The ANSWERS
Software Package

MONK

A Monte Carlo Program for Nuclear Criticality Safety Analyses

An Introduction to MONK7A
for MONK6 Users

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AEA

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1	Oct 1993		Original Issue
2	Feb 1994	3.2 & 3.4 3.5 App. A App. B App. C	Further advice on checking data Expanded description of SKETCH MCANO example updated Examples updated ZONEMAT source description revised

Issued by: N R Smith

1. INTRODUCTION

This document describes MONK7A by comparing the features it contains with those of its immediate predecessor, MONK6B. The release of MONK6A in 1987 was the culmination of the original MONK6 development project which started in 1979. Some minor enhancements then followed which led to the release of MONK6B in 1989. Subsequently, and in recognition of the inherent problems that would limit the future development possibilities for MONK, a major reconstruction exercise was undertaken to bring MONK into a more modern software environment. This work has been performed as part of the AEA/BNFL software development collaboration.

Externally, the major features and options of MONK6B have been retained in MONK7A, although some minor options have not been carried forward; some of these latter options may be included at a later date. In addition there are some new features in MONK7A. These changes are summarised in this document, together with some modifications to the code user image.

Internally, MONK7A is a significantly different code than MONK6B, with large sections of the software having been re-written or replaced. These activities have been performed for two principal purposes:

- to install MONK in a more modern programming environment (the so-called MCANO Modular Code Scheme), to facilitate future development and maintenance
- to enable MONK and MCBEND to share facilities where practicable, so that the use of Monte Carlo particle transport development resources can be optimised

A further objective of the work was to ensure that adequate back-compatibility was provided so that MONK users could take as much advantage as reasonably possible of their invested effort in existing code models. On this point, certain compromises have had to be reached, but it is believed that the resulting code will prove an adequate and acceptable replacement for MONK6B, and a suitable vehicle for onward development.

2. OVERVIEW OF MONK7A

A major aim of the MONK7 development project was to provide adequate back-compatibility with existing MONK6 input specifications so that they could be submitted to MONK7A without undue effort. This was considered an essential requirement to allow criticality assessors ready access to the new code. Since it is desirable to extend and enhance the repertoire of MONK7A and, where appropriate, share facilities with the shielding code MCBEND, it was up to the developers to do this in a way which was acceptable to the criticality users and not to indulge in change for change's sake.

A large part of the MCANO development programme has been concerned with combining the functionality of MCBEND and MONK into a single modular code scheme and rationalising, wherever appropriate, the areas within the existing codes which overlapped. One of the main areas of activity has been the geometry package where MONK and MCBEND have traditionally employed different specification formats and tracking routines. Some rationalisation was seen as being essential in this fundamental area if the full benefits of the MCANO code scheme were to be realised.

The rationalisation has lead to the production of a new geometry specification package (Fractal Geometry or FG), which combines the best features of the existing MONK and MCBEND

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facilities, yet maintains (for back-compatibility) the existing geometry user images of both codes. However, whatever format the user employs to specify the geometry, MONK will convert the data and perform the geometry tracking using the FG package, which is considerably more efficient than its equivalent in either MCBEND or MONK.

A further major change is the incorporation of a new thermalisation treatment based on a superior physical model for hydrogen when bound in water and poly-carbons. To access the new treatment requires the specification of different identifiers for the nuclides involved. Note that the MONK6B treatment (using the HINH2O nuclide) has been retained for back-compatibility.

MONK7A contains a new starting source option to replace many of those contained in MONK6B. Here diversion from strict back-compatibility may be encountered although simple approximations to many of the MONK6B source options is automatically provided for in MONK7A. However the changes to input specifications to use the new option explicitly are relatively minor.

The output from MONK7A is another area where major changes have occurred although little of significance has been lost. The input interpretation summary has been completely overhauled to produce a common format for MONK and MCBEND; the opportunity has been taken to tidy up the layout and remove redundant information. The results section has changed rather less in content and format (as requested by the majority of users). However some general tidying and miscellaneous improvements have been performed and greater user control over what is printed is now available.

Concerning the input, it should be noted that MONK7A has two distinct user images:

- that of MONK6: for back-compatibility with existing work
- that of MCANO: intended for new work and the image upon which future development will be based. For this image the geometry can be specified either in the MONK6 form or in the new MCANO FG form.

The geometry description makes up the majority of a MONK input specification, and as the MONK6 geometry has been maintained unaltered as one option for a MONK7A geometry description, the differences between the user images when using the MONK6 geometry specification option are not major.

Appendix A shows how the same case is specified in three different ways: MONK6 format, MCANO format with MONK6 geometry description and MCANO format with FG description. In this Appendix, the differences between the two MCANO specifications and the MONK6 form are highlighted in bold and annotated. It is felt that the experienced MONK user will be readily able to adapt to the modest changes required.

It is hoped that over a period of time the MCANO input will become the preferred option for all users as it retains all the best features of the MONK6 format, yet removes some of the minor irritations that have been observed over the years. It will also provide access to new developments which will be applied only to the MCANO input format and enable easier moves between the criticality and shielding application areas.

3. CODE FUNCTIONALITY

This section reviews the functionality of MONK7A compared with that of MONK6B, under the headings of the five input units of the MONK6 User Guide. Further details of MONK7A can be found in the code User Guide.

3.1 Material Data and Main Control Data

3.1.1 Multigroup Data

The only purpose served by the multigroup option of MONK6 is to enable cross-checks to be performed very easily with independent nuclear data sets. Detailed comparisons can always be made using other Monte Carlo codes provided the user is prepared to specify the problem again, meeting the input requirements of another code. The MONK6 multigroup option therefore shortens that requirement but it must be recognised that it only concentrates on the nuclear data part of the input specification, and so, as an independent check, it is not comprehensive.

SCALE

The US SCALE system is the international standard for criticality work, despite its well-known limitations, and so was seen as the most useful alternative nuclear data source for MONK6. However to keep costs down to acceptable levels no validation work was performed to assess the accuracy of the basic data or of the resonance pre-processing techniques, and instead users have always been directed to the SCALE validation documentation.

Despite these caveats the SCALE libraries have been used to good effect to cross-check continuous energy calculations with MONK6 and this option has therefore been included in MONK7A, where the level of support provided is the same as that for MONK6.

WIMS

The recommended route for accessing WIMS data in MONK6 is via the subgroup treatment (as developed for MONK5W), which is considered preferable to using the earlier multigroup route via the code WAFT. Therefore the WAFT route has not been included in MONK7A.

Concerning the subgroup method, it should also be noted that the treatment now present in MONK5W has been significantly enhanced from the one that was incorporated in MONK6, meaning there is no sense in simply transferring the MONK6 treatment into MONK7A. However the effort required to create in MONK7A the new MONK5W subgroup treatment is substantial and with it goes a continuing maintenance requirement to prevent a recurrence of the obsolescence problem. After much consideration, it has been concluded that the work required to perform this is not cost-effective at present, and for independent cross-checking using WIMS data, users should consider employing the MONK5W code. Therefore the WIMS subgroup option is also not available as a route into MONK7A.

KENO-IV Hansen & Roach

The only other built-in multigroup data route for MONK6 is that to the KENO-IV Hansen and Roach working format library. This library contains a number of known errors and support for it has discontinued in the USA where it does not form part of SCALE-4. Therefore this option is not included in MONK7A. However access to a Hansen and Roach cross-section library will still be possible via the SCALE route discussed above.

3.1.2 Tracking Modes

FISSION

The FISSION tracking mode (superhistory tracking to calculate k-effective) is by far the most widely used option; indeed the majority of users employ no other. It is therefore in MONK7A with the same functionality as in MONK6.

