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Thermal Neutron Flux Contours from Criticality Event

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Abstract: The generation of thermal neutron flux contours from a criticality event is demonstrated for an idealized building with a criticality event in one of the rooms. The MCNP Monte Carlo computer code is used to calculate the thermal neutron flux.

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THERMAL NEUTRON FLUX CONTOURS FROM CRITICALITY EVENT
Revision 0

WHC-SD-SQA-ANAL-502

Prepared by:

L. L. Carter

August 1996

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1.0 SUMMARY

An idealized building was utilized to demonstrate the generation of thermal neutron flux contours by using the MCNP Monte Carlo code[1] to calculate the thermal fluxes. Such contours can be used in the determination of optimal placement of criticality alarms. All of the MCNP comparisons used the Plutonium Nitrate Solution Criticality neutron source of Reference 2 (Case 3) with source strength 6.237×10^{13} neutrons/second. The idealized building contains a room where the criticality event is postulated to occur and a corridor with one bend. The walls of the corridor and the building are all ordinary concrete 30 cm thick.

Shown in Figure 1 are the thermal neutron flux contours within the building, where the outside perimeter of Figure 1 is the 30 cm thick outer walls of the building. Figure 2 is an expanded view showing the room where the criticality event occurs and its immediate vicinity. These contours clearly show the flux decrease from attenuation through the walls and the increased flux down the corridor. The MCNP calculations required 37.5 hours of cpu time on an HP-735 so are quite number crunching intensive. The one standard deviation statistical uncertainties in the MCNP calculation are typically less than one percent for the room and vicinity shown in Figure 2 and less than ten percent within most of the building of Figure 1.

The following section describes the MCNP calculations in some detail including the optimization considerations. We have demonstrated with this generic problem that it is possible to optimize an MCNP calculation sufficiently to obtain the flux information to generate flux contours with computer times of a few days.

My thanks to Karl Hillesland for making the contour plots with the PV-Wave[a] visualization package on a UNIX[b] platform.

2.0 DETAILS REGARDING THE MCNP CALCULATIONS

2.1 GEOMETRY MODEL

The plan view of Figure 1 that shows the contours is also used to describe the geometry. The Plutonium Nitrate Solution Criticality neutron source of Reference 2 (Case 3) with source strength 6.237×10^{13} neutrons/second is in the center of the 10^8 thermal flux contour of Figure 1. The walls of this room, of the corridor, and of the building (perimeter of Figure 1) are all ordinary concrete 30 cm thick. The height of the corridor and all rooms

---

[a]PV-Wave is a trademark of Precision Visuals.

[b]UNIX is a trademark of AT&T.

is assumed to be 240 cm, and the width of the corridor is also assumed to be 240 cm in this idealized calculation.

A spatial grid of 42 mesh intervals in x (abscissa in Figure 1), 39 mesh intervals in y, and one mesh interval in z along the 240 cm height between floor and ceiling were used by MCNP to calculate the thermal neutron fluxes for input into PV-Wave visualization package to obtain the contour plots. The MCNP calculations were actually made with the Hanford version of MCNP since this allows for automatically tallying on such a fine mesh. However, with some additional tallies the same data could be generated with the standard MCNP from LANL.

MCNP importances[1] were used to improve the calculational efficiency. The air and walls along each straight section of the corridor were divided into two sets of cells of approximately equal length for setting importances. The importance was increased a factor of four between each of these sets of cells along the corridor and by a factor of sixteen between the room containing the source and the entrance from this room into the corridor.

The MCNP input file for this generic calculation to demonstrate the generation of thermal neutron flux contours is listed in Appendix A.

3.0 REFERENCES

Breismeister, J. F., Editor, "MCNP - A General Monte Carlo Code N-Particle Transport Code, Version 4A", LA-12625, Los Alamos National Laboratory, Los Alamos, New Mexico, dated 1993.

Miles, R.E., "DEVELOPMENT OF LOCATION CRITERIA FOR THE ROCKY FLATS PLANT CRITICALITY ALARM DETECTORS," Nuclear Safety Engineering Technical Report No. NSTR-001-91, EG&G Rocky Flats, August 7, 1991.

