to Appendix 4 for the new flowchart and notes.

To summarise:

- Default to 2 radii for rod and clad
- MORE keyword to select additional radii
- Additional materials specified for each annulus
- Subsidiary holes allowed in annuli

2.20 TRIANGLE HOLE – USER DEFINED NUMBER OF RADII

The TRIANGLE hole has been modified to enable the user to specify more than two radii for each pin should additional detail be required. This change removes the need for a GLOBE subsidiary hole in many cases. Refer to Appendix 5 for the flowchart and notes.

To summarise:

- Default to 2 radii for rod and clad
- MORE keyword to select additional radii
- Additional materials specified for each annulus
- Subsidiary holes allowed in annuli

2.21 PART/REGION DISPLAY FOR ACTION TALLIES

The action tally tables for the source, boundary crossings and region action tallies in MONK8A presented the results by assembled model region only. This caused the user constantly to refer to the FG analysis tables to map this region number back to what they had entered. This enhancement additionally lists the part and local region number adjacent to each result in the output tables for the above tallies. No additional user input is required to select this option.

2.22 DEPLETION REFUELLING

A problem experienced with MONK8A during depletion calculations was the inability to enter material compositions after cycle 1 to modify one or more of the materials. A further problem was caused by the code not handling nuclides which were present in two materials but at different temperatures. These two limitations in MONK8A have been fixed in MONK8B. To summarise:

- Allows material composition to be changed after the first cycle
- Composition data overwrites interface file data for all references to the original material and in burn regions

- Nuclides in materials at different temperatures are now handled correctly

2.23 COMPONENT MULTIPLICATION

During certain criticality calculations it is useful to know the relative contribution to k-effective from different parts of the system. To accomplish this, an option has been added to MONK8B that allows the user to request that for one or more parts in the model, the part (component) multiplication be determined. To activate the option:

- Enter in the CONTROL DATA input unit the keywords COMPONENT MULTIPLICATION FOR PARTS followed by a list of one or more parts for which the multiplication is required.

To summarise:

- Input via the CONTROL DATA unit
- Select a list of one or more PARTS for scoring
- For each selected PART tallies are scored during tracking
- For each selected PART the tallies are used to calculate the multiplication
- In the output the multiplication and standard deviation for each selected PART is printed
- The output is of the form:

```
*****
* COMPONENT MULTIPLICATION ANALYSIS *
*****
* PART          K-EFFECTIVE      ST.DEV *
*****
          1          0.5912        0.0060
          2          0.5819        0.0047
          3          0.6015        0.0052
```

2.24 SUMMARY TABLE OUTPUT

When a looping calculation is requested in MONK it is necessary to search through all the output files to find the K(THREE) value and any parameter details required. This new option enables the user to write K(THREE) and varying amounts of parameter detail to an additional file to simplify assembling the results for inspection. To activate the option:

- In the CONTROL DATA input unit enter the keywords SUMMARY TABLE OUTPUT
- The above keywords can be followed by the optional keyword ALL to list all the parameters used, not just those which change during looping.
- In the datasets file add the named channel SUMTAB and assign to this channel the file into which the results are to be written.

To summarise:

- Provides a concise record of the final value of K(THREE) and its standard deviation in a single file for each loop followed by the looping parameters
- Keywords SUMMARY TABLE OUTPUT in the CONTROL DATA unit
- Optional keyword ALL to list all parameters, not just those that change between loops
- New channel SUMTAB in datasets

2.25 MULTI-LINE FORMULAE

The restriction that formulae had to reside fully on a single line has been removed for MONK8B. In addition, no continuation character is required for those formulae which move onto the following lines.

e.g.
 BOX M2 0.0 0.0 0.0 [.....] [.....
] [.....]

To summarise:

- In MONK8A formulae had to be on a single line
- MONK8B allows the use of multi-line formulae
- no continuation character is required

2.26 GLOBAL HOLE OPTION

Alongside the existing H and BH hole type specifier in the MATERIAL GEOMETRY input unit is the new GLOBAL HOLE, GH, specifier. This new specifier means that the hole to which it applies uses as its origin the origin of the global model. All the existing holes can be used with GH and there are no restrictions on its use in combination with H and BH. To summarise:

- A hole defined in the global model co-ordinates
- New keyword GH...
- All existing holes can be used with GH
- Can be freely used with part holes (H) and body holes (BH)

2.27 CLONE PARTS

It is becoming more common for models to include lists of parts which are identical to some earlier part in order to create additional zones for scoring purposes. This task has been simplified by the addition of the CLONE keyword syntax. For example, given part 1 has been defined

and it is necessary to create 22 further parts identical to 1 but with distinct zone numbering, the syntax:

PART 2 UNTIL 23 CLONE 1

can be used to generate the additional 22 parts.

2.28 PART NUMBER SEQUENCES

The need to easily generate lists of numbers when specifying ARRAY parts has led to the development of additional tools in the MATERIAL GEOMETRY input unit. The input syntax :

FROM IP TO JP or IP:JP:KP

defines a sequence of consecutive part numbers from IP to JP, in the second case with a step size of KP (note there must be no spaces either side of the ':', also KP is optional with the default value of 1).

As an example consider an ARRAY part:

FROM 3 TO 8	3 4 5 6 7 8
2 3 1:4	2 3 1 2 3 4
FROM 6 TO 8 5:9:2	6 7 8 5 7 9

2.29 GROUP REPEAT OPTION

A further input tool is the group repeat syntax which can be used to repeat lists of number. The group repeat syntax is:

n*{item1 item2...}

defines a list of items that is repeated 'n' times.

As an example consider an ARRAY part:

2*{1 2 3 3 2 1}	1 2 3 3 2 1
	1 2 3 3 2 1

2.30 LATTICE, SQUARE AND TRIANGLE HOLES – NOCHECK OPTION

During the inclusion of the LATTICE, SQUARE and TRIANGLE holes into MCANO for the development of MONK7A a check was included which prevents the overlap of pins in these holes. Since the incorporation of the reactor physics capability into MONK8A the different behaviour of these holes in MONK5W (where overlaps were permitted) has been

identified. A modification has been added to the HOLE DATA input unit in MONK8B whereby the use of the NOCHECK option suppresses the checking of pin overlaps in these three holes. The NOCHECK keyword is entered immediately after the BEGIN HOLE DATA keywords and applies to all occurrences of these three hole types.

e.g.

```
BEGIN HOLE DATA  
NOCHECK  
.....  
END
```

2.31 MONACC

MONACC is a development undertaken for Rolls Royce Marine Power (RRMP) and makes use of the collision files produced by MONK8B to enable the user to generate Action Count results for user specified volumes. The basic shapes available include BOX, SPHERE, X/Y/ZROD and these can be nested to give the counts within the volumes between the bodies. Additionally the results can be by nuclide/energy group/material or summed over any one or more of these. Full details will be found in the MONACC User Guide [4] which not only describes how to use MONACC, but also details the changes to a MONK input required to produce the required collision files.

Note that MONK8A does not produce the correct format of collision file for use by MONACC.