FMODE

The FMODE tracking option allows the user to compute k-effective and the migration area for a finite-sized uniform material body subjected to some imposed geometric buckling mode. FMODE is occasionally used as a survey tool and has therefore been implemented in MONK7A.

FIXSOURCE

The functionality of the rarely-used MONK6 FIXSOURCE option is similar to that of a simple MCBEND calculation, although the MCBEND option cannot at present deal with near-critical systems. However it is considered that users of the MONK6 option would be much better served by the facilities of the MCBEND code and so a direct equivalent to the FIXSOURCE option has not been included in MONK7A. If the full functionality of the MONK6 option is seen as a requirement for the future then MCBEND could be enhanced to provide it.

SURFMULT

The MONK6 SURFMULT option is also similar to a MCBEND option and clearly a joint rationalised option would be sensible for MCANO. However there are no known users of this option in MONK6, so a SURFMULT equivalent has not been included in MONK7A.

3.1.3 Miscellaneous Items

Parameterisation

The parameterisation option was designed at a time when computer editing facilities were primitive and it was used to set up a range of survey calculations quickly. Better ways of accomplishing these same ends are now commonly available to users. Therefore parameterisation has not been included in MONK7A. Any existing cases that employ this option will need to be changed, but this can be accomplished with global editing commands that are available on most computer systems.

GROUPS option

The GROUPS option for setting non-standard scoring bins for the neutron flux will be accepted by the MONK6 user image of MCANO, except that the ability to use multigroup names to select certain schemes is not present due to the changes to the multigroup processing outlined above. However alternative and more versatile facilities exist for specifying the scoring energy structure in the MCANO user image.

Nuclear Data Adjustment

The ability for users to adjust the nuclear data will be considered for implementation in a later release of MONK7. It is not used in standard criticality safety work, but it does have a potential future role to play in establishing sensitivities to nuclear data.

Nuclide Selection

One of the major new developments for MONK7A has been the production of a new thermalisation modelling treatment employing up-to-date hydrogen scattering data from the JEF library. The new treatment has been designed to replace the MONK6B treatment, with the use of the HINH2O nuclide being replaced by J2H/H2O or J2H/CH2 for hydrogen in water or hydrogen in poly-carbons respectively (note that the J2 in the name is used to indicate that the source of the data is the JEF2 library).

The effects on k-effective of the new treatment have been shown to be small for many situations, but the extra physical realism will provide greater potential accuracy. Note that the existing MONK6 thermalisation treatment for hydrogen-in-water (HINH2O) has been retained for back-compatibility. The remaining nuclides in the continuous energy nuclear data library are unchanged, although the library has been extended by the addition of some further fission product nuclides.

3.2 Geometry Data

MONK6 simple body geometry

The MONK6 simple body geometry format is retained as an option of the Fractal Geometry specification, and hence back-compatibility with most of the invested effort in creating MONK6 models is immediately achievable. However, as the MONK7 geometry tracking package operates in a significantly different manner to that of MONK6, users are advised to re-check old models using VISAGE and VISTA.

In addition a new package (Fractal Geometry or FG) has been added to MONK7A via the MCANO user image. FG comprises a coherent set of parts (including equivalents to the MONK nest and cluster) together with a general part offering complete freedom of overlapping possibilities. Some new body types have also been added. A brief summary is given in Appendix B.

A minor change for the MONK6 geometry route into MONK7A is that rotation data using direction cosines can be introduced by the keyword DCOSINES as an alternative to the pair of keywords ROTATE DCOSINES. In addition it should be noted that the MONK5 option of using CENTRE to translate bodies (not described in the MONK6 User Guide) is not accepted by MONK7A; the same applies to the introductory total number of parts integer.

FILTERS

The little-used FILTER facility will be read by MONK7A via the MONK6 user image, but will cause no action to be taken (i.e. a FILTER of 1.0 will be assumed). This will have the effect of slowing down the calculation by a small amount, although studies have shown that the benefit of the FILTER option is not large in general. No alternative to the FILTER option is present in MONK7A.

3.3. Hole Material Data

All the MONK6 hole material data will be accepted unaltered by MONK7A via the MONK6 user image. However some improvements have been made to the hole material specification syntax via the MCANO image and so its image will be slightly different; these are summarised below:

- no initial material list is required following the hole name keyword (see example in Appendix A)
- ORIGIN can be used instead of HTRANS and DCOSINES can be used instead of HROT. In addition ROTATE can be used to supply rotation data by angles. This has been done to introduce consistency with the translation and rotation syntax for MONK6-style simple bodies.
- Alternative keywords have been included for some of the hole specifications as follows:

Hole	MONK6B keyword	Alternative MONK7A keyword
GLOBE	B	SUB (to improve clarity)
GLOBE	A	RECT (to improve clarity)
GLOBE	BOB	ROTY (to improve clarity)
TRIANGLE	MATS	PINS (for consistency with LATTICE hole)

In addition the HOM hole has slightly revised input requirements.

Two new holes are present in MONK7A: XYZMESH and RZMESH, which both provide facilities in a single hole that are only available in MONK6 from the combination of two or more holes. The new holes are described in Appendix C.

3.4. Control Data

3.4.1 K-effective Differentials

The differential capability of MONK6 covers two distinct problem areas: compositional and geometrical. The compositional type is of most use whereas at present theoretical problems make the geometrical type rather inefficient in general situations. Similarly the MONK6 search and optimisation technique has some limitations that need resolving.

The MCBEND code has a sensitivity option for cross sections which works on the same principle as the MONK6 differential facility (i.e. correlated tracking - but taken at the infinitesimal limit). It was considered that rather than adding the existing MONK6 facilities to MONK7A a review exercise should be performed that considers the possibilities for rationalising the MONK6 and MCBEND options. Therefore the MONK6 k-effective differential and search and optimisation techniques are not available in MONK7A.

3.4.2 Output Control

The format and content of the MONK7A output has been finalised following comments from MONK6 code users. The result is that most MONK6 output tables will appear in MONK7A - the only exception is the table showing the variation of k-effective with stage number, which has been dropped because of the confusion it caused and the limited value it added. Most of the tables have been re-formatted to improve the layout. Any of the output tables apart from the main k-effective results (the first five items below) can be suppressed if required. The default MONK7A output content comprises:

- Current value of k-effective and time taken, printed to the output file as the calculation proceeds
- Cumulative k-effective estimators
- Individual stage k-effective estimators
- Neutron balance summary
- Plot of k-effective against stage number
- Neutron fluxes
- Source distribution by region
- Boundary crossings (with a slightly revised definition - see MONK7A User Guide)
- Material action counts
- Region action counts
- Neutron parameters
- Case categorisation (revised scheme - see below)

Note that for the region-based tallies, bodies containing subsidiary parts now receive a zero score - this removes an inconsistency in the MONK6 output. The first part of the output file, where the interpretation of the input data is printed, is considerably altered and hopefully improved.

The stage and superhistory parameters are interpreted in the same way as for MONK6 although it should be noted that the little used time limit (usually set to zero) is now interpreted in seconds for consistency with other ANSWERS codes. It should also be noted that as soon as the calculation has reached the requested standard deviation it will terminate, unlike MONK6 which continues until three consecutive stages are below the requested limit.

NONORM, OPTIONS, PARTITION

These less important EDIT options are not appropriate for MONK7A and so, for old cases, these are read but ignored.

SAVEHIST

The SAVEHIST option of MONK6 is a rarely-used feature that has a direct equivalent in MCBEND. The format for the files produced by the two options is different but the files contain essentially the same information. However the MCBEND format is widely-used as an external link to other shielding codes. Therefore the MONK6 option has not been carried forward and users wishing to achieve its functionality should employ the MCBEND equivalent via the MCANO user image.