Figure 1. Thermal Neutron Flux Contours (neutrons/cm²-s) for Generic Room and Hallway

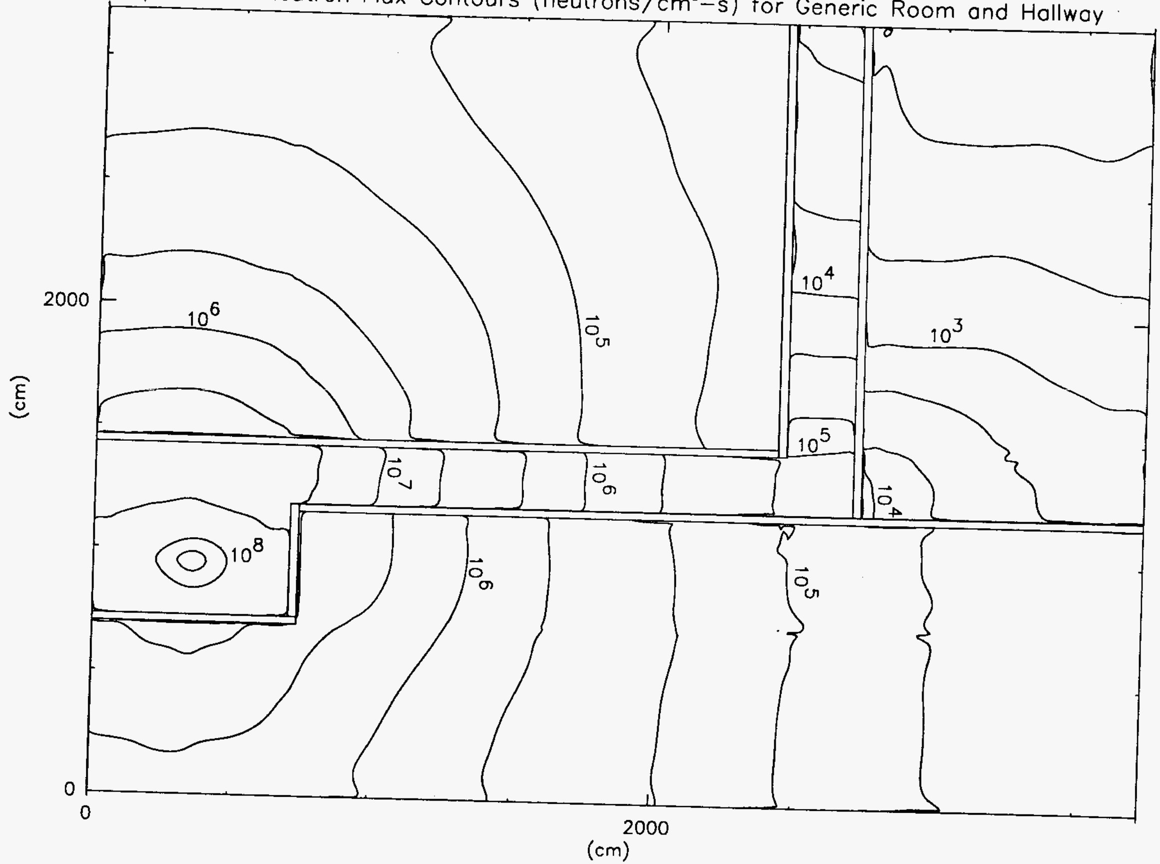
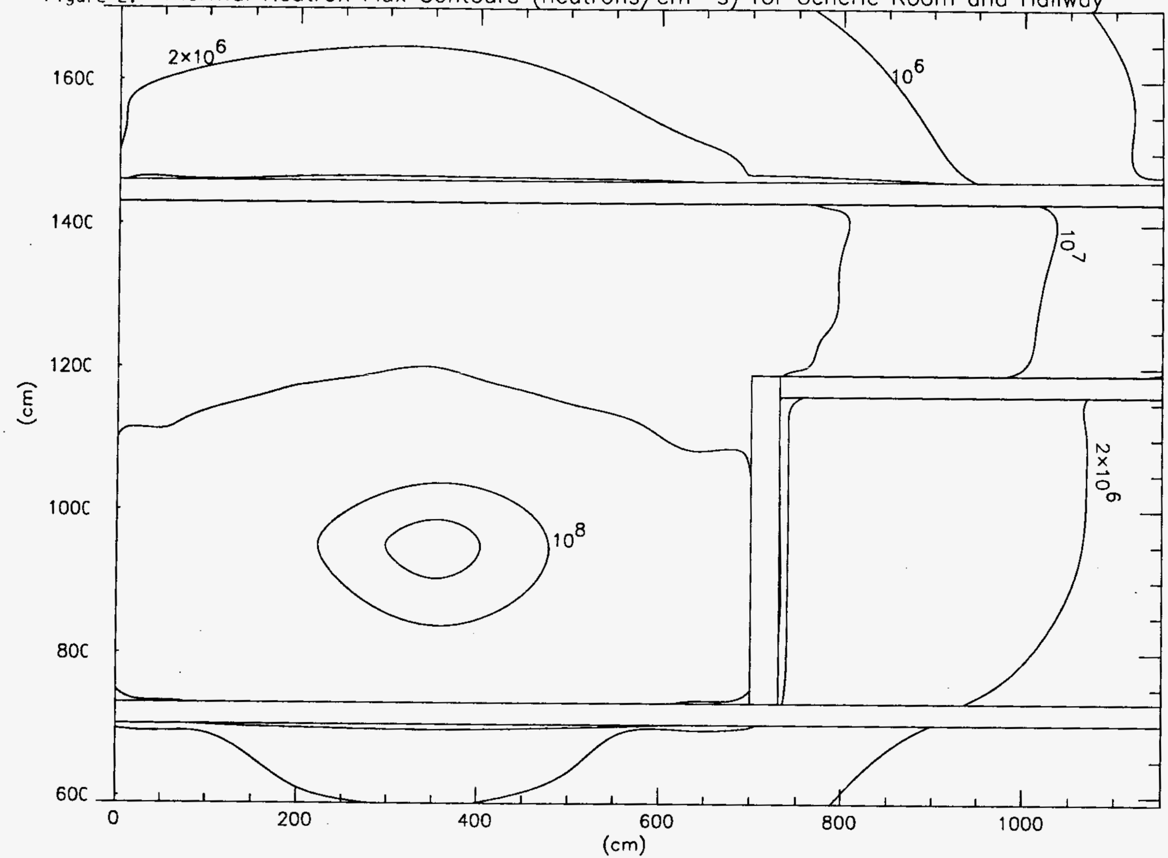