2.32 COWL

The COWL suite of codes developed for RRMP allows the number densities from, say, a depleted element in a reactor core to be transferred into that same element located in a transport flask. This transfer allows the depleted number densities to be used to determine the behaviour of the fuel within the transport flask through a further run of MONK8B. The use of this suite of codes is described in the User Guide [5].

2.33 BIRTH STORE SOURCE TALLY AND BIRTH STORE PLUS FISSION SOURCE TALLY

Two further tallies have been added to the Source tally option activated by the SCEDST keyword in the ACTION TALLY input unit. These two tallies respectively tally by region the samples extracted from the birth store and tally by region the sum of the samples extracted from the birth store and those emerging from fission events. The first tally allows the user to inspect how the source used for each stage has averaged out over the complete run. The second tally, by also including fission events gives an idea of the overall distribution of source events throughout the run.

To summarise:

- Tally all sources by region from birth store
- Tally all sources by region from both birth store and fissions

2.34 FG ZONE SUB-DIVIDE

This option enables two body types to be subdivided automatically to generate additional scoring zones. The SUBDIVIDE part thus allows a single BOX or ZSEC body to be subdivided by an XYZ or RθZ mesh (respectively) to form a cluster. Each subdivision forms a separate body and thus a separate zone. By default, each zone is a scoring region.

2.35 JENDL3.2 DICE LIBRARY

A new DICE format nuclear data library has been produced based upon the Japanese JENDL3.2 evaluations. The nuclides in this library can be referenced directly using the MATERIAL DATA input unit, but the recommendation is to use an updated material database with the MATERIAL SPECIFICATION unit. The nuclear data library is assigned using the DICE named channel in datasets and it is mandatory to use the appropriate thermal data library assigned to the named channel THERM. At the time of writing these files respectively are:

```
dice00jn3v1.dat
therm00jn3v1.dat
```

2.36 UPDATED JEF2.2 AND ENDF/B-VI DICE LIBRARIES

The JEF2.2 and ENDF/B-VI nuclear data libraries have now been made mutually consistent so that any nuclide present in one library will always be found in the other. Where (for example) JEF2.2 data is not available for a particular nuclide then ENDF/B-VI data will be used.

Additional nuclides have been added to both libraries for completeness and these comprise: O17, Zn-natural and Sb/Xe/Sm fission products.

Again it is mandatory to use the appropriate thermal data library assigned to the named channel THERM. At the time of writing these files respectively are

for JEF2.2:

```
dice96j2v6.dat
therm96j2v6.dat
```

and for ENDF/B-VI:

```
dice97e6v4.dat
therm97e6v4.dat
```

2.37 DICE/THERMAL LIBRARY COMPATIBILITY CHECK

The old DICE nuclear data library and its corresponding thermal data library did not include any checks to ensure the user has selected two compatible libraries. This omission has caused some problems so MONK8B now includes a check that can be used with the latest versions of all nuclear and thermal data libraries. This check ensures that the two libraries the user has selected are compatible, otherwise a message is printed and the run aborted. Should the user employ old versions of these libraries which do not allow the code to make these checks then it is still possible for a mismatch to occur. Hence it is recommended that the libraries issued with MONK8B be adopted for all calculations (including those with MONK8A).

To summarise:

- Code checks latest versions for compatibility
- Old versions can still be used but cannot be checked
- Mismatched DICE and THERM generates an error message and aborts the job

2.38 BIRTH STORE SAVE/LOAD OPTION

Increasing use of MONK8 for depletion and looping calculations has shown the need for a method of storing and reloading the birth store data for those cases where the model has not changed significantly. Thus this capability has been added to MONK8B. This option will also be of use for slowly converging criticality calculations, where an initial run can be used to generate a source distribution for subsequent calculations. To activate this option:

- To save the birth store at the end of the run enter the keywords SAVE BIRTH STORE in the CONTROL DATA input unit, and add the named channel BSAVE into datasets and assign the file to it into which the data will be written.
- To load the birth store at the start of the run enter the keywords LOAD BIRTH STORE in the CONTROL DATA input unit, and add the named channel BLOAD into datasets and assign the file to it from which the data will be read.

It is possible to use both save and load options in a single run and this can be made more sophisticated by using the selective looping controls @#0-01.

2.39 REVISED MATERIAL SPECIFICATION UNIT (INCLUDING WIMS DATA)

The MATERIAL SPECIFICATION input unit has been enhanced to enable the use of TYPE WIMS. This new TYPE allows the unit to be used for a WIMS data calculation. It is necessary to reference the latest MONK material database to make use of this enhancement.

e.g.

```
BEGIN MATERIAL SPECIFICATION
TYPE WIMS
....
```

END

2.40 PARAMETERS AS FUNCTIONS OF PARAMETERS

MONK8A limited the use of parameters by not providing the capability for one parameter to be some function of a previously defined parameter. This restriction has been removed in MONK8B. For example:

```
@pi=3.14159
@height = 23
@radius = 4
@volume = [@height*@pi*@radius^2]
```

As a reminder to those using parameters in burnup calculations: it is mandatory in MONK8B to place all parameter definitions between the NCYCLE line and the final FINISH line. This also applies to any input units and inter-unit control keywords (such as COLUMN), these also must lie between the NCYCLE and FINISH lines.

2.41 FIRST ORDER SENSITIVITY

MONK8B now includes a first-order sensitivity capability which enables the user to determine the sensitivity of K(THREE) to material density, nuclide, reaction and energy group. Appendix 6 includes the flowchart for the new SENSITIVITY DATA input unit and both an example input and output demonstrating the use of the new option.

2.42 GHOLE OPTION

The GHOLE option is an extension to the new HOLE keyword described in 2.15 above. If GHOLE is used instead of HOLE then whenever the immediately following hole is referenced (either directly from FG or as a subsidiary hole) then it will take its origin from the global model irrespective of how the hole was referenced (e.g. H, BH or GH). This new keyword can be used in conjunction with the new GLOBAL HOLE (GH) described in 2.26 to enable the user more easily to build models where the hole positions are a function of the global system, e.g. water level in a partially flooded flask.

e.g.

GHOLE 7 ! the following hole will always use system origin

PLATE 0 0 1 ! plate hole here, but any hole can be used

:

HOLE 12 ! hole 12 is a globe hole with its origin depending on how it was referenced

GLOBE -7 ... ! subsidiary hole 7 will always use system origin irrespective of how called

2.43 IF...ELSE...ENDIF DIRECTIVES

There is now a facility in MONK to enable the use of IF...ELSE...ENDIF directives during a looping calculation to determine which block of input is used during each loop. The format is

```
|IF EXPR1 TEST EXPR2  
<some input>  
|ELSE  
<some alternative input>  
|END
```

Where EXPR1 and EXPR2 are parameters, integers or real values, but not formulae. TEST is one of >, <, =, >= or <=.

If the results of the test is true then the block between |IF and |ELSE (or |ENDIF if no |ELSE is used) will be read. If the test is false and |ELSE is used then the block between |ELSE and |ENDIF will be read.

Note the use of | to start each IF, ELSE and ENDIF keyword. Additional restrictions are:

- The | must be in column 1
- The IF...ELSE...ENDIF constructs cannot be nested
- IF, ELSE and ENDIF must be in upper case and come immediately after the | with no intervening spaces
- Formulae cannot be used in the IF test.