CATEGORY

Categorisation is now being used more regularly as it has a proven record of recognising criticality cases with unusual characteristics. The MONK6B categorisation facility has been modified for MONK7A, as experience has demonstrated that some fine tuning is required. A summary of the MONK7A scheme is given in Appendix D.

RANDOM NUMBERS

MONK7A employs a different random number generator to that used by MONK6 and this has different seeding requirements. However it is still possible to start a MONK7 calculation with a 'random' seed.

STABILISED RANDOM NUMBERS

The rarely-used stabilised random number generator option of MONK6 is not in MONK7A, although the keyword is accepted and ignored via the MONK6 user image. The generator offers no advantage for normal calculations and is not a serious omission.

PUNCH

The PUNCH facility is not in MONK7A via the MONK6 user image (although the keyword will be read) and users wishing to dump and restart calculations should switch to the MCANO user image where a similar option already exists. The current recommended practice for criticality calculations is to combine the results from independent MONK calculations rather than extend the length of a single run, and so the removal of the PUNCH facility is not considered a serious loss of capability.

3.4.3 Source Data

Spatial Options

A new source option has been added to MONK7A (called ZONEMAT) which is available via both the MONK6 and MCANO user images. This option is intended to replace many of the old MONK6 options and can be augmented by one of the MCBEND source options now available via the MCANO user image. For cases using one of the removed MONK6 source options a simple alternative will be substituted whenever possible. Note that this simple alternative may be some way from an optimum specification and users are advised to check the starting source distribution carefully. The ZONEMAT source option is described in Appendix E.

Energy/Angular Options

As far as source energy and angular distributions are concerned the vast majority of MONK calculations employ the default options of an isotropically distributed source from a U235 fission spectrum. Some other options exist for special applications, but all of these are now covered by the wide range of options offered from MCBEND via the MCANO user image. Therefore MONK7A users wishing to employ alternative source energy and/or angular distributions should use the MCANO user image. If any of the MONK6 special source options is encountered, whilst reading an input file for MONK7A, the case will fail.

3.5. SCAN

A replacement for SCAN and PICTURE (the MCBEND equivalent to SCAN) has been developed; the new code is called SKETCH. SKETCH can perform the following geometry checking functions:

- Display material, region or zone numbers (or contents) at the mid-points of a regularly spaced mesh in a selected plane passing through an FG model. This model visualisation function has been largely superseded by the use of VISAGE (see below).
- Perform checks for undefined or doubly defined regions of an FG model.
- Estimate zone, region and material volumes within selected regions of an FG model.
- Estimate body surface areas within selected regions of the FG model.
- Perform a detailed diagnostic trace of a single pre-defined track.
- Create a file for detailed analysis using the high resolution display program VISAGE. In this case SKETCH is normally used embedded in VISAGE and the data required for SKETCH are supplied via VISAGE windows. However SKETCH can also be used in 'stand-alone' mode to produce an input picture file for VISAGE if required.

Note that some of the checking capabilities of SKETCH are not available via VISAGE and require the use of SKETCH in 'stand-alone' mode. The use of these additional facilities is particularly recommended for complex models.

4. VALIDATION

The on-going validation programme for MONK6B comprising detailed experimental re-evaluations will switch to using MONK7A following the new code's release. The validation and integral testing that has been performed for MONK7A prior to its release is described in Appendix F.

APPENDIX A - COMPARISON OF MONK6 AND MCANO USER IMAGES

Input Data for MONK6 User Image

```
* Typical MEB containing 7 PWR fuel elements
* --------------------------------------------

* Simplified version of MEB 1196 (fully flooded)

* 4.47% enriched UO2 fuel
* pin radius = 0.474cm
* zirconium can thickness = 0.062cm
* pin pitch = 1.43cm
* element length = 414.02cm (assumed same as MEB tube length)

************************************************************************

FISSION
6 14 NUCNAMES

* material 1 ... water
* material 2 ... boral
* material 3 ... steel
* material 4 ... concrete
* material 5 ... zirconium
* material 6 ... UO2

ATOM 0.998   O 1.0          HINH2O 2.0
ATOM 2.646   HINH2O 0.177   O 0.088      AL27 8.82
             B10 0.7912     B11 3.2088     C 1.0
ATOM 7.85    FE 9.74        CR 2.54      NI 1.0
ATOM 2.25    HINH2O 1.0     O 3.954      SI 1.527
ATOM 6.5     ZR 1.0
ATOM 10.4    U238 4012.3    U235 190.22  U234 1.7871
             O 8408.5

CM

************************************************************************

* Part 1 - fuel element and half-thickness of boral on sides

NEST 2
BOX   ORIGIN 0.32 0.0 0.0   BH1   22.54 22.54 414.02
BOX                           2   23.18 22.54 414.02


* Part 2 - spacer tube

NEST 2
BOX   ORIGIN 0.32 0.0 0.0   1   3.40 22.54 414.02
BOX                         2   4.04 22.54 414.02


* Part 3 - array of two elements

ARRAY 2 1 1   1 1
```

```
* Part 4 - array of three elements separated by spacer tubes

ARRAY 5 1 1   1 2 1 2 1


* Part 5 - top row of elements

NEST 2
BOX   ORIGIN 0.32 0.0 0.0   P3   46.36 22.54 414.02
BOX                          2   47.00 23.18 414.02


* Part 6 - central row of elements

NEST 2
BOX   ORIGIN 0.32 0.64 0.0   P4   77.62 22.54 414.02
BOX                           2   78.26 23.82 414.02


* Part 7 - bottom row of elements

NEST 2
BOX   ORIGIN 0.32 0.64 0.0   P3   46.36 22.54 414.02
BOX                           2   47.00 23.18 414.02


* Part 8 - assemble all elements and add surrounding water

CLUSTER 4
BOX   ORIGIN -23.50 11.91 0.0    P5   47.00 23.18 414.02
BOX   ORIGIN -39.13 -11.91 0.0   P6   78.26 23.82 414.02
BOX   ORIGIN -23.50 -35.09 0.0   P7   47.00 23.18 414.02
ZROD                              1   43.50 414.02


* Part 9 - MEB structure

NEST 10
ZROD   ORIGIN 50.6 50.6 74.06   P8   43.50 414.02
ZROD   ORIGIN 50.6 50.6 66.44    3   43.50 426.72
ZROD   ORIGIN 50.6 50.6 38.18    1   43.50 454.98
ZROD   ORIGIN 50.6 50.6 35.24    3   43.50 457.92
ZROD   ORIGIN 50.6 50.6 25.16    1   43.50 468.00
ZROD   ORIGIN 50.6 50.6 23.26    3   43.50 469.90
ZROD   ORIGIN 50.6 50.6 15.00    1   43.50 478.16
ZROD   ORIGIN 50.6 50.6 15.00    3   44.45 478.16
BOX    ORIGIN 0.0 0.0 15.0       1   101.20 101.20 493.16
BOX                              4   101.20 101.20 508.16

* full specular reflection to simulate infinite array of flasks

ALBEDO 1 1 -0.6 1 1 -0.74

************************************************************************
```

```
* Hole 1 - LWR fuel element positioned in centre of compartment

SQUARE 3  1 5 6   HTRANS 11.27 11.27 0.0
       1.43 0.0 0.0 0.474 0.536
       WRAP 15 15 10.546 10.546 10.546 10.546
       6 5 1 1 1

************************************************************************

-1 20 1000 0 STDV 0.0030 -1

* Position source randomly over all fuel elements

MULTIFISS STD
REGION 1 PART 9 /
END
```