Figure 2. Thermal Neutron Flux Contours (neutrons/cm²-s) for Generic Room and Hallway



APPENDIX A

LISTING OF MCNP INPUT FILE FOR CALCULATION OF THERMAL NEUTRON FLUXES

Prepared by:

Leland L. Carter
Westinghouse Hanford Company
August 1996

APPENDIX A

LISTING OF MCNP INPUT FILE FOR CALCULATION OF THERMAL NEUTRON FLUXES

```
 generic building to demonstrate criticality detector contours, ilee
c       room with source
    1  2 -.0010556   -3   2  -23   19  99  -42 41
    2  3 -2.53       -4   2  -24   18  (3:-19:23) (-22:23) -42 41
    3  3 -2.53       -5   2  -25   17  (4:-18:24) (-21:24) -42 41
c       corridor next to source
    4  2 -.0010556   -6   3  -23   22                      -42 41
    5  3 -2.53       -6   4  -24   23                      -42 41
    6  3 -2.53       -6   5  -25   24                      -42 41
    7  3 -2.53       -6   4  -22   21                      -42 41
    8  3 -2.53       -6   5  -21   20                      -42 41
    9  2 -.0010556  -10   6  -23   22                      -42 41
   10  3 -2.53       -8   6  -24   23                      -42 41
   11  3 -2.53       -7   6  -25   24                      -42 41
   12  3 -2.53      -11   6  -23   21  (10:-22)            -42 41
   13  3 -2.53      -13   6  -21   20                      -42 41
   14  3 -2.53      -13  11  -23   21  (-12:-22)           -42 41
c          corridor beyond bend
   15  2 -.0010556  -10   9  -26   23                      -42 41
   16  3 -2.53       -9   8  -26   23                      -42 41
   17  3 -2.53       -8   7  -26   24                      -42 41
   18  3 -2.53      -11  10  -26   23                      -42 41
   19  3 -2.53      -12  11  -26   23                      -42 41
   20  2 -.0010556  -10   9  -27   26                      -42 41
   21  3 -2.53       -9   8  -27   26                      -42 41
   22  3 -2.53       -8   7  -27   26                      -42 41
   23  3 -2.53      -11  10  -27   26                      -42 41
   24  3 -2.53      -12  11  -27   26                      -42 41
c        other rooms
   25  2 -.0010556   -7   2  -27   25                      -42 41
   26  2 -.0010556  -13  12  -27   22                      -42 41
   27  2 -.0010556  -13   2  -20   16  (5:-17)             -42 41
c        outside concrete walls
   28  3 -2.53       -2   1  -25   17                      -42 41
   29  3 -2.53      -14   1  -20   15  (13:(-2 -17):-16)   -42 41
   30  3 -2.53      -14  10  -28   20  (13:27)             -42 41
   31  2 -.0010556  -10   9  -28   27                      -42 41
   32  3 -2.53       -9   1  -28   25  (-2:27)             -42 41
c       ceiling and floor
c        above/below cells 1 and 28
   41  3 -2.53       -5   1  -25   17  -44  42
   42  3 -2.53       -5   1  -25   17  -46  44
   43  3 -2.53       -5   1  -25   17  -41  43
   44  3 -2.53       -5   1  -25   17  -43  45
c        above/below cell 4
```

```
      45  3 -2.53      -6   5  -25   20  -44  42
      46  3 -2.53      -6   5  -25   20  -46  44
      47  3 -2.53      -6   5  -25   20  -41  43
      48  3 -2.53      -6   5  -25   20  -43  45
c          above/below cell 9
      49  3 -2.53     -12   6  -25   20  -44  42
      50  3 -2.53     -12   6  -25   20  -46  44
      51  3 -2.53     -12   6  -25   20  -41  43
      52  3 -2.53     -12   6  -25   20  -43  45
c          above/below cell 15
      53  3 -2.53     -12   7  -26   25  -44  42
      54  3 -2.53     -12   7  -26   25  -46  44
      55  3 -2.53     -12   7  -26   25  -41  43
      56  3 -2.53     -12   7  -26   25  -43  45
c          above/below cells 20 and 31
      57  3 -2.53     -12   7  -28   26  -44  42
      58  3 -2.53     -12   7  -28   26  -46  44
      59  3 -2.53     -12   7  -28   26  -41  43
      60  3 -2.53     -12   7  -28   26  -43  45
c          above/below cells 26 and 30
      61  3 -2.53     -14  12  -28   20  -44  42
      62  3 -2.53     -14  12  -28   20  -46  44
      63  3 -2.53     -14  12  -28   20  -41  43
      64  3 -2.53     -14  12  -28   20  -43  45
c          above/below cells 27 and 29
      65  3 -2.53     -14   1  -20   15  (5:-17)  -44  42
      66  3 -2.53     -14   1  -20   15  (5:-17)  -46  44
      67  3 -2.53     -14   1  -20   15  (5:-17)  -41  43
      68  3 -2.53     -14   1  -20   15  (5:-17)  -43  45
c          above/below cells 25 and 32
      69  3 -2.53      -7   1  -28   25   -44  42
      70  3 -2.53      -7   1  -28   25   -46  44
      71  3 -2.53      -7   1  -28   25   -41  43
      72  3 -2.53      -7   1  -28   25   -43  45
c          critical source 3
      80  1  -1.0215   -99
c           outside world
      89  0    (14:-1:28:-15:46:-45)

       1   px    -30.
       2   px      0.
       3   px    700.
       4   px    708.
       5   px    730.
       6   px   1500.
       7   px   2430.
       8   px   2452.
       9   px   2460.
      10   px   2700.
```

```
    11   px   2708.
    12   px   2730.