2.44 PSEUDO AND REAL COLLISION TALLIES

An additional diagnostic printout has been provided for MONK calculations which is useful for monitoring the ratio of pseudo to real collisions in hole geometries. Real collisions are defined as those which produce some change in energy, direction or number of samples. Pseudo collisions are additional collisions used to step through hole geometries and which contribute to the scoring process, but produce no change in the sample tracked. Note that neither tally includes leakage events.

Inspection of these data can show whether the proportion of pseudo collisions during a calculation was excessive, suggesting that there might be an absorber being modelled in the holes that might better be modelled explicitly using Fractal Geometry. An example could be a model where there is a trace of Boron-10 in a hole. Such a model might benefit in terms of computational efficiency from having the material containing the Boron-10 explicitly modelled using Fractal Geometry.

3 Summary

This report has introduced the main new features of MONK8B which provide a range of additional options to assist both the criticality and the reactor physics assessor:

- ICSBEP Format Output
- Fission Spectrum Scoring
- Outer Boundary Reflection Tallying
- Albedo Material Tallying
- Alphanumeric Part and Material Names
- Buckling Option with DICE Data
- Hole Tallying with DICE Data
- Duplicate/Ambiguous ZONEMAT Data
- Fissile Nuclide Concentration
- ROOTE Fission Spectrum Sampling
- Simple Hole Rotation
- Globe Hole – Different Sub-unit Materials
- Globe Hole – Sub-unit Orientation in Degrees
- Globe Hole – Radii in Increasing Order
- Hole Numbering
- Lattice Hole – User Defined Number of Radii
- Plate Hole – Plate Boundaries in Increasing Order
- RTZMESH Hole
- Square Hole – User Defined Number of Radii
- Triangle Hole – User Defined Number of Radii
- Part/Region Display for Action Tallies
- Depletion Refuelling
- Component Multiplication
- Summary Table Output
- Multi-line Formulae
- Global Hole Option
- Clone Parts
- Part Number Sequences
- Group Repeat Option
- Lattice, Square and Triangle Holes – NOCHECK Option
- MONACC
- COWL
- Birth Store Source Tally and Birth Store Plus Fission Source Tally
- FG Zone Sub-Divide
- JENDL DICE Library
- Updated JEF2.2 and ENDF/B-VI DICE Libraries
- DICE/Thermal Library Compatibility Check
- Birth Store Save/Load Option

- Revised Material Specification Unit (including WIMS data)
- Parameters as functions of parameters
- First order sensitivity
- GHOLE option
- IF...ELSE...ENDIF directives
- Pseudo and real collision tallies

A major programme of pre-release testing has been completed which has not only considered the new features of the code but also a large set of older models to ensure that existing features have not been disturbed. This test programme has also included significant contributions from the user community with beta code versions. Further details on the new features are contained in the user guide issued to accompany MONK8B. Additional advice and information is available via the usual ANSWERS customer support channels.

4 References

- [1] The ANSWERS Software Service
An Introduction to the New Features of MONK7B
ANSWERS/MONK(97)5
- [2] The ANSWERS Software Service
An Introduction to the New Features of MONK8A
ANSWERS/MONK(98)7
- [3] The ANSWERS Software Service
MONK User Guide for Version 8
ANSWERS/MONK(98)6
- [4] The ANSWERS Software Service
User Guide for MONACC
NCD/MCANO/TR.1/17
- [5] The ANSWERS Software Service
User Guide for the Prototype Version of COWL for MONK8
NCD/MCANO/TR.1/18

Appendices

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Appendix 2	LATTICE Hole
Appendix 3	RTZMESH Hole
Appendix 4	SQUARE Hole
Appendix 5	TRIANGLE Hole
Appendix 6	SENSITIVITY Option

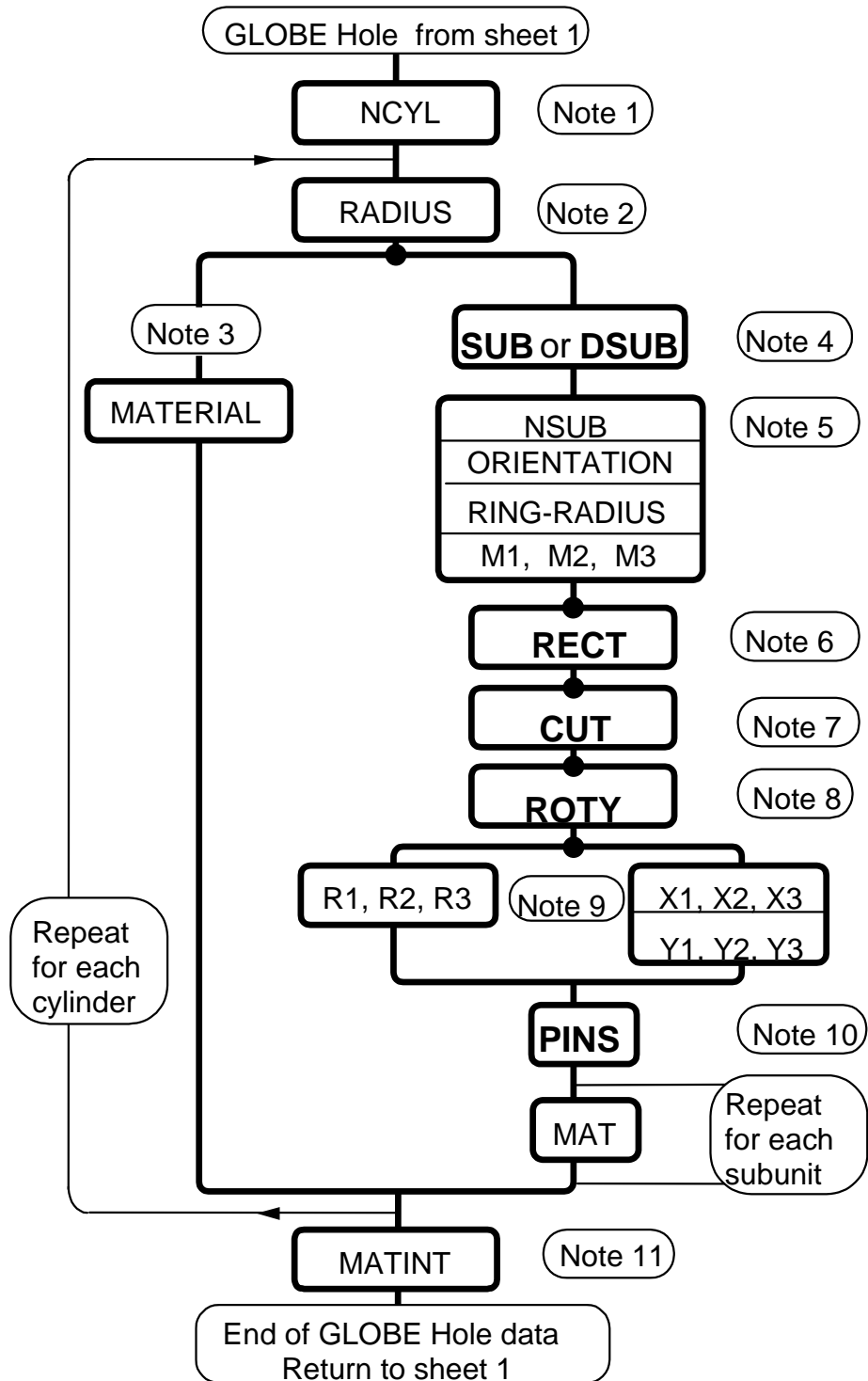
Appendix 1

GLOBE HOLE

Notes on GLOBE Hole

The GLOBE Hole models a geometry consisting of a set of cylinders, concentric with the z-axis. This defines a set of annular spaces, each of which may contain a ring of sub-units. The sub-units are either cylinders or rectangular prisms with their axes parallel to the z-axis of the hole.