Input Data for MCANO User Image - MONK6 Geometry Description

(Differences from MONK6 user image are highlighted in bold)

```
* Typical MEB containing 7 PWR fuel elements
* ------------------------------------------

* Simplified version of MEB 1196 (fully flooded)

* 4.47% enriched UO2 fuel
* pin radius = 0.474cm
* zirconium can thickness = 0.062cm
* pin pitch = 1.43cm
* element length = 414.02cm (assumed same as MEB tube length)

************************************************************************

BEGIN MATERIAL DATA
MONK 6 14 NUCNAMES

* material 1 ... water
* material 2 ... boral
* material 3 ... steel
* material 4 ... concrete
* material 5 ... zirconium
* material 6 ... UO2

* note additional comment facility (! and end of line)
* note use of J2H/H2O to replace HINH2O
* note CM is now the default and so the keyword is not mandatory

ATOM 0.998   O 1.0             J2H/H2O 2.0                 ! water
ATOM 2.646   J2H/H2O 0.177     O 0.088         AL27 8.82
             B10 0.7912        B11 3.2088      C 1.0       ! boral
ATOM 7.85    FE 9.74           CR 2.54         NI 1.0      ! steel
ATOM 2.25    J2H/H2O 1.0       O 3.954         SI 1.527    ! concrete
ATOM 6.5     ZR 1.0                                        ! zirconium
ATOM 10.4    U238 4012.3       U235 190.22     U234 1.7871
             O 8408.5                                      ! UO2

END

************************************************************************

BEGIN MATERIAL GEOMETRY


* Part 1 - fuel element and half-thickness of boral on sides

NEST 2
BOX   ORIGIN 0.32 0.0 0.0    BH1   22.54 22.54 414.02
BOX                            2   23.18 22.54 414.02
```

```
* Part 2 - spacer tube

NEST 2
BOX    ORIGIN 0.32 0.0 0.0    1    3.40 22.54 414.02
BOX                           2    4.04 22.54 414.02


* Part 3 - array of two elements

ARRAY 2 1 1   1 1


* Part 4 - array of three elements separated by spacer tubes

ARRAY 5 1 1   1 2 1 2 1


* Part 5 - top row of elements

NEST 2
BOX    ORIGIN 0.32 0.0 0.0    P3    46.36 22.54 414.02
BOX                            2    47.00 23.18 414.02


* Part 6 - central row of elements

NEST 2
BOX    ORIGIN 0.32 0.64 0.0    P4    77.62 22.54 414.02
BOX                             2    78.26 23.82 414.02


* Part 7 - bottom row of elements

NEST 2
BOX    ORIGIN 0.32 0.64 0.0    P3    46.36 22.54 414.02
BOX                             2    47.00 23.18 414.02


* Part 8 - assemble all elements and add surrounding water

CLUSTER 4
BOX    ORIGIN -23.50 11.91 0.0     P5    47.00 23.18 414.02
BOX    ORIGIN -39.13 -11.91 0.0    P6    78.26 23.82 414.02
BOX    ORIGIN -23.50 -35.09 0.0    P7    47.00 23.18 414.02
ZROD                                1    43.50 414.02


* Part 9 - MEB structure

NEST 10
ZROD    ORIGIN 50.6 50.6 74.06    P8    43.50 414.02
ZROD    ORIGIN 50.6 50.6 66.44     3    43.50 426.72
ZROD    ORIGIN 50.6 50.6 38.18     1    43.50 454.98
ZROD    ORIGIN 50.6 50.6 35.24     3    43.50 457.92
ZROD    ORIGIN 50.6 50.6 25.16     1    43.50 468.00
ZROD    ORIGIN 50.6 50.6 23.26     3    43.50 469.90
ZROD    ORIGIN 50.6 50.6 15.00     1    43.50 478.16
ZROD    ORIGIN 50.6 50.6 15.00     3    44.45 478.16
BOX     ORIGIN 0.0 0.0 15.0        1    101.20 101.20 493.16
BOX                                4    101.20 101.20 508.16
```

```
* full specular reflection to simulate infinite array of flasks

ALBEDO 1 1 -0.6 1 1 -0.74
END

*************************************************************************

BEGIN HOLE DATA

* Hole 1 - LWR fuel element positioned
* in centre of compartment
* note no need for initial material list after SQUARE keyword
* new keyword ORIGIN (to replace HTRANS) for consistency with
* simple body specification

SQUARE ORIGIN 11.27 11.27 0.0
       1.43 0.0 0.0 0.474 0.536
       WRAP 15 15 10.546 10.546 10.546 10.546
       6 5 1 1 1

END

*************************************************************************

BEGIN CONTROL DATA

STAGES -1 20 1000
STDV 0.0030

END

*************************************************************************

BEGIN SOURCE GEOMETRY

* Position source randomly over all fuel elements

ZONEMAT
ZONE 1 PART 9 / MATERIAL 6

END
```

Input Data for MCANO User Image - Fractal Geometry Description

(Differences from MONK6 user image are highlighted in bold)

```
* Typical MEB containing 7 PWR fuel elements
* ---------------------------------------------

* Simplified version of MEB 1196 (fully flooded)

* 4.47% enriched UO2 fuel
* pin radius = 0.474cm
* zirconium can thickness = 0.062cm
* pin pitch = 1.43cm
* element length = 414.02cm (assumed same as MEB tube length)

*************************************************************************

BEGIN MATERIAL DATA
MONK 6 14 NUCNAMES

* material 1 ... water
* material 2 ... boral
* material 3 ... steel
* material 4 ... concrete
* material 5 ... zirconium
* material 6 ... UO2

* note additional comment facility (! and end of line)
* note use of J2H/H2O to replace HINH2O
* note CM is now the default and so the keyword is not mandatory

ATOM 0.998   O 1.0             J2H/H2O 2.0                ! water
ATOM 2.646   J2H/H2O 0.177     O 0.088       AL27 8.82
             B10 0.7912        B11 3.2088    C 1.0        ! boral
ATOM 7.85    FE 9.74           CR 2.54       NI 1.0       ! steel
ATOM 2.25    J2H/H2O 1.0       O 3.954       SI 1.527     ! concrete
ATOM 6.5     ZR 1.0                                       ! zirconium
ATOM 10.4    U238 4012.3       U235 190.22   U234 1.7871
             O 8408.5                                     ! UO2

END

*************************************************************************

BEGIN MATERIAL GEOMETRY

PART 1 NEST      ! fuel element and half-thickness of boral on sides
BOX    BH1    0.32 0.0 0.0    22.54 22.54 414.02
BOX     M2    0.0 0.0 0.0     23.18 22.54 414.02

PART 2 NEST      ! spacer tube
BOX    M1    0.32 0.0 0.0    3.40 22.54 414.02
BOX    M2    0.0 0.0 0.0     4.04 22.54 414.02

PART 3 ARRAY     ! array of two elements
2 1 1   1 1

PART 4 ARRAY     ! array of three elements separated by spacer tubes
```

```
5 1 1   1 2 1 2 1

PART 5 NEST        ! top row of elements
BOX   P3   0.32 0.0 0.0     46.36 22.54 414.02
BOX   M2   0.0 0.0 0.0      47.00 23.18 414.02

PART 6 NEST        ! central row of elements
BOX   P4   0.32 0.64 0.0    77.62 22.54 414.02
BOX   M2   0.0 0.0 0.0      78.26 23.82 414.02

PART 7 NEST        ! bottom row of elements
BOX   P3   0.32 0.64 0.0    46.36 22.54 414.02
BOX   M2   0.0 0.0 0.0      47.00 23.18 414.02

PART 8 CLUSTER     ! assemble all elements and add surrounding water
BOX   P5   -23.50 11.91 0.0       47.00 23.18 414.02
BOX   P6   -39.13 -11.91 0.0      78.26 23.82 414.02
BOX   P7   -23.50 -35.09 0.0      47.00 23.18 414.02
ZROD  M1   0.0 0.0 0.0            43.50 414.02

PART 9 NEST        ! MEB structure
ZROD   P8    50.6 50.6 74.06      43.50 414.02
ZROD   M3    50.6 50.6 66.44      43.50 426.72
ZROD   M1    50.6 50.6 38.18      43.50 454.98
ZROD   M3    50.6 50.6 35.24      43.50 457.92
ZROD   M1    50.6 50.6 25.16      43.50 468.00
ZROD   M3    50.6 50.6 23.26      43.50 469.90
ZROD   M1    50.6 50.6 15.00      43.50 478.16
ZROD   M3    50.6 50.6 15.00      44.45 478.16
BOX    M1    0.0 0.0 15.0         101.20 101.20 493.16
BOX    M4    0.0 0.0 0.0          101.20 101.20 508.16

* full specular reflection to simulate infinite array of flasks

ALBEDO 1 1 -0.6 1 1 -0.74
END

************************************************************************

BEGIN HOLE DATA

* Hole 1 - LWR fuel element positioned
* in centre of compartment
* note no need for initial material list after SQUARE keyword
* new keyword ORIGIN (to replace HTRANS) for consistency with
* simple body specification

SQUARE ORIGIN 11.27 11.27 0.0
       1.43 0.0 0.0 0.474 0.536
       WRAP 15 15 10.546 10.546 10.546 10.546
       6 5 1 1 1

END

************************************************************************

BEGIN CONTROL DATA

STAGES -1 20 1000
STDV 0.0030
```