    13   px   3730.
    14   px   3760.
    15   py    -30.
    16   py      0.
    17   py    700.
    18   py    722.
    19   py    730.
    20   py   1160.
    21   py   1182.
    22   py   1190.
    23   py   1430.
    24   py   1438.
    25   py   1460.
    26   py   2300.
    27   py   3190.
    28   py   3220.
    41   pz   -120.
    42   pz    120.
    43   pz   -128.
    44   pz    128.
    45   pz   -150.
    46   pz    150.
c        radius of source
    99   s      350. 950. 0.     19.8
c      x-surfaces for fine rectangular tally mesh
   101   px      -29.99
   102   px       -9.99
   103   px         .01
   104   px       19.99
   105   px       99.99
   106   px      299.99
   107   px      399.99
   108   px      599.99
   109   px      679.99
   110   px      699.99
   111   px      709.99
   112   px      719.99
   113   px      729.99
   114   px      749.99
   115   px      799.99
   116   px      999.99
   117   px     1300.01
   118   px     1600.01
   119   px     1900.01
   120   px     2200.01
   121   px     2410.01
   122   px     2430.01
```

```
    123   px    2440.01
    124   px    2450.01
    125   px    2460.01
    126   px    2480.01
    127   px    2580.01
    128   px    2680.01
    129   px    2700.01
    130   px    2710.01
    131   px    2720.01
    132   px    2730.01
    133   px    2750.01
    134   px    2800.01
    135   px    2900.01
    136   px    3100.01
    137   px    3300.01
    138   px    3500.01
    139   px    3710.01
    140   px    3730.01
    141   px    3740.01
    142   px    3750.01
    143   px    3759.99
c         y-surfaces for fine rectangular tally mesh
    201   py     -29.99
    202   py      -9.99
    203   py        .01
    204   py      19.99
    205   py      99.99
    206   py     299.99
    207   py     499.99
    208   py     679.99
    209   py     699.99
    210   py     710.01
    211   py     720.01
    212   py     730.01
    213   py     750.01
    214   py     900.01
    215   py    1000.01
    216   py    1100.01
    217   py    1140.01
    218   py    1160.01
    219   py    1170.01
    220   py    1180.01
    221   py    1190.01
    222   py    1210.01
    223   py    1300.01
    224   py    1410.01
    225   py    1430.01
    226   py    1440.01
    227   py    1450.01
```

```
  228   py    1460.01
  229   py    1480.01
  230   py    1600.01
  231   py    1800.01
  232   py    2000.01
  233   py    2300.01
  234   py    2600.01
  235   py    2900.01
  236   py    3050.01
  237   py    3170.01
  238   py    3190.01
  239   py    3200.01
  240   py    3219.99
c      z-surfaces for fine rectangular tally mesh
  301   pz    -119.99
  302   pz     119.99

c data cards
mode    n
prdmp    j -480 1
kcode  5000 1.0 10 210
ksrc    350. 950. 0.
print    110
c       plutonium solution, -1.0215 g/cm**3
m1    94239.55 5.9830e-5  94240.50 3.1358e-6
      1001.50 6.6623e-2  8016.50 3.3312e-2
mt1     lwtr.01t
c       air at -.0010556 g/cm**3
m2    7014.50 3.4493e-5  8016.50 9.5358e-6
c       Rocky Flats concrete at -2.53 g/cm**3
m3    1001.50 8.42e-3 8016.50 4.423e-2 14000.50 1.587e-2 13027.50 2.52e-3
      11023.50 1.05e-3 20000.50 2.93e-3 26000.55 3.0e-4 19000.50 6.9e-4
c          1          2          3          4          5
imp:n      1          1          2         16         16
c          6          7          8          9         10
           2         16          8         64         64
c         11         12         13         14         15
          16         64         16        256        256
c         16         17         18         19         20
         256         64        256        256       1024
c         21         22         23         24         25
        1024        128       1024       1024         16
c         26         27         28         29         30
         256          8          1          8        256
c         31         32
        1024         16
c         41         42         43         44         45
          .5       .125         .5       .125          8
c         46         47         48         49         50
```

```
             1          8          1         16          2
c           51         52         53         54         55
            16          2         64          8         64
c           56         57         58         59         60
             8        256         16        256         16
c           61         62         63         64         65
            64          8         64          8          2
c           66         67         68         69         70
            .5          2         .5          8          1
c           71         72         80         89
             8          1       .125          0
fc4    fine mesh tally of thermal flux as 1st energy group
f4:n    (1 30i 32 80)
fs4    -2000000  43 40 2 101 41i 143  201 38i 240  301 302
e4     1.e-7 30.
```

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