- 1** NCYL is the number of concentric cylinders.
- 2** This is the radius of each containing cylinder. These data should now be supplied in order of increasing radii but for back compatibility decreasing order is acceptable.
- 3** This option applies when sub-units are not required. MATERIAL is the material content of this annular space. Subsidiary holes receive co-ordinates in the frame of the globe hole.
- 4** This keyword selects the sub-unit option for this annular space using either S values (SUB, see note 5) or degrees (DSUB).
- 5** NSUB is the number of sub-units. Each sub-unit has a local co-ordinate system with Z-axis along the prismatic axis in the same direction as the globe hole and X and Y axes located at the prismatic axis in the ring.
ORIENTATION defines the orientation of the sub-unit ring. It is supplied as the value S such that; the sub-unit ring is rotated until the first sub-unit centre makes an angle $= 180*(1-S)/NSUB$ with the X-axis of the globe hole. Hence S lies between 0.0 and 2.0 inclusive.
RING-RADIUS is the radius of the circle containing the centres of the sub-units. Sub-units are by default allowed to overlap into the next outer annular space but not into the next inner annulus. This radius may be set in the outer annular space. Where sub-units from adjacent annuli overlap the outer ring always takes precedence over the inner ring. M1, M2 and M3 are the material contents of the 3 zones in the sub-unit ring working outwards. Subsidiary holes receive co-ordinates in the frame of the sub-unit. M1 must be entered even if PINS option used.
- 6** This keyword specifies rectangular sub-units with sides parallel to the local X and Y axes. The default is cylindrical sub-units.
- 7** Sub-units from the adjacent, inner, annular space are excluded from this annulus. If there is any overlap the inner ring of sub-units are cut back to the containing ring of the inner space. If this keyword is not specified then overlapping is allowed.
- 8** The local co-ordinate system for the sub-unit is normally orientated so that each Y-axis lies on the outward normal to the sub-unit ring. If this option is used the Y-axis of each individual sub-unit is rotated so that it lies parallel to the Y-axis of the hole.
- 9** For cylindrical sub-units the three values R1, R2 and R3 must be supplied. These are the radii of the sub-unit and its zones working outwards.
For rectangular sub-units six values must be supplied. X1, X2 and X3 are the semi-lengths of the sub-units and its zones on the local X-axis, working outwards. Y1, Y2 and Y3 are the semi-widths of the sub-units and its zones on the local Y-axis, working outwards.
- 10** PINS option allows different materials or subsidiary holes to be placed in each sub-unit thus replacing M1. The first material is placed in the pin that is oriented along the X-axis prior to any rotation using ORIENTATION being applied. The remainder of the materials are entered in an anti-clockwise order when looking down the positive Z-axis towards the origin.
- 11** MATINT is the material outside the outermost cylinder and between sub-units. Subsidiary holes receive co-ordinates in the frame of the globe hole.



Appendix 2

LATTICE HOLE

Notes on LATTICE Hole

This hole models a geometry consisting of an infinite uniform lattice of subsidiary arrays of cladded rods. The rods in the subsidiary array may all be different in both size and composition but the pitch is uniform throughout and the interstitial material is constant.

- 1 The number of pins in the X and Y directions in the subsidiary lattice to be repeated periodically.
- 2 The RECT option allows for a different lattice pitch in the X and Y directions. PHIX is the pitch in the X direction and PHIY the pitch in the Y direction.
- 3 The lattice pitch for a square lattice.
- 4 Defines an off-set such that the pin initially at the origin is positioned at (-DX, -DY) - note the negative signs.
- 5 The position of the optional wrapper is given in terms of its inner and outer distances (in the X and Y direction) from the geometric centre of the subsidiary array i.e. $PHIX*(NI-1)/2$, $PHIY*(NI-1)/2$.
- 6 The user can specify extra rod radii by use of the keyword MORE. The default is 2.
- 7 This option is used if the pins all have the same rod radius, can radius and can material. The order of the pins is increasing X followed by increasing Y. The rod material itself may vary. If this option is not used it is possible for each rod to be of different size and/or clad material.

RROD is the radius of the rod.

RCAN is the radius of the can.

MROD is the material of the rod. Subsidiary holes receive co-ordinates in the frame of this pin (long repetitious lists of values can be encoded by enclosing repeating portions in brackets followed by an asterisk and the repeat count).

MCLAD is the material of the pin cladding. Subsidiary holes receive co-ordinates in the frame of the local pin.

- 8 This option is used for rods with a square clad cross-section.

RADIUS is the radius of the rod.

LENGTH is the half-length of the side of the square can.