AEA

```
END

*************************************************************************

BEGIN SOURCE GEOMETRY

* Position source randomly over all fuel elements

ZONEMAT
ZONE 1 PART 9 / MATERIAL 6

END
```

APPPENDIX B - SUMMARY OF FRACTAL GEOMETRY

A summary of the Fractal Geometry (FG) options is given below:

B1. NEST AND CLUSTER PARTS

The FG nest is functionally the same as the MONK6 nest but has a slightly revised specification. The bodies making up the nest are still specified working from the inside out. The differences are best illustrated by means of a simple example. The MONK6 style nest specification (say part 1):

```
NEST 2
BOX   ORIGIN 0.0 0.0 5.0       2     10.0 10.0 20.0
BOX                            3     10.0 10.0 30.0
```

becomes

```
PART 1 NEST
BOX   M2     0.0 0.0 5.0     10.0 10.0 20.0
BOX   M3     0.0 0.0 0.0     10.0 10.0 30.0
```

The differences are: introductory PART i to introduce FG part number i; no need for ORIGIN keyword, but origin data required for all bodies; the contents are now placed next to the body type name so that all the dimensional information is together.

For rotations, the FG nest requirements are to specify the direction vectors for any two of the three rotated axes (in MONK6 the z and x axis were the only options). There is no equivalent to the MONK6 option of specifying rotations by defining a rotation axis and a twist angle. For example the MONK6 specification:

```
BOX   ORIGIN 0.0 0.0 5.0   ROTATE DCOSINES 1.0 0.0 0.0 0.0 0.0 -1.0
      2      10.0 10.0 20.0
```

becomes:

```
BOX   M2     0.0 0.0 5.0     10.0 10.0 20.0       VZ 1.0 0.0 0.0       VX 0.0 0.0 -1.0
```

or

```
BOX   M2     0.0 0.0 5.0     10.0 10.0 20.0       VZ 1.0 0.0 0.0       VY 0.0 1.0 0.0
```

or

```
BOX   M2     0.0 0.0 5.0     10.0 10.0 20.0       VY 0.0 1.0 0.0       VX 0.0 0.0 -1.0
```

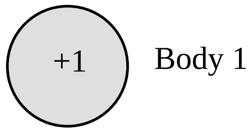
The FG cluster is also functionally the same as the MONK6 except that overlaps are not permitted; these are handled by the general part. The syntax for the FG cluster is the same as for the FG nest and bodies can be specified in any order except that the container must come last.

B2. GENERAL PART

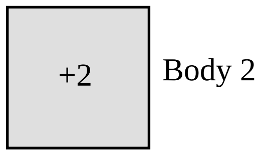
In a FG general part the bodies may overlap to any extent and zones are defined as in the combinatorial geometry of MCBEND7. In a general part each body is given a body number, n; then the volume of space inside body n is referenced as +n and the volume of space outside body n is referenced as -n.

Each zone in the part is then defined as being inside some bodies and outside others by a list of signed body numbers. Using this device any possible combination of overlap volumes can be declared as a zone. Some simple examples (in two dimensions) are shown in the following sketches:

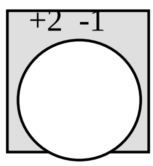
The shaded area is a zone defined as inside the circular body number 1



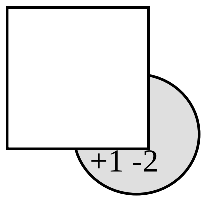
The shaded area is a zone defined as inside the square body number 2



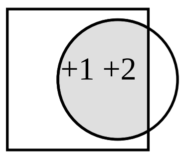
The shaded area is a zone defined as inside the square body number 2 but outside the circular body number 1



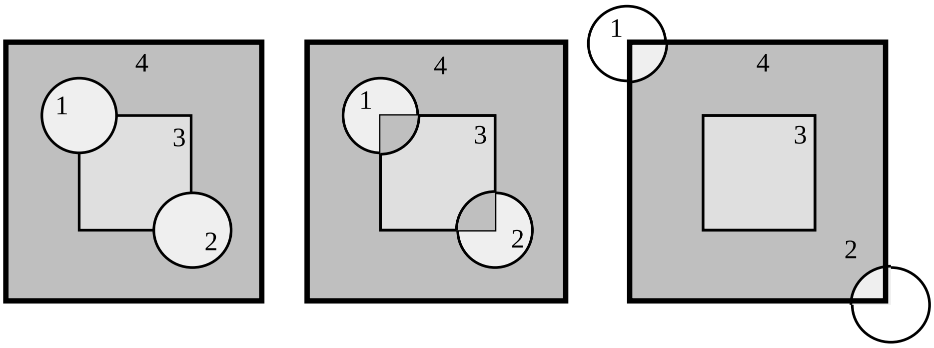
The shaded area is a zone defined as inside the circular body number 1 but outside the square body number 2



The shaded area is a zone defined as being inside the circular body number 1 *and* inside the square body number 2



The sketches below show some further simple zones. The left hand sketch contains four zones defined by: +1, +2, +3 -1 -2, and +4 -1 -2 -3. The middle sketch contains six zones defined by: +1 -3, +2 -3, +3 -1 -2, +1 +3, +2 +3, and +4 -1 -2 -3 (note - this is an example of a part containing more zones than bodies). The right hand sketch contains four zones defined by: +1 +4, +3, +2 +4, and +4 -1 -2 -3.



In a general part the container does not necessarily have to be the last body specified and the order of specifying bodies and zone definitions is at the user's discretion. Note that the order of presentation does however serve to number the bodies and similarly for the zones independently of the bodies.

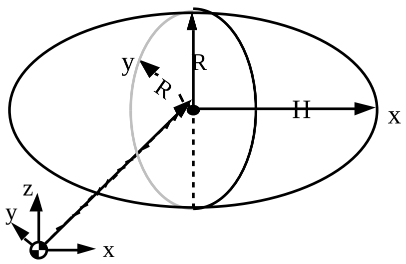
Note that each point in space inside the container body must be assigned uniquely to one and only one zone. The code cannot check for itself that this has been accomplished in a general part and subtle errors can easily occur with complicated examples. The effect on the Monte Carlo calculation can be unpredictable. Note also that the code cannot calculate the volumes of the zones in a general part.