- 9 For rods with a circular clad cross-section :-

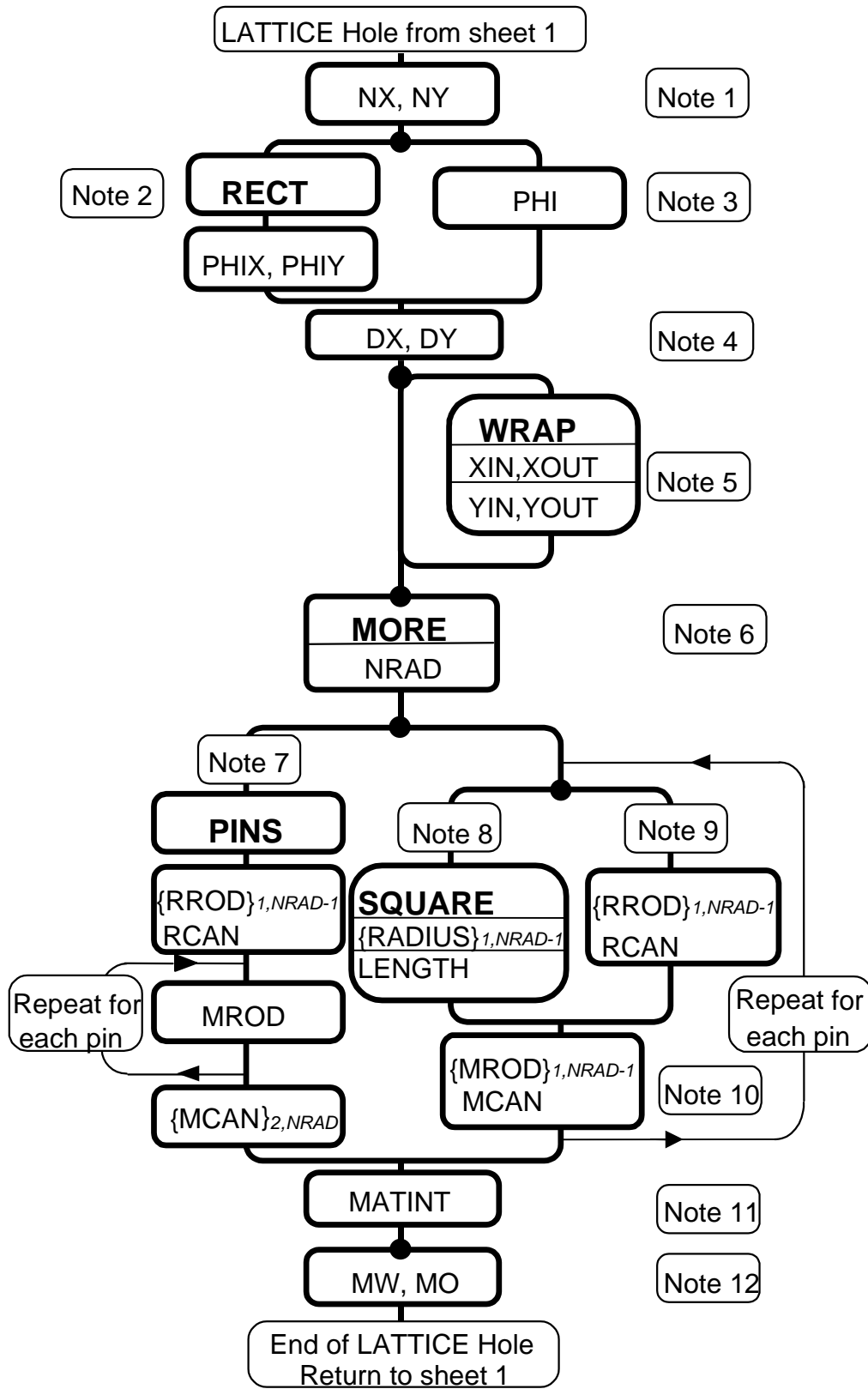
RROD is the radius of the rod.

RCAN is the radius of the can

- 10 MROD is the material of the rod, MCAN is the material of the cladding. Subsidiary holes receive co-ordinates in the frame of the local pin.

- 11 MATINT is the material of the interstitial space. Subsidiary holes receive co-ordinates in the frame of the lattice hole.

- 12 These data are only required for wrapper cases (where the keyword WRAP has been used). MW is the material of the wrapper and MO is the material outside the wrapper - in both cases subsidiary holes receive co-ordinates in the frame of the LATTICE hole.



Appendix 3

RTZMESH HOLE

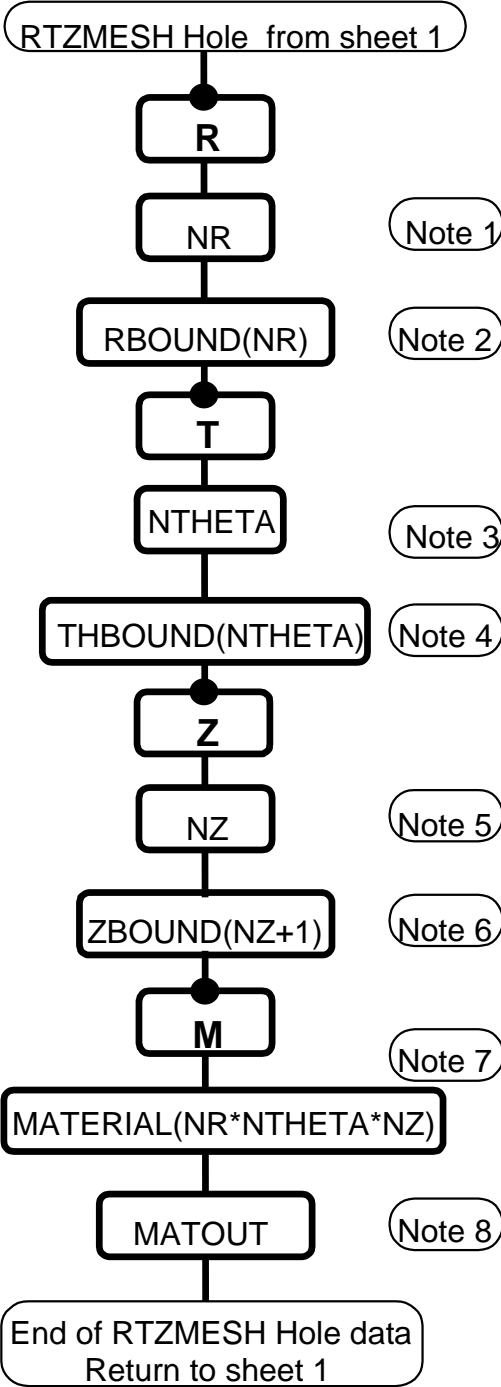
Notes on RTZMESH Hole

The RTZMESH simply models an R-Theta-Z mesh and allows material numbers to be allocated to each mesh cell. Any of the materials may be a subsidiary hole inheriting the co-ordinate system of the RTZMESH hole.

- 1** The number of radial mesh intervals required.
- 2** The list of R boundary values. NR values are required and these must be supplied in ascending order.
- 3** The number of Theta mesh intervals.
- 4** The list of Theta boundary values. NTHETA values are required and these must be supplied in ascending order.
- 5** The number of Z mesh intervals.
- 6** The list of Z boundary values. NZ+1 values are required and these must be supplied in ascending order.
- 7** The list of material numbers. A value must be supplied for each mesh interval - hence NR*NTHETA*NZ values are required. The order in which this data must be supplied is with the R component varying most rapidly - ie all the annular cells for a fixed THETA and Z mesh interval followed by those for the next THETA mesh and finally for the next Z mesh and so on.

Long repetitious lists of values can be encoded by enclosing repeating portions in brackets followed by an asterisk and the repeat count.

- 8** MATOUT is the material outside the mesh system.



Appendix 4

SQUARE HOLE

Notes on SQUARE Hole

The SQUARE hole models a geometry consisting of an infinite uniform square lattice of cladded rods. Optionally the lattice may be confined to a finite rectangular array and be surrounded by a rectangular wrapper.

- 1** The lattice pitch. This is the centre-to-centre spacing between pins in both X and Y directions. By default one pin is placed at the hole origin with its axis along the Z-axis of the hole co-ordinate frame.
- 2** Lattice off-set values in the X and Y directions. This shifts the lattice of pins so that the new origin is at (-DX, -DY) - note the negative signs.
- 3** MORE enables the user to specify additional rod radii. Defaults to 2.
- 4** RROD is the radius of the rod and inner annuli and RCAN is the radius of the cans or cladding. The radii are entered in increasing order.
- 5** This option is used to provide a rectangular wrapper symmetrically placed with respect to the hole co-ordinate frame in the XY plane.