For general parts other than the global part, the code can identify the container as being the body which does not appear with a '-' prefix in any of the zone descriptions. This rule is relaxed in the case of the global zone so that the outer boundary of the problem can be surrounded with special materials. The code can still identify the container as the body occurring in a zone description as a single negative number.

B3. NEW BODY OPTIONS

Rotated ellipse

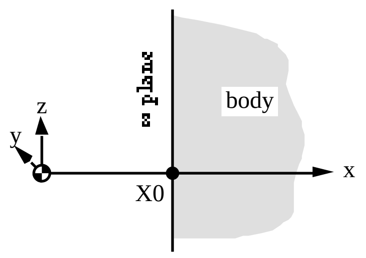
This body is formed by rotating an ellipse about one of its axes. Note that this is not a completely general ellipsoid since all sections normal to the axis of rotation are circular. It is defined by:

• the keyword **XREL, YREL** or **ZREL** (the first letter indicates the axis of rotation) • the half axis length normal to the axis of rotation (R) • the half axis length along the axis of rotation (H)	 This sketch shows the variation: XREL

Infinite plane

An infinite plane is the entire volume of space on one side of a plane orthogonal to one of the co-ordinate axes. Its use is fairly limited except in very specific applications. It has no origin, cannot be rotated, cannot be used in a NEST or CLUSTER, and cannot contain a subsidiary part or body hole material. It has occasional use for slicing a body in a general FG part or for simulating an orthogonal mesh system such as those used in deterministic codes. It is defined by:

- the keyword **XP, YP** or **ZP** (the first letter indicates the direction of the normal)
- the co-ordinate where the plane cuts the axis referenced in the first letter of the name (X0)

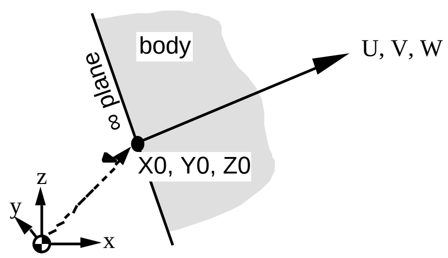


The co-ordinate may be positive or negative. The 'inside' of the body contains all points with a higher X,Y or Z co-ordinate than the **XP**, **YP** or **ZP** body respectively.

Infinite half space

An infinite half space is a generalisation of the infinite plane family of bodies defined above. The 'inside' of the body is the entire volume of space on one side of a plane passing through a defined point with a freely directed normal pointing into the body. It cannot be used in a NEST or CLUSTER and cannot contain a subsidiary part or body hole material. Rotations are neither necessary nor allowed since the specification includes general orientation. It is defined by:

- the keyword **IHS**
- the co-ordinates of its origin (X0, Y0, Z0 - any point in the plane)
- the direction ratios of a normal pointing into the body (U, V, W)

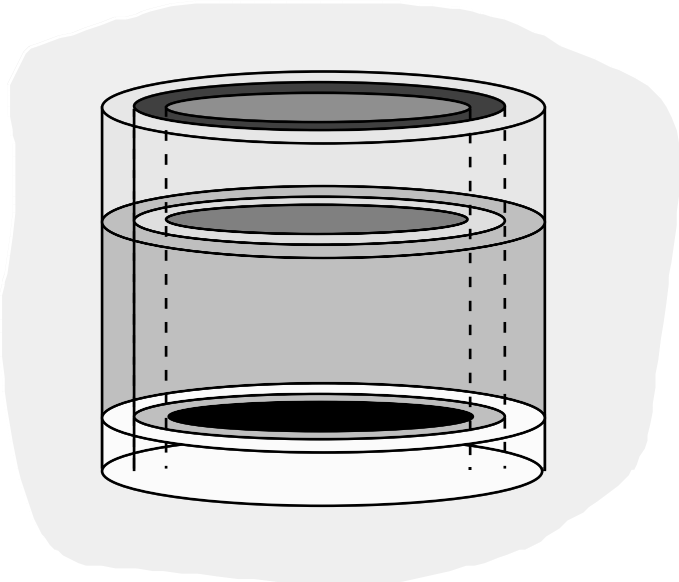


APPENDIX C - MONK7A NEW HOLE GEOMETRIES

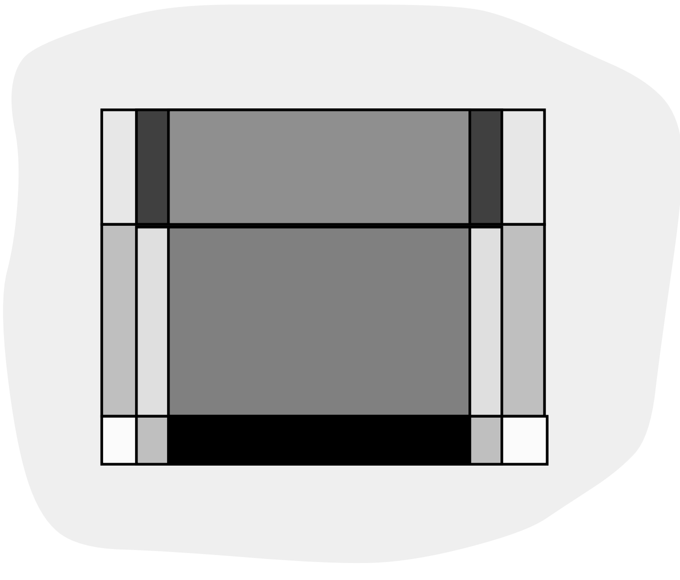
MONK7A contains the following two new hole geometries:

C1. RZMESH

This hole, as its name suggests, allows the user to allocate materials within a defined RZ mesh. The mesh system is surrounded on all sides by an enclosing material, and any material within the hole may be a subsidiary hole.

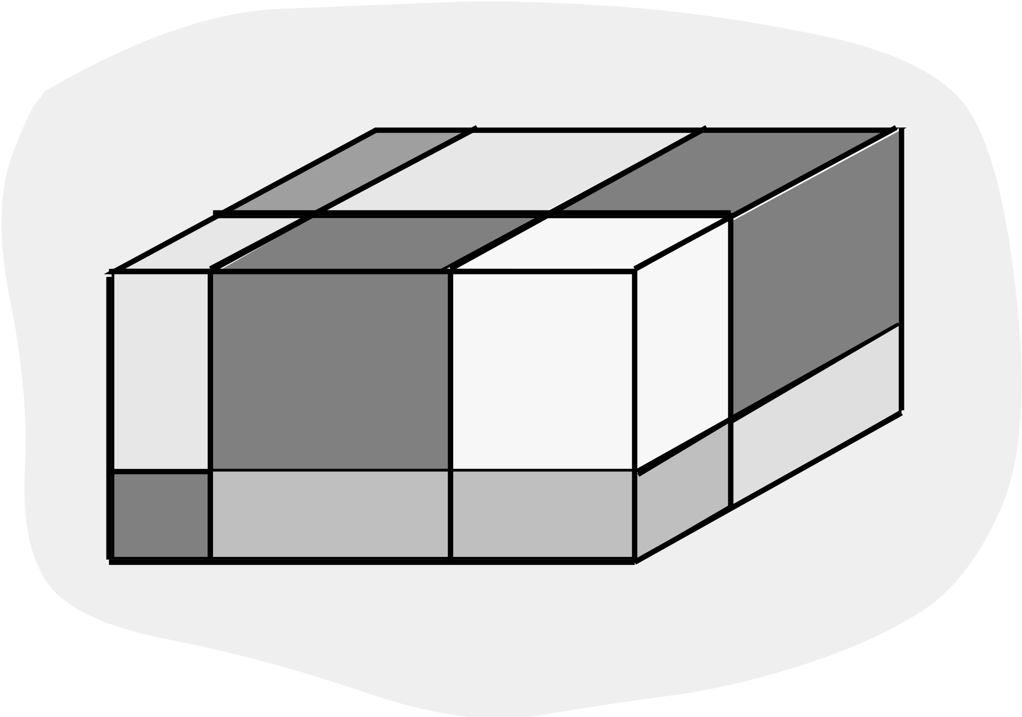


The user simply defines the R and Z mesh boundaries in increasing order and then supplies a material map for the mesh system. A vertical cross-section through the centre of the above mesh system is shown below:



C2. XYZMESH

This hole, as its name suggests, allows the user to allocate materials within a defined XYZ mesh. The mesh system is surrounded on all sides by an enclosing material, and any material within the hole may be a subsidiary hole.



The user simply defines the X, Y and Z mesh boundaries in increasing order and the supplies a material map for the mesh system.

APPENDIX D - MONK7A CATEGORISATION SCHEME

D1. INTRODUCTION

A case categorisation scheme was introduced into MONK6 as an aid to the criticality assessor in identifying relevant validation calculations. When neutrons move around a system they perceive the engineering description as being apparently distorted due to the differing cross-section values of the various materials; these effects are sometimes difficult for the analyst to visualise. Categorisation provides an objective physics-based view of the system as seen by the neutrons. In practice the categorisation information supplied by the code is used in conjunction with additional selection criteria provided by the code user.

The categorisation concept is regarded as a useful feature of MONK, but experience with the MONK6 categorisation scheme has suggested that the scheme needs to be tuned somewhat to increase its usefulness. This following section describes the revised categorisation scheme as implemented in MONK7A.

D2. MODIFIED CATEGORISATION SCHEME REQUIREMENTS

The existing MONK6 categorisation scheme is based on the following seven properties:

A	type of fissile material	(3 partitions)
B	non-fuel absorption	(2)
C	leakage	(4)
D	resonance absorption	(3)
E	fast fission	(4)
F	spectrum	(3)
G	geometry	(3)

This gives rise to 2592 different categories (3x2x4x3x4x3x3), the majority of which will never arise in practice due to their unlikely combination of properties.

Reported use of the above categorisation scheme has identified two main problems:

- there is not sufficient independence between the properties leading to an unnecessarily large number of categories

- some of the partition boundaries of the scheme need revision to reflect real differences between systems. In addition some partitions are redundant.

A more detailed expansion of the above summary of the problems with the MONK6 scheme is as follows. The information provided by the spectrum type is largely contained elsewhere (a combination of resonance absorption and fast fission); this category has therefore been dropped from the MONK7A scheme in conjunction with the provision of a revised definition of the resonance absorption category. The attempt to categorise the geometry has not provided useful additional information; this category has also been dropped from the MONK7A scheme. The distinction between a plutonium system and a mixed system as currently measured is very small as the principal fissile isotope in the majority of mixed systems is Pu239; it is therefore proposed that the definitions be revised to identify unusual 'other' situations (genuine mixed U235/Pu239 and U233 systems for example).

AEA

One property that is recognised as being useful to categorise systems is the hydrogen to fuel ratio. In keeping with the idea of categorising a case according to the neutron's view of the system this can be measured by the hydrogen to uranium/plutonium collision rate in the fuel regions; therefore a category has been added to the MONK7A scheme which will provide distinctions between the physical state and concentration of the fissile materials.

In addition to the above modifications, other minor modifications to the scheme have been made leading to the following summary of the MONK7A categories:

A	type of fissile material	(3 partitions)
B	non-fuel absorption	(3)
C	leakage	(3)
D	resonance absorption	(3)
E	fast fission	(3)
F	hydrogen fuel content	(4)

This leads to 972 categories (3x3x3x3x3x4), much reduced from the MONK6 scheme but still sufficiently large to provide useful distinctions between systems. The full specification of the revised scheme is given in MONK7 User Guide.

Analysis of the category numbers for the 44 standard cases given in the MONK6 validation summary report shows that although the total number of categories is much reduced for the MONK7A scheme the number of different categories occupied by the standard cases increases from 19 to 22. This supports the view that the original scheme contains a certain amount of redundancy and the fact that the revised scheme has not lead to any loss of resolution. The remaining duplication of category numbers within the standard cases is largely due to the fact that certain areas are very well covered by validation experiments with limited significant differences between experimental configurations as measured by the categorisation scheme.

APPENDIX E - THE ZONEMAT STARTING SOURCE OPTION

E1. INTRODUCTION

MONK6 contains a wide range of starting source options to meet the requirements of criticality calculations. Some of these options were developed some time ago to address what were then perceived to be sampling/settling problems. Following the theoretical analysis of Monte Carlo eigenvalue algorithms which led to the development of the superhistory tracking algorithm, a greater understanding of the sampling/settling process was achieved. This led to a greater awareness of the parameters that can cause problems and a reduced need for fine detail spatial starting source distributions.

The development of MONK7A was a convenient time to rationalise the MONK source options, particularly taking account of the very wide range of facilities inherited in the MCANO scheme from MCBEND. This appendix describes the spatial starting source package for MONK7A, the functionality of which is derived as follows:

- including a new option (ZONEMAT) to collect together the most useful MONK6 features not covered by MCBEND features
- employing existing MCBEND features where there is overlap with useful MONK6 features
- discontinuing certain MONK6 features where the use for them no longer exists

Note that most of the MONK6 spatial source options will be accepted by MONK7A and those that are not directly supported in the new code will be converted into a simple alternative. This will provide back-compatibility for the majority of existing cases. However it is recognised that the supplied alternatives may not be very efficient in some cases and so the new MONK7A option will be available in the MONK6 and MCANO user images. Following this route means a minor deviation from strict back-compatibility, but one that does not affect the description of the geometry model in any way or affect the accuracy of the calculations.

E2. MONK7A SOURCE SPECIFICATION

E2.1 ZONEMAT Spatial Source Option

As a result of discussions with MONK6 users it is considered that the most useful MONK6 source options are VOLUME, FISSILE and MULTIFISS. These have been combined into a more flexible option for MONK7A as described below.

The input data for the new source option will comprise the keyword ZONEMAT, to introduce the option, followed by any number of geometry zones selected in a format similar to that used in MONK6 (i.e. ZONE i PART j /). Any of the zones selected may be followed by the keyword MATERIAL and a list of materials to which the selection of source points in that zone will be restricted. A further option is that the keyword ALL can be used to replace the zone specification to indicate the whole problem (all zones). The ZONEMAT option contains features of the VOLUME, FISSILE and MULTIFISS source options but provides greater flexibility in the selection of source bodies and materials.

A zone in MONK7A corresponds to a volume element in MONK6 (i.e. it is the space occupied by the contents of a simple body). However in MONK6 the string 'REGION i PART j /' selected the entire volume inside the boundaries of REGION i even when there were nested bodies inside it. It is considered that the new ZONE option more closely matches the majority of requirements but to provide direct back-compatibility, the keyword BODY can be employed instead to select the entire volume inside the simple body boundaries. Note that the keyword PART can be employed on its own to select an entire part.

The ZONEMAT option of MONK7A selects starting source points in the following way. For each starting source point, the zone it is in is selected at random from the list given. If no material restriction is specified for that zone the source point is then selected at random from within the zone. If a material restriction applies then the material present at the selected point is determined. Note that a zone may contain a real material, a hole material or a subsidiary part and in the latter case the hierarchy is followed to its lowest level to identify a real material. If the material present does not match one from the supplied list for that source zone, the point is rejected and another from the same zone is selected. After a large number of unsuccessful attempts to find a material from the restricted list the next point in that zone is accepted whatever the material present; a message is printed to indicate that this has happened.