NRODX and NRODY are the number of rods in the X and Y directions respectively.

XINNER and XOUTER define the inner and outer boundary planes of the wrapper in the X-direction. Pairs of planes are placed symmetrically about the origin.

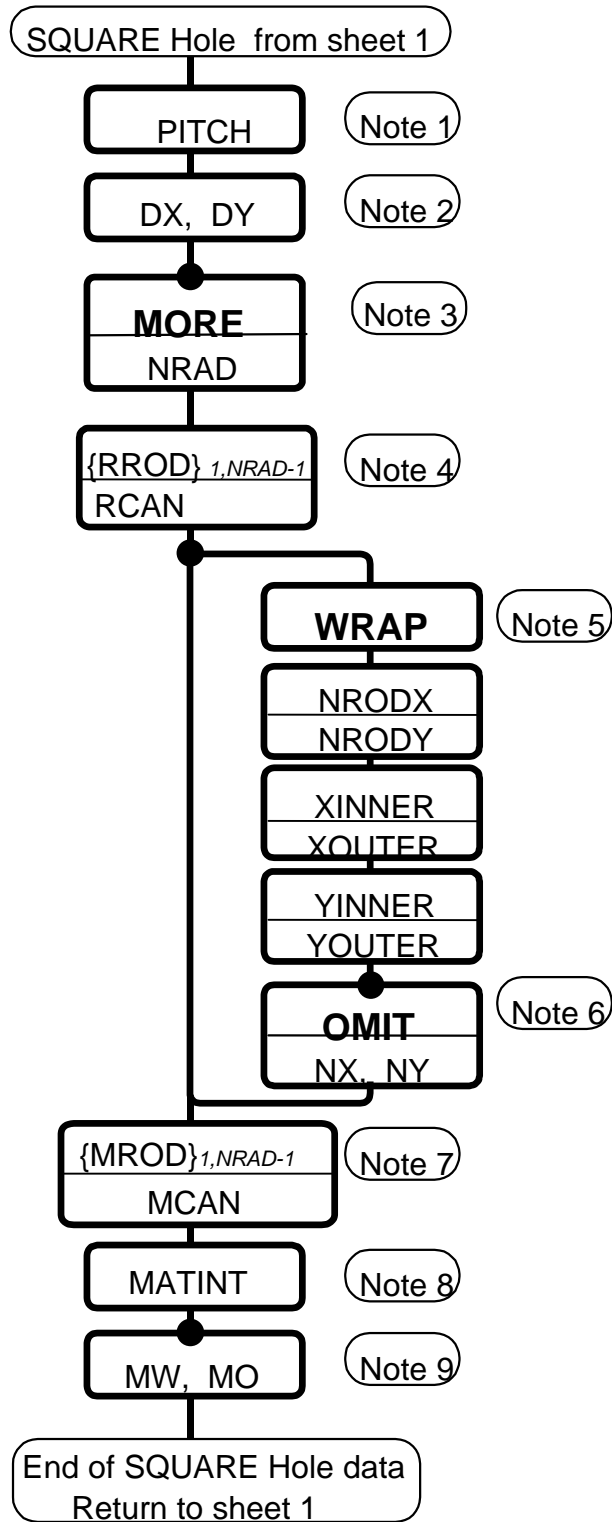
YINNER and YOUTER define the inner and outer boundary planes of the wrapper in the Y-direction. Pairs of planes are placed symmetrically about the origin.

If the wrapper is specified such that it is coincident with any of the pins then the wrapper takes precedence and will 'overwrite' the pins.

- 6** This option is used to omit rods at the corners of the rectangular array and replace them with the interstitial material.

The input values NX and NY are the numbers of rods remaining in the outer rows and columns respectively. These values must have the same parity (ie even or odd) as the respective dimensions NRODX and NRODY (Note 4) to maintain the symmetry.

- 7** Material contents. The MROD are the material content of the rod and inner annuli, MCAN is the material content of the can or cladding. Subsidiary holes in here receive co-ordinates in the frame of the local pin. The material are entered in order of increasing radii in the rod.
- 8** Material contents. MATINT is the interstitial medium. Subsidiary holes in here receive co-ordinates in the frame of the SQUARE hole.
- 9** This data is only required for wrapper cases (where the keyword WRAP has been used). MW is the material content of the wrapper and MO is the material present outside the wrapper. In both cases subsidiary holes receive co-ordinates in the frame of the SQUARE hole.