The ZONEMAT option is best illustrated by a series of examples. Although listed below in the MCANO input format, the ZONEMAT option is also available via the MONK6 input format.

<u>To request a single source zone</u>

```
BEGIN SOURCE GEOMETRY
ZONEMAT
ZONE 1 PART 2 /
END
```

<u>To request equal sampling from three source zones</u>

```
BEGIN SOURCE GEOMETRY
ZONEMAT
ZONE 1 PART 2 /
ZONE 1 PART 3 /
ZONE 1 PART 4 /
END
```

<u>To request two source zones, with sampling restricted to materials 5 and 6 within the second zone</u>

```
BEGIN SOURCE GEOMETRY
ZONEMAT
ZONE 1 PART 2 /
ZONE 2 PART 3 /      MATERIAL 5 6
END
```

To request source sampled over the whole problem from material 1 only

```
BEGIN SOURCE GEOMETRY
ZONEMAT
ALL /    MATERIAL 1
END
```

To request equally sampled combinations of the above two examples

```
BEGIN SOURCE GEOMETRY
ZONEMAT
ZONE 1 PART 2 /
ZONE 2 PART 3 /      MATERIAL 5 6
ALL /    MATERIAL 1
END
```

E2.2 MCBEND Source Features Useful to MONK7A

Due to the nature of its intended applications, MCBEND contains a much wider range of source options than MONK. Some of the MCBEND source options are directly relevant to criticality applications and to avoid unnecessary duplication some of these are available in MONK7A.

For the spatial source distribution it is considered that the new ZONEMAT option meets the majority of requirements. However MONK7A will also take from the MCBEND repertoire the single point source and the simple source mesh capability. This latter option enables the other part of the MONK6 VOLUME option to be imitated, where a new source volume is described in the source geometry, as well as simulating the use of the MONK6 SURFACE options. Note that the MCBEND simple source mesh provides much greater versatility than the MONK6 options it replaces.

E3. STATUS SUMMARY OF MONK6 SPATIAL SOURCE OPTIONS

Given below is a list of all the MONK6 spatial source options and their status within MONK7A. Note that if the MONK6 input format for MONK7 is employed, most of the options are accepted and converted into a simple alternative, although this may not be a very efficient way of proceeding for some cases. A warning message is printed stating that an alternative has been supplied. For the MCANO input format only the MONK7/MCBEND options described above are permitted.

As mentioned above the ZONEMAT option is available in each format so that equivalents of the most important of the MONK6 options are available in MONK7A via both formats. However some of the less well-used MONK6 options are not directly supported in the MONK6 input format and if none of the alternatives are appropriate then use of the new MCANO input format is required. In addition there are no equivalents in either MONK7 input format for the MULTIPOINT, POINTLAT, MULTILINE and LINELAT options. It is considered that these options are no longer required and an appropriate distribution can be obtained by employing one of the other source options.

Option	Status in MONK7A via MONK6 input format	Equivalent in MONK7A via MCANO input format
RESTART	Not supported - will need to use MCANO input format	DUMP/RESTART option
READ SOURCE	Not supported - will need to use MCANO input format	DUMP/RESTART option
VOLUME (geometry body)	Supported	ZONEMAT option
VOLUME (defined shape)	Supported	Simple source mesh
SURFACE (geometry body)	Keyword accepted but interpreted as a VOLUME source	Simple source mesh (LAMINA)
SURFACE (defined shape)	Keyword accepted but interpreted as a VOLUME source	Simple source mesh (LAMINA)
POINT	Supported	POINT
MULTIPOINT	Keyword accepted but interpreted as a POINT source	No equivalent
POINTLAT	Keyword accepted but interpreted as a POINT source	No equivalent
LINE	Keyword accepted but interpreted as a POINT source	Simple source mesh (LAMINA)
MULTILINE	Keyword accepted but interpreted as a POINT source	No equivalent
LINELAT	Keyword accepted but interpreted as a POINT source	No equivalent
FISSILE	Keyword accepted (and source string is essential) but interpreted as a VOLUME source - consider changing input to use ZONEMAT	ZONEMAT option
MULTIFISS	The STD use is approximated but the additional options are not accepted - consider changing input to use ZONEMAT	ZONEMAT option

Note that for the MONK6 input specifications the back-compatibility model that has been used in the MONK6 User Guide. In particular this means that supplementary source strings are not accepted.

APPENDIX F - MONK7A PRE-RELEASE TESTING

F1. INTRODUCTION

This appendix summaries the software test plan that was produced for MONK7A. It describes how the program has been tested prior to its formal release to ANSWERS customers.

F2. TEST PLAN

The testing covered by the plan consisted of integral testing of the MONK7A code under the following five stages:

F2.1 Correction of MONK6B Errors

All reported errors contained in the MONK6 observation file have been investigated. Note that due to the replacement of major sections of the coding and the removal of certain options many of the MONK6B observations are not applicable to MONK7A. For those that do apply, a suitable test case has been run to check that the error has been corrected.

The acceptance criterion for this stage was for all applicable MONK6B errors to have been eliminated from MONK7A.

F2.2 MONK6B Core Validation Set (MONK6 User Image)

The MONK6B core set of forty four validation cases have been run with MONK7A with the following objectives:

- To test the acceptability of MONK6 input specifications to MONK7A over a wide range of problems
- To test the MONK7A output tables for a wide range of problems
- To test the values of k-effective calculated by MONK7A. Although the coding has been extensively changed, one option is for MONK7A is to use the same nuclear data as MONK6B and therefore produce statistically indistinguishable results.

The acceptance criterion for this stage was for the sets of MONK7A and MONK6B results to be statistically consistent as described in an existing ANSWERS commissioning procedure.

F2.3 MONK6B Core Validation Set (New Thermal Treatment)

Although direct back-compatibility with the MONK6B nuclear data library is provided by MONK7A, the recommended option was to employ the new thermal treatment. For the code user this means employing the new JEF-based bound hydrogen data for hydrogen in water and hydrogen in poly-carbon as appropriate. The new model is a better theoretical representation of the hydrogen collision processes and is based on modern data, although it is not expected to produce major differences in the calculated values of k-effective. All suitable cases from the

MONK6B core set have been re-specified to use the new data and re-run to determine the effect of the new thermal treatment on the calculated values of k-effective for a range of problems.

The acceptance criterion for this stage was for the effect on k-effective of employing the new thermal treatment not to be statistically significant at the three standard deviation level.

F2.4 MONK6B Core Validation Set (MCANO User Image)

A representative sample of the input specifications for the cases run in Section F2.3 have been converted into the MCANO user image. These have been re-run with the objective of confirming the compatibility of the two user images.

The acceptance criterion for this stage was for the results of the cases run to be identical to those performed in Section F2.3.

F2.5 New MONK6 Validation Database

The MONK validation database is undergoing a major overhaul comprising the re-evaluation of selected critical experiments. All such experiments studied to date have been re-specified and re-run using MONK7A together with the new thermal treatment. These calculations will form the basis of the MONK7A validation database which will be expanded as more experiments are studied.

The acceptance criterion for this stage was for the differences between MONK7A and MONK6B results to be consistent with the results observed in Section F2.3.

F2.6 In Service Use Prior to Release

A beta-release of MONK7A was made available to AEA staff at Winfrith and BNFL staff at Risley and Sellafield. Users in both organisations were encouraged to employ the code alongside MONK6B for as many of their on-going projects as possible and report their observations on supplied ANSWERS pro forma. The objective of this stage of the testing was to expose the new code to a wider range of problems and users to assess its reliability and robustness.

The acceptance criterion for this stage was for all major problems identified by code users to be addressed prior to formal release of the code.