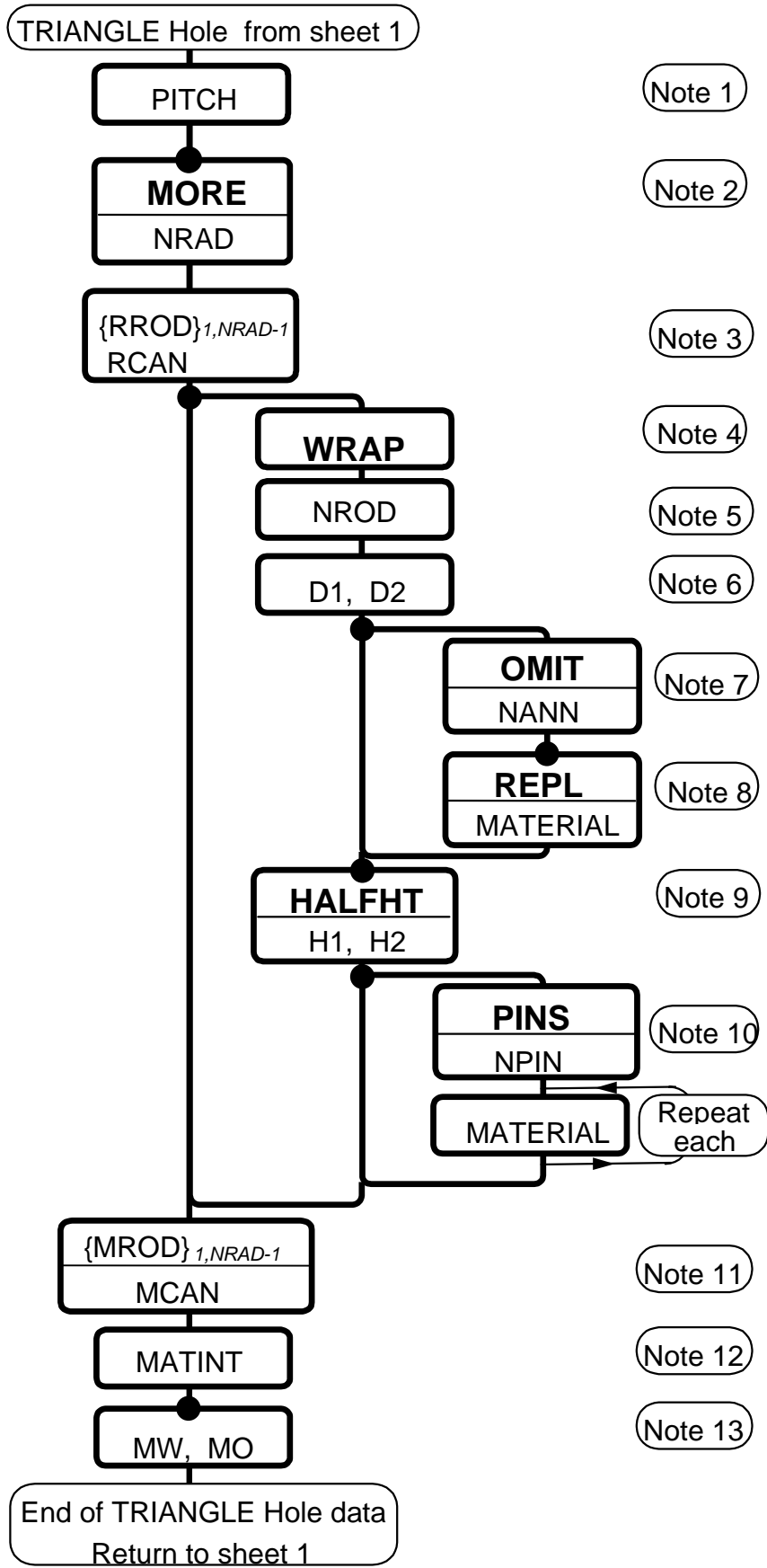
Appendix 5

TRIANGLE HOLE

Notes on TRIANGLE Hole

The TRIANGLE hole models an infinite triangular lattice of circular rods. Optionally the lattice may be finite and surrounded by a hexagonal wrapper.

- 1** The lattice pitch which is the centre-to-centre spacing between pins in all directions. One pin is placed at the hole origin with its Z-axis along the Z-axis of the hole co-ordinate frame.
- 2** Each rod consists of a central pin surrounded by a can. {RROD} are the radii of the rod and inner annuli and RCAN is the radius of the can. The radii are entered in increasing order.
- 3** MORE enables the user to specify additional rod radii. Defaults to 2.
- 4** This option is used to specify a regular hexagonal wrapper symmetrically placed about the hole origin with one pair of opposite sides parallel to the Y-axis of the hole.
- 5** The number of rods along one side of the outer hexagonal annulus of rods - this therefore defines the size of the finite lattice.
- 6** The perpendicular distances from the origin to the inside and outside of the wrapper respectively. This produces a uniform wrapper thickness of (D2 - D1). The wrapper will if necessary overwrite the rod array.
- 7** This option allows the corner pins to be omitted from one hexagonal annulus in the array. The annulus is specified by the value NANN which is the number of pins on each side of the hexagon. These corner pins are replaced by the interstitial material unless the REPL option is used (Note 7).
- 8** This option allows the corner pins identified by the OMIT option to be replaced by a material other than the interstitial material. Note that the new material applies to both the cladding and the rods.
- 9** This option has the effect of defining finite values for the height of the pin assembly and the wrapper.
H1 is the half-height of the pin assembly and H2 is the half-height of the wrapper. Both extend to these distances above and below the XY-plane.
- 10** This option allows the material content of each pin to be specified individually. NPIN is the number of pins along the hexagonal side; the same as NROD (Note 4). MATERIAL is the material of the pin - all rods have the same can material. Subsidiary holes receive co-ordinates in the frame of the local pin. Note that this option cannot be used in conjunction with the OMIT option. The total number of pins is $3NROD * (NROD - 1) + 1$. Long lists of values can be encoded by enclosing repeating portions in brackets followed by an asterisk and the repeat count. The order in which this data must be supplied is described in the Geometry Modelling Chapter.
- 11** MROD and MCAN are the material contents of the rod, annuli and can respectively. MROD must be supplied even if the PINS option is used but the value is not used. Subsidiary holes receive co-ordinates in the frame of the local pin.
- 12** MATINT is the material content of the interstitial medium. Subsidiary holes receive co-ordinates in the frame of the hole.
- 13** The material contents of the wrapper and the rest of space respectively. The rest of space includes the regions above and below the pin assembly inside the wrapper (if HALFHT has been used) as well as all space outside the wrapper. Subsidiary holes receive co-ordinates in the frame of the hole.



Appendix 6

SENSITIVITY OPTION

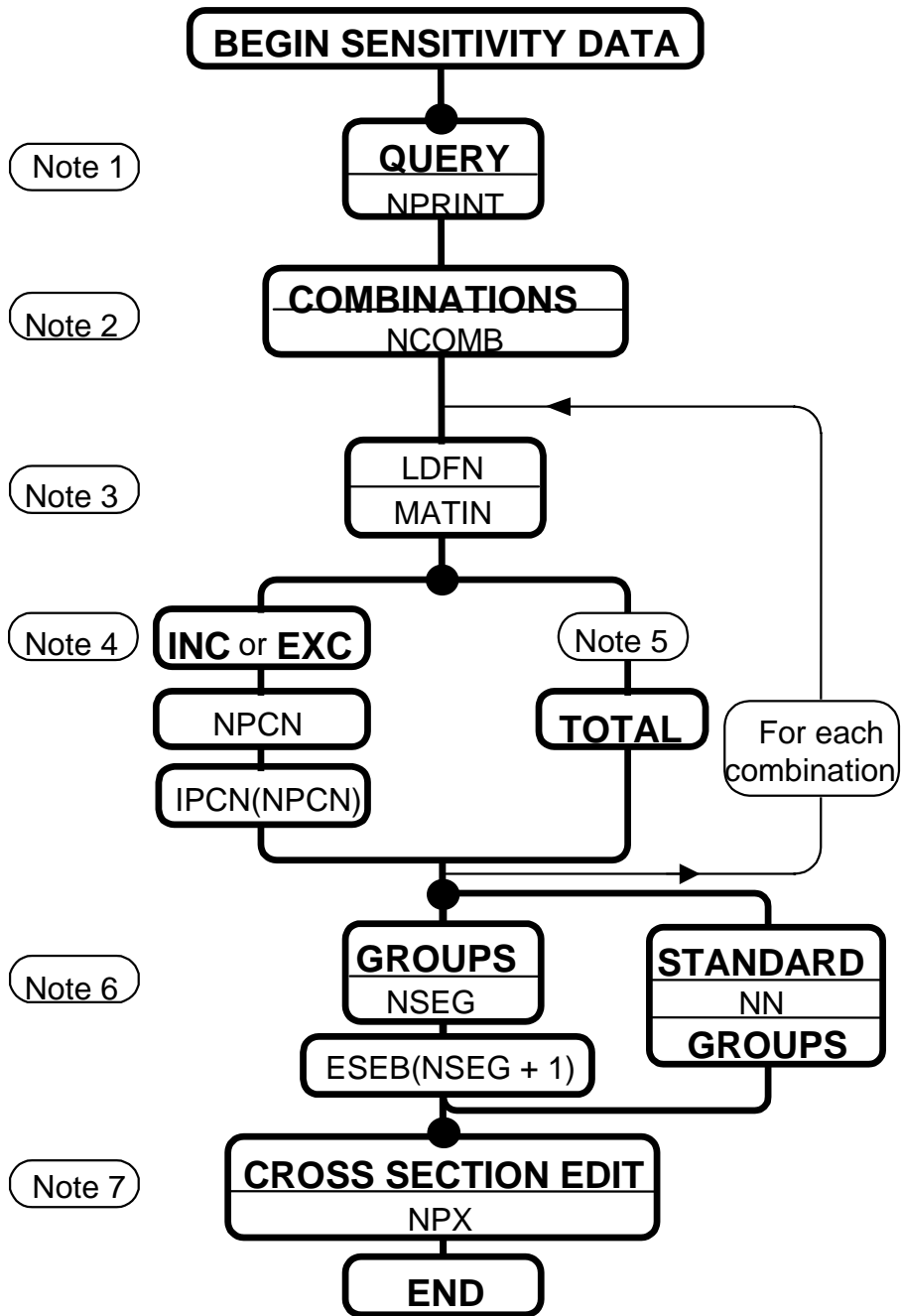
Notes

- 1 This option requests a printout logging the events of the first NPRINT samples. It produces copious output and is intended for fault diagnosis rather than general use.
- 2 This specifies the number of nuclide-material-cross-section combinations which are to follow.
- 3 For each combination, two parameters are defined to specify nuclide and material:
LDFN = Data file number of the nuclide. Values are as given in the Nuclear Data chapter (chapter 2 of the User Guide) with any suffix letters omitted. The details of the nuclides on a given data file are also printed during STAGE TWO execution of MONK.
MATIN= Material number in which perturbations to the nuclide cross-sections are to be made. This allows differentiation between, say, Oxygen in water and Oxygen in concrete. A zero value may be used to signify *any* material. An alphanumeric material name may be used.
- 4 For each combination, two parameters are defined to specify cross-section:
NPCN = Number of reactions which form the partial cross-section.
IPCN = a list of PCN values to be included (or excluded) from the partial cross-section. Values of PCN are given in the Nuclear Data chapter (chapter 2 of the User Guide).

If the keyword **INC** is used the listed PCN values are included in the partial cross-section. If the keyword **EXC** is used the partial cross section is the total cross-section *excluding* the listed reactions.

A special sensitivity is requested by choosing zero for the value of LDFN, a value of MATIN and the TOTAL cross-section. This records the total sensitivity to the chosen material over the entire energy range and effectively becomes a sensitivity to material density.

- 5 The keyword **TOTAL** requests perturbation of the total cross-section for the combination.
- 6 NSEG is the number of energy bands in which separate perturbations are to be made. This item is followed by the boundaries of the bands which are given in order of decreasing energy (MeV). The energy boundaries are completely independent of any other group schemes and need not necessarily span the entire energy range of the calculation. One could, for example, request sensitivities to changes in cross-section in the range 10.0 to 1.0 MeV in a calculation scoring down to thermal energies. Standard group schemes are available. The value NN specifies which standard energy group scheme is used. For example NN=28 would select the standard NADCON 28 group neutron scheme. Other options comprise 16 and 33 energy groups. Details of these can be found in the User Guide, chapter 4, input unit 17.
- 7 This requests that partial cross-sections for the first NPX DICE groups will be printed (refer to the energy structure in the Introduction chapter of the User Guide).



EXAMPLE INPUT

The following example input is for a fictitious case which is used to demonstrate some of the input and output formats available. The case used comprises six materials of which material 1, the fuel, includes the nuclides U235 and U238. The new SENSITIVITY DATA input unit must be added both to activate the sensitivity option and to select the data for the sensitivity calculation:

```
BEGIN SENSITIVITY DATA

COMBINATIONS 6
  9228 1 TOTAL
  9237 1 TOTAL
  0 1 TOTAL
  9228 1 INC 1 18
  9228 1 INC 14 18 5 6 7 8 9 10 11 12 13 14 15 16 17
  0 4 TOTAL
  9228 1 EXC 1 18

GROUPS 3
  15.0 1.0 0.001 0.0

END
```

Seven sensitivities are requested:

- sensitivity to the total cross section of U235 (9228 in the JEF2.2 library) in material 1
- sensitivity to the total cross section of U238 (9237) in material 1
- sensitivity to the total cross section of material 1
- sensitivity to the fission cross section of U235 (9228) in material 1
- sensitivity to the sum of a range of cross sections of U235 (9228) in material 1
- sensitivity to the total cross section of material 4
- sensitivity to the total cross section, excluding fission, of U235 (9228) in material 1

In addition the results are requested in three energy groups, noting that the sensitivity to the total cross-section of a material can only be scored over the whole energy range of the case, not that specified in the sensitivity data.

4 Partial cross section of DFN 9228 in material 1
 Sum includes PCN 18

ENERGY GROUP	BOUNDARIES (MEV)		SENSITIVITY		SENSITIVITY		SENSITIVITY	
			KCOLL	STDV	KSCORE	STDV	KTHREE	STDV
1	1.0000E+00	1.5000E+01	2.6251E-02	2.1944E-02	5.3252E-03	6.7071E-03	5.5244E-03	5.9664E-03
2	1.0000E-03	1.0000E+00	2.8297E-04	1.5772E-03	4.1732E-03	1.6013E-03	4.7283E-03	9.2707E-04
3	0.0000E+00	1.0000E-03	5.1490E-01	1.9412E-01	4.4089E-01	1.5353E-01	3.6250E-01	1.1464E-01

5 Partial cross section of DFN 9228 in material 1
 Sum includes PCN 18 5 6 7 8 9 10 11 12 13
 14 15 16 17

ENERGY GROUP	BOUNDARIES (MEV)		SENSITIVITY		SENSITIVITY		SENSITIVITY	
			KCOLL	STDV	KSCORE	STDV	KTHREE	STDV
1	1.0000E+00	1.5000E+01	2.6842E-02	2.1691E-02	5.3716E-03	6.9043E-03	2.4024E-03	6.3422E-03
2	1.0000E-03	1.0000E+00	-6.5110E-04	1.5795E-03	3.2637E-03	1.6435E-03	4.7010E-03	9.6459E-04
3	0.0000E+00	1.0000E-03	5.1490E-01	1.9412E-01	4.4089E-01	1.5353E-01	3.6250E-01	1.1464E-01

6 Total cross section in material 4

SENSITIVITY		SENSITIVITY		SENSITIVITY	
KCOLL	STDV	KSCORE	STDV	KTHREE	STDV
-2.9295E-02	1.7438E-02	5.9541E-02	4.6052E-02	2.4971E-02	3.1369E-02

7 Partial cross section of DFN 9228 in material 1
 Total excluding PCN 18

ENERGY GROUP	BOUNDARIES (MEV)		SENSITIVITY		SENSITIVITY		SENSITIVITY	
			KCOLL	STDV	KSCORE	STDV	KTHREE	STDV
1	1.0000E+00	1.5000E+01	-8.9838E-04	3.6372E-03	-2.1565E-03	2.8496E-03	-3.3294E-03	2.6701E-03
2	1.0000E-03	1.0000E+00	1.1466E-02	1.4457E-02	4.1985E-02	3.9174E-02	1.4030E-02	1.7512E-02
3	0.0000E+00	1.0000E-03	-8.6248E-02	4.4085E-02	-8.8439E-02	4.5306E-02	-9.9126E-02	3.7943E-02